IDENTIFICATION OF GYPSUM USING NEAR-INFRARED PHOTOGRAPHY AND DIGITAL LANDSAT IMAGERY

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IDENTIFICATION OF GYPSUM USING NEAR-INFRARED
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PREFACE

Section 208 of Public Law 92-500 (1972 amendment of the Water Pollution Control Act of 1948) requires federal, state, and local governments to develop water quality management programs. A prerequisite for the development of the programs is the ability to identify and locate point and non-point sources of water pollution.

This study is an evaluation of the utility of near-infrared aerial photography and digital Landsat imagery for the identification of oil field operation sites and gypsum outcrops and soil as point and non-point sources of water pollution. Gypsum outcrops and soils were mapped using high and low altitude near-infrared photography. Unsupervised and supervised classification techniques were used to evaluate the discrimination of oil field operation sites and gypsum outcrops and soil with digital Landsat imagery.

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CHAPTER I

ABSTRACT

Near-infrared aerial photography and Landsat digital data were evaluated in this study for identifying gypsum as a non-point source of water pollution and for the development of regional non-point source maps which can be used in south-central Oklahoma. A secondary objective was to assess the feasibility of using Landsat digital data to map oil field operation sites as point sources of water pollution.

Field investigations revealed that geobotanical anomalies were associated with gypsum outcrops and soil. Spectral signatures of the gypsum indicator plants on the high and low altitude color near-infrared photography were found to accurately delineate the vegetated gypsum outcrops and soil. Non-vegetated gypsiferous soil could be distinguished but not consistently discriminated on the color near-infrared films. The low altitude color near-infrared photography was more accurate than the high altitude color near-infrared photography for mapping gypsum in spite of its lower quality because of the inherent improvement in resolution. Neither vegetated gypsum outcrops and soil nor exposed gypsiferous soil were consistently discriminated on the low altitude near-infrared black and white photography.

Supervised and unsupervised computer processing techniques were applied to Landsat digital data for June 29, 1974, and March 9, 1978. The gypsum outcrops and soil and oil field operation sites were not com-

puter classified with a high degree of accuracy using Landsat digital data. The computer techniques suffer from limitations due to the lack of contrast between areas of gypsum indicator plants or oil field operation sites and surrounding vegetation and because of the small size of the gypsum and oil field operation sites, most of which are below the cited 1.1 acre resolution limit of the Landsat satellites. The development and refinement of other computer techniques may improve the discrimination capability of the automatic classification and mapping techniques.

CHAPTER II

INTRODUCTION

Over the past two decades the need to maintain and improve the quality of this Nation's water has become an increasingly important and complex problem for federal, state, and local governments.

Increased public awareness of water quality problems has prompted federal and state governments to pass legislation in attempts to protect, preserve, and develop the Nation's water resources. Among the many laws which have been passed is Section 208 of Public Law 92-500 (the 1972 amendment of Public Law 84-600 of 1956 which amends the Water Pollution Control Act of 1948). Section 208 requires state and local governments to develop water quality management programs to meet the goal of restoring and maintaining the chemical, physical, and biological integrity of the Nation's water.

A prerequisite to the development of water quality management programs is the identification and location of point and non-point sources of pollution. As a consequence, there exists a need to develop an efficient and economic means of mapping sources of water pollution.

Purpose

Oil field well and storage tank sites and gypsum outcrops and associated soils are common point and non-point sources of water polution in southwestern Oklahoma. The purpose of this study was to assess the use of two techniques of remote sensing, near-infrared aerial photography and Landsat digital data, as data bases for developing maps showing potential pollution due to gypsum and oil fields.

Near-infrared aerial photography was evaluated for its usefulness in mapping gypsum outcrops and soils because infrared films are capable of enhancing differences between vegetation, objects, and materials that are visually quite similar. The success of infrared photography in detecting subtle and unseen differences is due to the fact that infrared and visible radiation are not transmitted and reflected by natural and man-made objects in the same way.

The difference in the reflectivity of infrared and visible radiation by natural objects is most evident in the photography of vegetation. This phenomenon results from the ability of the chlorophyll contained in the spongy mesophyll tissue of plant leaves and blades to reflect a large percentage of near-infrared radiation and absorb most visible radiation. The chlorophyll content of vegetation is dependent upon the plant species and the health of the plant. Because the reflectivity of infrared radiation is sensitive to the chlorophyll content of plants, the reflectivity differences between individual plant species and those within species due to the effects of drought, soil salinity, disease, or abnormal uptake of minerals or toxic substances are more readily registered on infrared films.

Landsat digital data was evaluated for its applicability to the development of gypsum and oil field pollution source maps because: (1) the Landsat satellites have provided almost complete coverage of the earth's land surface which enables mapping techniques developed in this study to be applied or adapted to other geographical areas; (2) Landsat digital data is collected on a repetitive basis so that digital data collected under different conditions (i.e., angle of illumination, moisture conditions, and seasonal vegetation changes) may be selected for maximum enhancement of the mapable features; (3) each Landsat scene represents approximately 13,225 square miles, enabling large areas to be studied without requiring the time consuming and expensive construction of mosaics needed with aerial photographs; and (4) digital computer processing techniques can be applied to Landsat digital data stored on computer-compatible tapes (CCT's) resulting in images of higher quality and in more efficient means of data analysis.

Study Area

The study area (Figure 1) covers all or parts of Ranges 9-11 and Townships 4-7 of southeastern Caddo and northeastern Comanche counties. This region includes all of the Tonkawa and the northwestern half of the Little Washita River watersheds.

These two watersheds are a part of the Washita River Basin research area for the Southern Great Plains Hydrologic Research Watersheds of the Research Branch of the Scientific and Educational Administration, United States Department of Agriculture. This region has been studied in detail for the past fifteen years. A substantial amount of information has been collected on the meteorology and surface and ground-water hydrology. The Tonkawa and Little Washita River watersheds were chosen as the area of investigation of this study so that the results would be included as a part of the continuing research

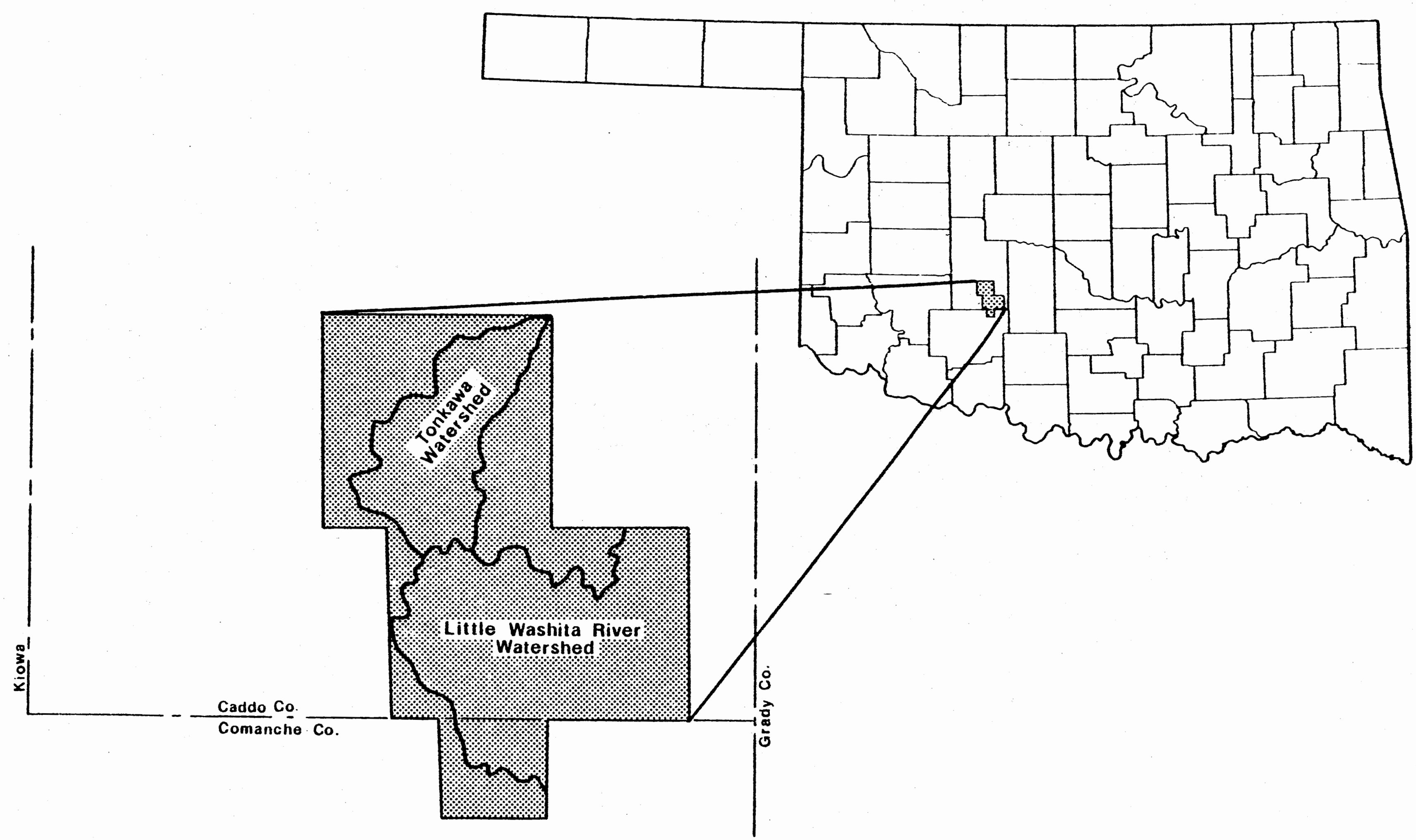

Figure 1. Index Map of Study Area

being conducted by the Southern Great Plains Hydrologic Research Watersheds Project.

Methodology

The potential of near-infrared aerial photography and Landsat digital data as data bases for water pollution source maps was evaluated by means of a study consisting of three parts: (1) Analysis of near-infrared aerial photography, (2) Supervised classifications of Landsat digital data and (3) Unsupervised classification of Landsat digital data.

The near-infrared aerial photo investigation was conducted in four phases. The first phase involved an evaluation of the capability of high and low altitude near-infrared aerial photography to consistently discriminate gypsum indicator plants and exposed gypsiferous soil. The general locations of gypsum outcrops and soils in the study area were determined from a previously published geologic map (Tanaka and Davis, 1963) of the region and from soil maps published in soil survey reports for Caddo and Comanche counties (Soil Conservation Service, 1973 and 1967). The parameters used to identify gypsum plant communities and exposed gypsiferous soil on the near-infrared aerial photographs were color, tone, texture, and contrast.

The second phase involved the field verification of the gypsum outcrops and soils photographed with the near-infrared aerial photography. This was followed by a third phase which consisted of preparing the following maps: (1) a gypsum outcrop and soil map (1:24000) from a high altitude color near-infrared transparency and (2) a gypsum outcrop and soil map from a low altitude color near-infrared mosaic (1:24000).

The fourth and final phase was an evaluation of the utility of high and low altitude color near-infrared photography for mapping gypsum outcrops and soil. The evaluation consisted of the computation and comparison of the total acreage of gypsum surface cover represented on each map. Oil field well and storage tank sites were not mapped with near-infrared aerial photography because these structures are easily recognized and mapped with conventional black and white and true color aerial photography.

The second part of the study was an assessment of Landsat digital data using supervised classification techniques. Using this approach, the investigator selected ground cover and land-use features to be used as training sets. Selection is made from supplementary sources (ground truth data). Training sets are used with the computer to discriminate the spectral data representative of each ground cover type and land-use feature.

The analysis of Landsat digital data in this study was conducted in four phases. The first phase involved the development of two supervised classifications for each of two Landsat (ERTS) scenes, scene E-1706-16332 for June 29, 1974, from Landsat I and scene E-30004-16290 for March 9, 1978, from Landsat III. The second phase involved the application of pre-classification data manipulation and enhancement techniques to the digital data of both Landsat scenes. The techniques included GODDARD, FRAME, GREYSCALE, DELIN-merge, SMOOTH, DELIN-subscene, REGISTRATION, and TRANSFORMATION. The third phase consisted of classifying the digital data of the study area from both scenes with the appropriate supervised classifications in several different dimensional spaces. The fourth and final phase involved the evaluation of the classifications according to the accuracy with which the gypsum and oil field training sets were classified.

The third part of the study was an analysis of Landsat digital data using an unsupervised classification. The unsupervised classification does not require training sets. Digital selection and definition of spectral classes are determined statistically and then used to classify the digital data into classes which may or may not represent the ground cover in the study area. The spectral classes are determined by using a clustering algorithm which calculates the statistical boundaries of the classes from a distribution of naturally occuring groups of similar reflectance values. After the unsupervised classification has been generated, the recognition and assignment of digital reflectance data to the appropriate spectral classes can be accomplished by the same algorithms used in the supervised classification.

The analysis was conducted in two sequential phases at the National Aeronautics and Space Administration's Earth Resources Laboratory (ERL) located in Slidell, Louisiana. The first phase involved the generation of an unsupervised classification for the Landsat II scene E-2900-16073 for July 10, 1977, using ERL's Search and MaxL31 programs on the Comtol/Varian Image Processing System. The second phase consisted of an evaluation of the resulting classification to determine whether any of the computer generated spectral classes or combination of classes exclusively represented gypsum outcrops and soil.

Previous Investigations

Introduction

Previous remote sensing investigations have evaluated the mapping capability of various instruments in detecting and delineating a wide range of lithological and mineralization features. The geologic objectives have varied from general formations and rocks to specific minerals. In mineral exploration programs the objectives have also included geologic related phenomena such as plant-mineral or -lithologic associations.

Among the variety of instruments which have been utilized to advance remote sensing capabilities are camera systems using conventional and near-infrared films and multispectral scanners operating in the visible through far-infrared portions of the spectrum from airborne and space platforms. The extension of remote sensing into the infrared region of the spectrum and the use of wide and narrow band sampling techniques has made it possible to reveal features which are impossible or difficult to detect with conventional aerial photography.

Rocks, Minerals, and Soils

Vincent and Thomson (1971) investigated the utility of ratio techniques to discriminate exposed silicate from non-silicate rocks. An airborne miltispectral scanner collected data from one channel in the 8.0 micrometer to 11.5 micrometer range and another in the 11.5 micrometer to 13.0 micrometer region of the spectrum over the Mill Creek, Oklahoma test site. They reported the ratio techniques were able to distinguish between highly siliceous rocks and non-silicates but were unable to achieve the same results with rocks of low silica content. They suggested that the use of a third channel would enable the technique to discriminate exposed acidic and basic siliceous rocks from non-silicates as well as detect differences in silica content as small as

14 per cent among silicates.

Watson and Rowan (1971) evaluated the feasibility of using digital data collected by an airborne multispectral scanner operated in the .4 micrometer to 1.0 micrometer region of the spectrum to map limestone and dolomite. They reported successful results in detecting outcrops of limestone and dolomite but only a 60 per cent accuracy in the discrimination of limestone from dolomite at the Mill Creek, Oklahoma test site.

El-Shazly, Abedl-Hady, and Morsy (1974) tested the significance of far-infrared thermal mapping in the detection and delineation of geologic features in the East Qatrani Desert Area of Western Egypt with an airborne multispectral scanner operated in the 8.0 micrometer to 14.0 micrometer range of the spectrum. They noted bright thermal anomalies were caused by limestone and anhydrite-gypsum. They observed that clays and sandstones which contain considerable amounts of gypsum and/or rock salt yield high thermal effects. They also recorded consistent thermal anomalies from uraniferous, carbonaceous clay which contained significant quantities of gypsum, salt, carbonates, and iron oxides.

Denih and Knapp (1975) tested the capability of an airborne multispectral scanner to detect altered ore-bearing zones in the Timok Magmatic Complex of eastern Yugoslavia. They mapped areas of copper mineralization with reflectance data recorded from ten channels in the visible and near-infrared (.32 micrometer to 1.10 micrometer) regions and one channel in the far-infrared (3.0 micrometer to 14.0 micrometer) portion of the spectrum. They observed that the highest thermal recordings were yielded by altered volcanic rocks, carbonate clastics of

Upper Cretaceous age and andesites.

Ballew (1975) evaluated the feasibility of correlating surface geochemistry with Landsat digital data for the purpose of locating areas of mineralization in the Washington Hill mercury mining district, near Virginia City, Nevada. Using ratio techniques and multiple regression analysis he was able to predict locations of geochemical anomalies which corresponded to known mining operations and zones of alteration.

Levine (1975) was able to differentiate serpentine and sandy soils on the San Francisco Peninsula by means of an unsupervised classification applied to Landsat digital data. He noted that the success of the classification was dependent upon seasonal changes in vegetation. He reported that the soils could be classified by the unsupervised technique only with digital data collected during the end of the dry season (early autumn).

Rowan, Goetz, and Ashley (1977) engaged upon a long term study of the feasibility of Landsat digital data to discriminate hydrothermally altered and unaltered rocks of the Goldfield, Nevada mining district. They developed an enhancement technique which combines contrast stretching with ratioing. Application of the technique to Landsat digital data enabled zones of hydrothermal alteration to be accurately mapped. Smith, Green, Robinson, and Haney (1978) successfully detected and mapped hydrothermally altered basic lava flows in Hamersley Basin, Western Australia, using Landsat digital data.

Everitt, Gerbermann, and Cuellar (1977) investigated the feasibility of using microdensitometry on Skylab photography of Starr County Texas to distinguish between saline and non-saline soils. They reported they were able to differentiate saline soil test sites from non-saline sites on the basis of information taken collectively from three types of black and white film. They observed that the differences in optical density readings which differentiated the saline from non-saline soils were the result of higher reflectivity from saline soils because of the lower percentage of vegetation cover. They also reported that no significantly different optical density readings were obtained among the soil test sites with color or color infrared films. They also noted that they were unable to differentiate all the saline soils from non-saline soils on the basis of information obtained from any one black and white film by itself.

Geobotanical Prospecting

Geobotanical prospecting consists of relating changes in plant morphology and distribution to geology. It is a relatively new mineral exploration technique which has been utilized in only a limited way in spite of the fact that plant-mineral associations have been a long observed phenomena.

Agricola (1556) and Barba (1729) recognized the retardation to growth and linear distribution of certain plant species along zones of mineralization. Agricola also noted the absence of frost on plants above mineralized veins in winter; also, Lidgey (1897) reported the occurrence of discolored vegetation along mineralized zones.

Plants can frequently be good indicators of soil conditions because the root systems often extend throughout a large soil volume. There are three principal ways in which the soil geochemistry can be manifested by vegetation: a) changes in soil mineral content can cause changes in ecology such as redistribution of plant communities and species relative to adjacent areas, b) stress due to minerals can cause morphological alterations in plants such as gigantism, dwarfing, abnormal flowering and fruiting, chlorosis, and leaf wilting or defoliation, and c) the mineral content of the soil is reflected by the mineral content of the foliage, so that the soil geochemistry can be investigated through an analysis of diagnostic vegetation.

Many plant-mineral and plant-lithologic associations have been found. Billings (1950) conducted an extensive study of the effects of hydrothermally altered andesite on vegetation and plant growth in the Virginia Range and eastern foothills of the Sierra Nevadas. He reported that open scrubby stands of yellow pines (Pinus ponderosa and P. jeffreyi) and certain sparce herbaceous species (Arenaria nuttallee, Spraguea umbellata, Lewsia rediviva, Eriophyllum lanatum var. integrifolium, Allium paryum, Festuca arida, Mimulus nanus, and particularly Eriogonum robustum) characterized weathered areas of alteration which are surrounded by unaltered soils dominated by sagebrush and pinyon-juniper climax zones. Leuder (1959) reported on the association of ragweed with zinc and red campion with copper mineralization.

Cannon (1957, 1960a, 1964) developed botanical methods of prospecting for uranium on the Colorado Plateau for the Division of Raw Materials of the U.S. Atomic Energy Commission. She observed that close associations exist between several plants and uranium ore deposits. She designated the plant genera Elymus salina (Salina wildrye), Eriogonum inflatum (Desert trumpet eriogonum), Oenothera caespitosa (Tufted evening-primrose), Allium acuminatum (Tapertip onion), Astragalus bisulcatus (Two-grooved poisonvetch), Astragalus confertiflorus (Blue poisonvetch), Astragalus thompsonae (Thompson loco), Astragalus preussi (Preuss poisonvetch), and Astragalus pattersoni (Patterson poisonvetch) as primary plant-indicators of uranium ore. Astragalus pattersoni and A. preussi were reported by her to be the two most useful indicators of mineralized soil. She noted that the distribution of A. pattersoni alone led to the discovery of two ore bodies in the Grants district.

She also reported that many plants which are indicative of the presence of gypsum or sulfate in the soil, are important in uranium prospecting. She included Abronia angustifolia, Anogra gypsophila, Astragalus allochrous, Cruptantha fulvocanescens, Dithyraea wislizen, Eriogonum rotundifolium, Lepidium montanum, Oryzopsis hymenoides, and Sporobolus giganteus as well as certain species of Mentzelia, Oenothera, and Streptanthus as calcium and/or sulfur indicators on the Colorado Plateau. She observed that Descuraninia (tansy mustard), Lepidium (pepperweed), and plants of the lily family (Liliaceae) are indicators of uranium ores which contain gypsum. She noted that Segolily and wild onion are the two most useful indicators of the lily group. She found that no one calcium- or sulfur-indicator plant could be considered indicative of mineralized soil; however, she did observe that the presence of a dense population of a variety of these plant genera was commonly indicative of a uranium deposit.

Barrett and Curtis (1972) reported on the recognition of anomalous communities of Helichrysum leptolepis which led to the discovery of copper-bearing argillite formations in the Witvlei area of South-West Africa. They also reported on the delineation of a major lead-zinc ore body by a geobotanical anomaly composed of Polycarpaea glabra and Eriachne mucronata in the Dugald River area, Cloncurry district, Australia.

Cole (1973) discovered the association of Hybanthus Floribundus with nickeliferous soils of Western Australia.

Barber (1975) conducted a floristic study of vascular plants on gypsum soils in Greer, Harmon, and Jackson counties, Oklahoma. She noted gypsum outcrops and soils often support a distinctive group of plants. She discovered 108 species occuring on gypsum soils, but only 30 were found to grow exclusively on gypsum in her study area. Barber reported that seven of the 30 species had herbarium records indicating occurrence only on gypsum. These are:

Condalia obtusifolia, Ephedra antisiphilitica, Haploesthes greggii, Hilaria matica, Juniperus pindhati, Nama Stevensii, and Phacelia intergrifolia.

She also listed six other species collected only from gypsum soils. They include:

Astragalus missouriensis, A. racemosus, A. lotiflorus, Asclipias engelmannia, Penstemon fendleri, and Psilostrophe villosa.

She observed that nine of the 30 speices associated with gypsum were also associated with limestone soils. These are:

Aristida longiseta, Astragalus mollissimus, A. plattensis, Mentzelia nuda, M. oligosperma, Opuntia leptocaulis, Polygala alba, Scutellaria drummondii, and Tridens elongatus.

She reported that although the remaining eight species of the 30 were found only on gypsum soils in southwestern Oklahoma they do occur on other types of soils elsewhere in the country. Those eight are:

Atriplex canescens, *Sporobolus airoides*, *S. cryptandrus*, *Chrysopsis villosa*, var. stenophylla, *Gaura parviflora*, *Grindelia squarrosa*, *Pellaea atropurpurea*, and *Schedonnardus paniculatus*.

Press (1974) noted that one of the first efforts to use remote sensing of geobotanical anomalies for mineral exploration was conducted during the early 1930's in Rhodesia and Katanga. He reported that panchromatic aerial photography was used to search for vegetation clearings caused by metal toxicity. He observed that the technique was successful because three major copper deposits were discovered using this technique.

Barrett and Curtis (1972) reported on remote sensing studies conducted to assess the potential of true color infrared aerial photography in the detection of known geobotanical and biogeochemical anomalies occupying proven zones of copper mineralization in South-West Africa and Western Queensland, Australia. They described how natural color and color infrared films revealed trees (*Dichrostachys cinera*) which exhibited biogeochemical anomalies in a zone of copper mineralization of South-West Africa.

The geobotanical anomalous community characterized by *Polycarpaea glabra* and *Ericacne mucranata* which marks the lead-zinc ore body in the Dugald River Lode, Cloncurry district, Western Queensland, Australia, was reported by Barrett and Curtis to yield a distinctive spectral signature on color infrared photos (1:5000 and 1:15000). They noted that subsequent examination of all color infrared aerial photography of their study area resulted in the identification of several areas of copper mineralization which exhibited spectral signatures similar to that of the Dugald River Lode geobotanical anomally.

Lyon (1975) investigated the correlation between soil geochemistry and Landsat I digital data at a molybdenum skarn deposit in the Pine Nut mountains near Carson City, Nevada. Using unsupervised clustering techniques on ratioed Landsat digital data, he was able to detect a well known one by two mile geobotanical anomaly in pine and juniper climax zones (Pinus monophylla and Juniperus utahensis). The anomally overlies a molybdenum mineralization deposit. He observed that the pines displayed significant morphological changes (needle loss, profusion of twiggy stems, and brittleness of branches) which were correlateable with the absorption of molybdenum.

Stratigraphy

All the stratigraphic units within the area of investigation are either Permian bedrock formations or Quaternary alluvial deposits. The Weatherford Gypsum Bed of the Rush Springs Formation and the Moccasin Creek Member of the Cloud Chief Formation are the gypsum units which outcrop within the study area. These two gypsum beds are undifferentiated on the gypsum outcrop and soil maps prepared for this study. Fay's (1962) stratigraphic column (Figure 2) is used in this report.

Permian System

The Marlow Formation is the oldest stratigraphic unit in the study area. The formation consists predominantly of reddish-brown gypsiferous siltstones, shales, and fine-grained sandstones interbedded with thin gypsum layers (O'Brien, 1963). The only exposure of the Marlow within the study area is along the northeastern border of the Tonkawa

SYSTEM	SERIES	GROUP	FORMATION	MBR BED	LITHOLOGY
QUATERNARY					Floodplain & stream deposition of sands & clays
					Terrace deposits of sands, clays, & gravels
PERMIAN	GUADALUPEAN	WHITEHORSE	CLOUD CHIEF	CLOUD CHIEF GYPSUM	Gypsum
				UNNAMED	Medium brown sandstone, shales, & siltstones
			RUSH SPRINGS	WEATHERFORD BED	Dolomites & gypsums
				UNNAMED	Reddish-brown, even to cross-bedded, friable, fine-grained sandstones & silty sandstones
			MARLOW	EMANUEL BED	Persistent, thin-bedded limestone & gypsum
				GRACEMONT BED	Pinkish white, calcareous, sandy shale
				UNNAMED	Orange brown sandstones, shales, & siltstones
				RELAY CREEK BED	Persistent, thin-bedded limestone & gypsum
				UNNAMED	Orange brown sandstones, shales, & siltstones
				VERDEN LENTIL	Light brown, calcareous, cross-bedded, fossiliferous sandstone
				UNNAMED	Orange brown sandstones, shales, & siltstones
				LOWER PINK SHALE	Pinkish white, calcareous, sandy shale
				UNNAMED	Orange brown & greenish-gray sandstones, shales & siltstones

Figure 2. Stratigraphic Column. Source: Fay (1962) and Havens (1977).

watershed.

Overlying the Marlow is the Rush Springs Formation, which consists of 135 to 300 feet of fine-grained, cross bedded to even bedded quartzose sandstone. Except for the Cement vicinity in southeast Caddo county, the color of the sandstone varies from medium- to light-red throughout the study area. O'Brien (1963) attributes the variation in color to the relative amount of iron oxide present as both the predominant cement and as a grain coating. At Cement, the color of the sandstone has been altered to pink, yellow, white, and gray. The discoloration is related to the oil and gas microseepage of the area which caused reduction and dissolution of iron by hydrocarbons (Donovan, 1979).

The Weatherford Gypsum Bed occurs in the upper part of the Rush Springs. The unit varies in thickness from 1 to 60 feet and consists of gypsum and dolomite (Havens, 1977). Within the study area, the Weatherford Bed outcrops throughout the northwestern half of the Little Washita River watershed and the southern end of the Tonkawa watershed. Ten to fifteen feet of dolomitic sandstones and siltstones separate the Weatherford Bed from the overlying Cloud Chief Formation (Olmsted, 1975).

The Cloud Chief is represented in the study area only by the Moccasin Creek Gypsum Member. This unit is composed of up to 30 feet of pink to white crystalline gypsum. Within the study area the outcrops of the Moccasin Creek Gypsum occur as topograhpic highs in the northwestern half of the Little Washita River watershed.

Quaternary System

The Quaternary deposits consist of high terrace gravels and sand and of lower floodplain unconsolidated sands, silts, and clays of the Washita River and Little Washita River drainages in the study area. O'Brien (1963) stated that many of the larger canyons and valleys have previously been filled with silty sand deposits. Present day stream levels are below the top of these canyon fill sediments (O'Brien, 1963).

CHAPTER III

TECHNIQUES OF INFRARED AERIAL PHOTOGRAPHY

Introduction

During the course of this investigation it was necessary to make a low altitude color infrared aerial photo flight using hand-held cameras. Successful near-infrared aerial photography requires photographic techniques not normally associated with standard black and white and true color aerial photography, principally because correct infrared film exposure settings cannot be determined from traditional light meters. Conventional light meters are not sensitive to the infrared portion of the spectrum, consequently, infrared radiation is not registered by the meter. Ordinary light meter readings of visible light cannot be used for infrared photography because of the differences in the reflectibility of infrared and visible radiation previously discussed in chapter two.

Little information detailing specific techniques for color infrared aerial photography with hand-held cameras from light aircraft exist in the literature. The purpose of this chapter is to summarize the procedures and methods of infrared aerial photography with hand-held cameras which were found to be successful in relation to the objectives of this study.

A prerequisite for any investigation involving infrared photography is a knowledge of the physics and optics of infrared radiation and films. Several publications which contain good discussions on infrared radiation and technology include those of Hackforth (1960), Holter *et al*. (1962), Wolfe (1965), and Simon (1966). Wagner (1965) extensively covers the theory and methods of infrared photography. Publications by Eastman Kodak which include helpful information on infrared aerial photography and infrared film characteristics are *Applied Infrared Photography*, *Kodak Data for Aerial Photography*, *Photography from Light Planes and Helicopters*, and *Kodak Infrared Films*. A review of the above publications will provide the inexperienced in infrared aerial photography with the basic fundamentals necessary for planning a successful aerial photo mission.

Aircraft

The light aircraft used for the low altitude photo flight was a six passenger Cessna Skymaster. The plane had been modified to facilitate vertical aerial photography by removing the right front and middle seats and installing a five inch diameter plexiglass camera port in place of the right front seat.

Weather

The weather conditions at the time of the purposed aerial photograph flight must be taken into consideration since adverse weather can render it impossible to achieve the desired photographic objectives.

Optimum weather conditions for an infrared aerial photo mission would include clear sky, little haze, low winds, and cool or cold air. Ideal weather conditions are almost essential, although some haze can be tolerated since infrared radiation has very good haze penetration capability. A clear sky is necessary because clouds greatly reduce the amount of infrared radiation reaching the earth's surface. Moderate to high cross winds cause considerable difficulty in maintaining the essential straight flight paths. Cool or cold air is not an absolute necessity for acceptable infrared photographs; however, visibility is better in cool air than warm air. Also, turbulence is generally less in cool air, which lessens the possibility of blurring the pictures.

Film and Camera Equipment

The combination of film exposure requirements, length of flight paths, and the 120 mile per hour flying speed necessitated the use of five 35 millimeter cameras in order to insure that a camera loaded with unexposed film was always available to replace the one in use after it's film was completely exposed.

Color (Kodak Ektachrome Infrared Film) and black and white (Kodak High Speed Infrared Film) infrared films were used to photograph the gypsum areas. Both types of film are sensitive to the visible and near-infrared regions (.4 micrometers to .9 micrometers) of the spectrum. The color infrared film was exposed through a Vivitar Number 15(G) Deep Yellow filter in order to eliminate visible radiation below .51 micrometer (blue and blue-green) and thereby achieve the desired color balance on the resultant photograph. The black and white infrared film was exposed only to near-infrared radiation (.7 micrometer to .9 micrometer) through the use of a Tifflen Number 87C Red visually opaque filter.

Altitude

In order to maintain the maximum possible resolution and restrict the number of photographs required to completely cover the gypsum areas to a reasonable number, the area photographed by each 35 millimeter slide was limited to one section (one square mile). The selected space requirement for each photograph and the use of 35 millimeter cameras with a focal distance of 55 millimeters required a flying height of approximately 14,500 feet above the ground.

Exposure Settings

It is not possible for reasons previously discussed in chapter two to obtain one single exposure setting (combination of f/stop and shutter speed) from a conventional light meter which will yield a correctly exposed infrared photograph. However, ordinary light meters can be used to determine a "base exposure setting" around which additional exposures are made (bracketing) in order to assure that at least one setting will result in an acceptable photograph.

The bracketing procedure consists of making five exposures of the target area to be photographed. Two exposures are made at the two f/stops above and below that of the indicated "basic setting" as well as at the base exposure setting itself.

Kodak recommends using a film speed of 100 ASA with conventional light meters to determine the average exposure setting for its color infrared film when used with a number 15 filter. A film speed of 10 ASA is recommended for determining the base exposure setting for the use of its black and white film (Kodak High Speed Infrared Film) with a number 87C filter. The light meter readings are made from the same altitude at which the infrared photographs are to be taken.

The best time of day for infrared aerial photography is between 10 a.m. and 2 p.m. This period will assure maximum infrared radiation and reduce adverse effects caused by low sun elevations.

Color Near-Infrared

A basic exposure setting of 1/250 second at f/8 was selected from the several correct shutter speed-f/stop combinations for the color infrared aerial photography of the gypsum areas. Light meter readings were taken of the ground from an altitude of 15,500 feet through the vertical camera port. The exposure bracketing procedure consisted of making four exposures of each of the 76 sections photographed using f/stops 16, 11, 8, and 5.6 with a shutter speed of 1/250 second. The most acceptable photos were made at exposure settings of f/11 and f/8 at 1/250 second. All of the 76 photographs taken at f/11 resulted in some degree of underexposure. Fifteen were slightly underexposed and the remaining 61 were significantly underexposed. All of the 76 photographs taken at f/8 resulted in some degree of overexposure. Fifteen were significantly overexposed and the other 61 were only slightly overexposed.

From a post flight evaluation of the photographs, the best exposure setting for the conditions which existed at the time of the flight was the half f/stop between f/11 and f/8 at 1/250 second. Lack of time and funds did not allow taking photographs at half f/stop increments. No reason can be given for the variation in the degree of under- and overexposure exhibited by the photography since it was not confined to any one roll of film, flight path, or camera and the weather conditions were ideal during the entire aerial photograph flight.

Black and White Near-Infrared

The exposure bracketing method used to take the black and white near-infrared aerial photographs differed from that used for the color infrared film because of inexperience with the black and white film and a visually opaque filter. Also, complete coverage of the gypsum areas was not made with the black and white film because of a shortage of funds and lack of experience with the film and filter.

The bracketing technique consisted of making exposures at all f/stops (f/1.8 through f/16) with each of four shutter speeds; 1/60 second, 1/125 second, 1/250 second, and 1/500 second. A separate roll of film was used for each shutter speed. Although no one shutter speed-f/stop combination was always consistent in producing acceptable photographs, a few exposure settings did yield good results.

The most acceptable black and white infrared photographs were made using f/stops 8, 5.6, and 4 at 1/60 second. Some good exposures were made at the following f/stop-shutter speed combinations: f/5.6 and f/4 at 1/125 second; f/5.6, f/4, f/2.8, and f/1.8 at 1/250 second; and f/1.8 at 1/500 second. All other exposure settings produced fair to poor results.

The inconsistency of obtaining acceptable photographs with any one exposure setting can be attributed to the adverse cloud conditions which developed during the black and white infrared aerial photograph flight and the photographer's lack of experience with the film and filter.

Recommendations

The exposure settings used in this study may not always produce the same results because of differences in weather conditions and nature of the subject or area to be photographed. It is recommended that trial exposures be made under conditions as similar as possible to those of any intended infrared aerial photographic investigation in order to learn which exposure settings will produce acceptable results.

CHAPTER IV

ANALYSIS

Formats of Near-Infrared Photography

Three formats of near-infrared photography, which include high and low altitude color and low altitude black and white, were obtained, examined, interpreted, and evaluated during the course of the first part of this study.

The high altitude color near-infrared photography consisted of complete coverage of the study area with nine by nine inch transparencies at a scale of 1:120,000. The photography was made by the National Aeronautics and Space Administration (NASA) on May 4, 1973, from an altitude of approximately 60,000 feet.

The low altitude color near-infrared photography consisted of a mosaic (1:20,000) constructed from 76 three by five inch prints which were enlarged from the 35 millimeter slides taken with a hand-held camera on March 25, 1979, during the low altitude photographic mission described in chapter three.

The mosaic included complete coverage of all sections in the study area which contained any type of gypsum surface cover. The 76 one-mile sections of gypsum outcrops and soil were restricted to the southern part of the Tonkawa watershed and northwestern half of the Little Washita River watershed.

The low altitude black and white near-infrared photography consisted of partial coverage of the gypsum areas with three by five inch prints at a scale of approximately 1:14,000. The photographs were taken on March 24, 1979, with four hand-held 35 millimeter cameras from an altitude of 12,500 feet. Complete coverage of the study area was not feasible with the black and white infrared film because the film's high speed required absolute darkness for loading and unloading the cameras. This lighting condition was not possible in the aircraft.

Interpretation of Near-Infrared Photography for the Identification of Gypsum Outcrops and Soil

All of the gypsum outcrops are vegetated and generally associated with a thin gypsiferous soil horizon. Most other gypsiferous soils within the study area are also overgrown by vegetation. The plant species indigenous to these gypsum outcrops and soil are distinctly different from the vegetation which dominates the surrounding non-gypsum soils. This is not unusual since gypsum often supports a distinctive flora (Barber, 1975). The association of certain plants with gypsum was studied by Barber (1975) in Greer, Harmon, and Jackson counties of southwestern Oklahoma as previously reported in chapter two.

Five plant species were found growing only on gypsum outcrops and soil in the study area of this report. These were:

> *Arenaria stricta*, *Allium drummandii*, *Chrysopsis villosa*, *Hymenoxys linearifolia*, and *Opuntia compressa* (Tyrl, oral communication, 1979).

Two of the five species were also listed by Barber (1975) as having been collected from gypsum soils. She reported that Chrysopsis villosa (golden aster) was found only on gypsum soil and Opuntia compressa (prickly pear cactus) was collected from both gypsum and redbeds in her study area. The remaining three species were not identified as common to gypsum soils in her report, however she noted that her list was not necessarily complete since her work covered only one season and many years would be required to compile a complete list of gypsum indicator plants of central and southwestern Oklahoma.

Examination of the color near-infrared aerial photography revealed that the gypsum indicator plants produced a unique spectral signature. The anomalous plant communities registered as a light to dark mottled blue on the high altitude color transparencies. The vegetated gypsum soils are easily distinguished and completely discriminated from all other features.

The gypsum indicator species produced a light to dark mottled blue and green color on the prints of the low altitude photographic mosaic. The quality of the color reproduction of the prints and of the 35 millimeter slides from which the prints were enlarged was not as good as that of the high altitude transparencies. This was attributed to automatic color film processing of the slides and prints as well as the photographer's inexperience with infrared photography. Of the low altitude photography, the color quality of the original 35 millimeter slides was better than that of the enlarged prints. This was also attributed to the nature of automatic commercial film processing.

In spite of the lower quality of the low altitude color photography, the vegetated gypsum areas were completely discriminated from all other features. Smaller areas of anomalous gypsum plant communities could be distinguished on the low altitude photographs than on the high altitude transparencies as a result of higher resolution.

The exposed gypsiferous (non-vegetated) soil sites yielded a pale yellow to white color on both the high and low altitude color photography. The exposed gypsiferous soils are easily distinguished on the color near-infrared photography but it could not be completely discriminated from other non-vegetated soils.

The zones of gypsum indicator plants produced dark mottled grey tones on the low altitude black and white near-infrared photographs. The areas of anomalous plant communities can be easily distinguished on the black and white prints, but they cannot be discriminated exclusively because other types of vegetation exhibit the same spectral signatures.

Exposed gypsiferous soils registered as light grey tones on the black and white photography. The exposed gypsiferous soils are easily distinguished on the black and white prints; but, as in the case with the color near-infrared photography, it was not possible to discriminate exposed gypsiferous soils from other non-vegetated soil types.

Comparison of Color and Black and White Near-Infrared Photography

A comparison of a low altitude color near-infrared photograph with a black and white near-infrared photograph of the same section (Figure 3) illustrates the greater discrimination capability of color near-infrared photography. The vegetation exhibited by the two small dark grey "oxbow" ellipses in the small encircled area near the right center of both photographs are brush and shrubs which are not common

Figure 3. Low Altitude Color Near-Infrared and Black and White Near-Infrared Photographs of Section 19, Range 10 West, Township 5 North, Caddo County, Oklahoma

to gypsum soils. The blue-green mottled color within the larger encircled area near the left center of the color photograph and the mixture of light to dark grey tones of the equivalent area on the black and white photograph represent the anomalous gypsum plant communities. Both areas are easily discriminated because of their different colors in the color photograph. In the black and white photograph, both areas display the same grey tone and so it is not possible to differentiate the two types of vegetation using black and white infrared photography.

Evaluation of Color Near-Infrared Aerial Photography

A map of vegetated gypsum outcrop and soil was prepared from each type of the color near-infrared aerial photography (low and high altitude) in order to evaluate the potential of the two remote sensing techniques as data bases for developing non-point source water pollution maps.

The High Altitude IR Gypsum Outcrop and Soil map (Plate I) was prepared using the high altitude color transparencies (1:120,000). These transparencies were used as a guide to distinguish the areas of anomalous gypsum plant communities and used in conjunction with black and white aerial photographs (1:24,000) to delineate vegetated gypsum outcrops and soil. The map was prepared at a scale of 1:24,000 on stabline and included the southern end of the Tonkawa watershed and northwestern half of the Little Washita River Watershed.

The Low Altitude IR Gypsum Outcrop and Soil map (Plate II) was prepared using the low altitude color photographic mosaic. By overlaying the mosaic with stabline, the anomalous vegetated gypsum areas were distinguished and mapped at a scale of 1:20,000. The map was photographically reduced to a scale of 1:24,000 on matte acetate and includes the southern end of the Tonkawa watershed and northwestern half of the Little Washita River Watershed.

The areas on the color aerial photography which displayed the spectral signatures of gypsum indicator plants were field checked in order to establish the ground truth of the color near-infrared signatures. All of the areas which exhibited the spectral signatures of the gypsum indicator plants were found to accurately delinate the vegetated gypsum outcrops and soil.

Supervised Classification

Landsat scenes were selected from two different periods of the year in order to evaluate the effects of soil moisture variation and seasonal vegetation changes upon the classification of all gypsiferous soil types. The scenes selected were Landsat I scene E1706-16332 for June 29, 1974, and Landsat III scene E30004-16290 for March 9, 1978. Vegetation is in full foliage during June but is dormant in March with the exception of winter wheat. The June scene exhibits dry soil moisture conditions. No rainfall was recorded in the study area for a period of 12 days prior to the acquisition of the scene. The March scene represents wet soil moisture conditions. Approximately 3/4 to 1 inch of rain fell throughout the study area on March 7, 1978.

Identification of Ground Cover Classes

The first step in the development of the supervised classification was the identification of all significant ground cover classes in the study area for each scene. The identification of ground cover classes was made from an examination of supplementary data sources (ground truth) which included:

United States Department of Agriculture (USDA) Agricultural Stabilization and Conservation Service (ASCS) 578 forms (crop records) of 1974 and 1978

May, 1974 black and white ASCS (USDA) aerial photographs (1:24,000)

May, 1973 NASA High Altitude Color Near-Infrared aerial photographs (1:120,000)

Soil Conservation Service (SCS) soil maps of Caddo and Comanche counties

The ground cover classes used for the supervised classifications of each scene are listed in Tables I and II.

Delineation of Ground Cover Classes

Five ground truth maps (1:24,000) were prepared which delineated the ground cover identified within the study area. These maps are:

High Altitude IR Gypsum Outcrop and Soil Map, Plate I

Vegetated Gypsum Outcrop and Soil Map, Plate III

June 29, 1974 Ground Truth Map, Plate IV

March 9, 1978 Ground Truth Map, Plave V

Oil Well and Storage Tank Site Map, Plate VI

High Altitude IR Gypsum Outcrop and Soil Map. The High Altitude IR Gypsum Outcrop and Soil Map (Plate I) delineates the vegetated gypsum outcrops and soil and the exposed gypsiferous soil. Exposed gypsiferous soil sites were mapped using the Soil Conservation Service soil maps of Caddo and Comanche counties and black and white aerial photographs. The map includes the southern portion of the

TABLE I

GROUND COVER CLASSES FOR JUNE 29, 1974

Classes
Vegetated gypsum outcrops and soil
Exposed gypsiferous soil
Town
Water
Dense woodland
Moderately dense woodland
Sudan
Alfalfa
Cotton
May maize
Bare ground and June maize
Improved pasture
Unimproved pasture
Oil well and storage tank sites

TABLE II

GROUND COVER CLASSES FOR MARCH 9, 1978

Classes
Vegetated gypsum outcrops and soil
Exposed gypsiferous soil
Town
Water
Dense woodland
Moderately dense woodland
Sudan
Alfalfa
Cotton
Maize
Wheat
Improved pasture
Unimproved pasture
Oil well and storage tank sites
Barley
Oats

Tonkawa watershed and northwestern half of the Little Washita River watershed.

Vegetated Gypsum Outcrop and Soil Map. The Vegetated Gypsum Outcrop and Soil Map (Plate III) delineates only vegetated gypsum outcrops and soil. The vegetated gypsum areas were mapped at a scale of 1:24,000 from Soil Conservation Service soils maps of Caddo and Comanche counties. Black and white aerial photographs were used to distinguish between vegetated and non-vegetated gypsum areas. The map includes the southern end of the Tonkawa watershed and northwestern half of the Little Washita River watershed.

June 29, 1974 Ground Truth Map. The June 29, 1974, Ground Truth Map (Plate IV) delineates all significant types of ground cover (i.e., perennial native vegetation, cultivated fields, water bodies, and urban districts) present in the Tonkawa watershed on June 29, 1974. The location of all cultivated fields and the identification of the ground cover exhibited by the field (i.e., plowed, newly planted, or crop type) was made by a simultaneous examination of the Agricultural Stabilization and Conservation Service's 578 forms (crop records) and black and white aerial photographic coverage of the Tonkawa watershed.

March 9, 1978 Ground Truth Map. The March 9, 1978, Ground Truth Map (Plate V) delineates only ground cover which is different from that noted in the June period due to seasonal agricultural practices within the Tonkawa watershed. The identification of the ground cover exhibited by all cultivated fields on March 9, 1978, was made using the same procedure which was used to identify the agricultural ground cover for the

June, 1974 Ground Truth Map (Plate IV). The ground cover which remains constant in location (perennial vegetation, water bodies and urban districts) was not delineated.

Oil Well and Storage Tank Site Map. Oil and gas well sites and storage tank locations were delineated on the Oil Well and Storage Tank Site Map (Plate VI) using black and white aerial photos (1:24,000) of May, 1974. The map was prepared at a scale of 1:24,000 and includes the northwestern half of the Little Washita River watershed.

Assignment of Training Sets

A training set was assigned to each of the ground cover classes with the exception of the vegetated gypsum outcrops and soil. Two training sets were assigned to the vegetated gypsum class. The two sets were required in order to evaluate the suitability of two different sources of ground truth for the vegetated gypsum outcrops and soil. The two sources used for vegetated gypsum ground truth were the Soil Conservation Service soils maps of Caddo (April, 1973) and Comanche (August, 1967) counties and the High Altitude IR Gypsum Outcrop and Soil Map.

Two groups of training sets were organized for each Landsat scene. The two groups for each scene were labeled Soil and IR to identify which ground truth source was used for the vegetated gypsum class. Tables III and IV list the training sets of the Soil and IR groups for the June and March scenes. Because of differences in ground cover between June and March, the training set groups of the June and March scenes are not identical. The resulting four training set groups were

TABLE III

TRAINING SETS FOR JUNE 29, 1974

Training Set Group	Soil		IR
Class Symbol	Training Set	Class Symbol	Training Set
1	Vegetated Gypsum Outcrop and Soil (from SCS soils maps)	2	Vegetated Gypsum Outcrop and Soil (from High Altitude IR Map)
3	Exposed Gypsiferous Soil	3	Exposed Gypsiferous Soil
4	Town	4	Town
5	Water	5	Water
6	Dense Woodland	6	Dense Woodland
7	Moderately Dense Woodland	7	Moderately Dense Woodland
8	Sudan	8	Sudan
9	Alfalfa	9	Alfalfa
A	Cotton	A	Cotton
B	May Maize	B	May Maize
C	Bare Ground and June Maize	C	Bare Ground and June Maize
D	Improved Pasture	D	Improved Pasture
E	Unimproved Pasture	E	Unimproved Pasture
F	Oil Well and Storage Tank Sites		

TABLE IV

TRAINING SETS FOR MARCH 9, 1978

Training Set Group	Soil		IR
Class Symbol	Training Set	Class Symbol	Training Set
1	Vegetated Gypsum Outcrops and Soil (from SCS soils maps)	2	Vegetated Gypsum Outcrops and Soil (from High Altitude IR Map)
3	Exposed Gypsiferous Soil	3	Exposed Gypsiferous Soil
4	Town	4	Town
5	Water	5	Water
6	Dense Woodland	6	Dense Woodland
7	Moderately Dense Woodland	7	Moderately Dense Woodland
8	Sudan	8	Sudan
9	Alfalfa	9	Alfalfa
A	Cotton	A	Cotton
B	Maize	B	Maize
C	Wheat	C	Wheat
D	Improved Pasture	D	Improved Pasture
E	Unimproved Pasture	E	Unimproved Pasture
F	Oil Well and Storage Tank Sites	G	Barley
G	Barley	H	Oats
H	Oats		

labeled June Soil, June IR, March Soil, and March IR.

Delineation of Training Sets

The third step in the organization of the supervised classification consisted of delineating training sets from the ground truth maps onto two grids. The grids which consisted of 10 columns per inch in the horizontal direction and eight lines per inch in the vertical direction were produced by the computer line printer for the Landsat scenes to serve as reference sources for geographical coordinates (line and column numbers). The coordinates were used to designate the locations of the training sets within the Landsat scenes and to geometrically correct the Landsat greyscale images. The grids were geographically referenced to the study area by overlaying each one on a topographic map and drawing in the section lines. The corresponding section lines of the ground truth map and grid served to reference the map and grid to each other. By overlaying each grid sequentially on the ground truth maps appropriate for each scene, the training sets were delineated on their respective grids.

The locations of most of the ground cover classes (water, urban districts, perennial vegetation, pasture, oil well and storage tank sites, and gypsum) are the same for both scenes. Only the agricultural classes change in distribution between June and March. Therefore, the only training sets which were to be delineated on separate grids for each scene were those for the agricultural classes. The training sets for all the June ground cover classes were delineated on the June grid. Only the March agricultural training sets were delineated on the March grid. The computer classification program is used to obtain the complete March training set data by updating the previously processed June training sets.

Digitization of Training Set Data

The fourth and final step in the development of the supervised classification involved digitizing the training sets. The training sets were digitized by compiling the coordinates of each area which served as part of a training set. The digitized data was recorded on computer cards to serve as the training set data for the classification program.

Format of LANDSAT Imagery

The two formats of Landsat imagery used in this investigation were black and white photographic prints and digital data stored on computer-compatible tapes (CCT). The multispectral composition of each Landsat scene consists of four channels or bands of the electromagnetic spectrum labeled four, five, six, and seven. The spectral limits of each band are 0.5 to 0.6, 0.6 to 0.7, 0.7 to 0.8, and 0.8 to 1.1 micrometers (10^{-6} meters) respectively. Each Landsat scene consists of approximately 7,581,600 data points or pixels (picture element) arranged in a matrix consisting of 2,340 lines of approximately 3,240 columns. Each pixel represents the average reflectance of 1.1 acres.

For storage on computer-compatible tapes, each Landsat scene is divided into four vertical strips of equal column width. The digital data of all four bands from each strip is organized into a separate file (dataset). The resulting four files are stored sequentially on on the CCT, so that the first file represents the leftmost strip of the scene.

Computer Processing Programs

Pre-classification computer processing and enhancement techniques were applied to the digital data of the two scenes in order to eliminate unnecessary data and to correct radiometric and geometric distortions. After the enhancement and correction techniques were completed, the supervised classification of the digital data was executed in two sequential phases. The programs used in this analysis of Landsat digital data included GODDARD, FRAME, GREYSCALE, SMOOTH, REGISTER, TRANSFORMATION, and DELIN, all of which are described in the following sections. The DELIN program was used several times with different options identified as DELIN-merge, DELIN-subscene and DELIN-classification. The analysis flow chart shown in Figure 4 illustrates the sequence of procedures used for automatic data processing and the development of the supervised classification. The computer program listings appear in Appendix A and the job control cards for the programs are listed in Appendix B.

GODDARD (Recombination of Landsat CCT Files)

The digital data of a Landsat scene is organized into four files on the computer-compatible tapes (CCT) received from the Earth Resources Observation Systems (EROS) Data Center at Sioux Falls, South Dakota. In order to simplify all further computer processing, the GODDARD program was used to combine the original four files into one file. The resulting single file of data was labeled the "GODDARD" dataset.

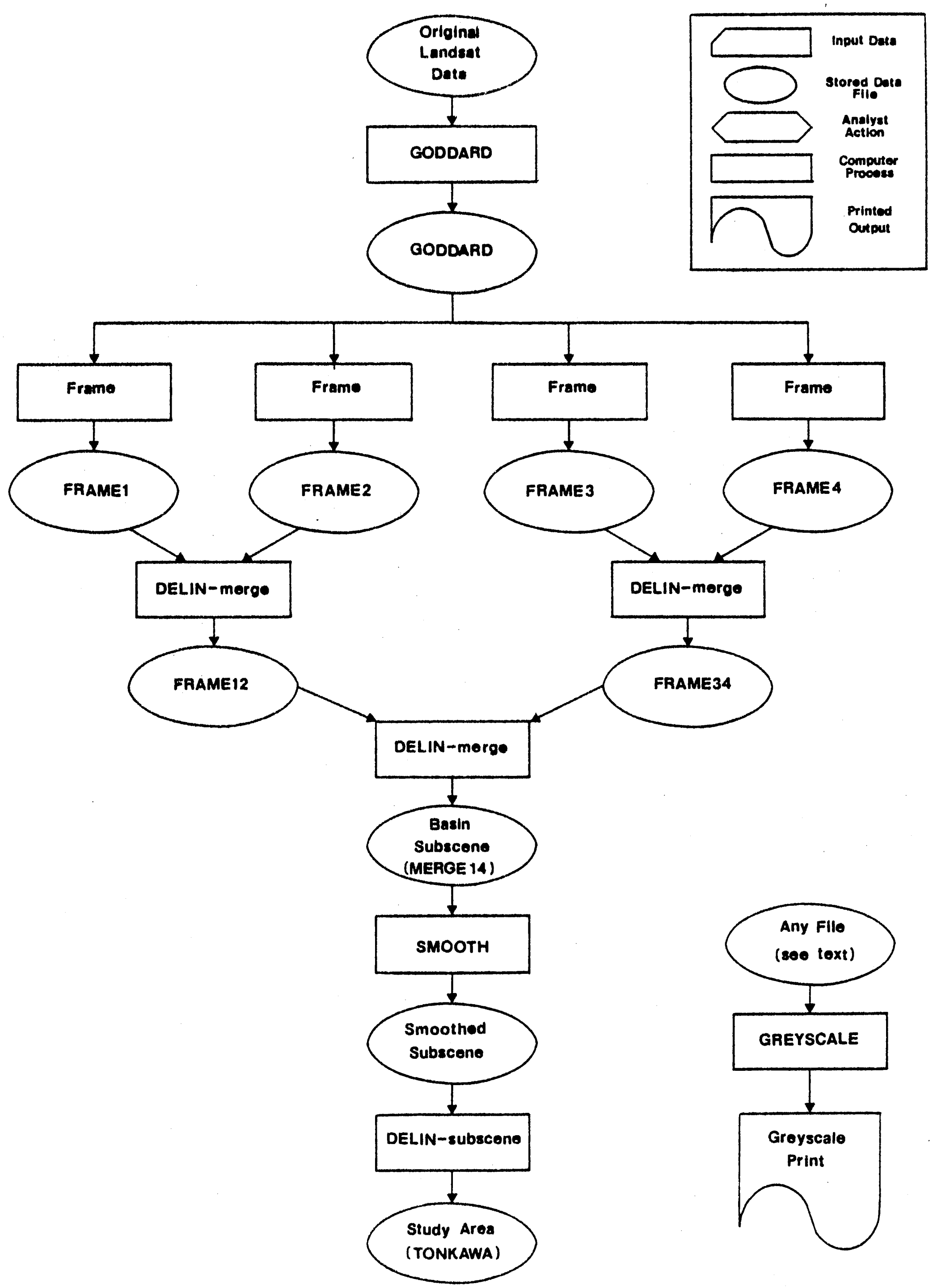

Figure 4. Analysis Flow Chart

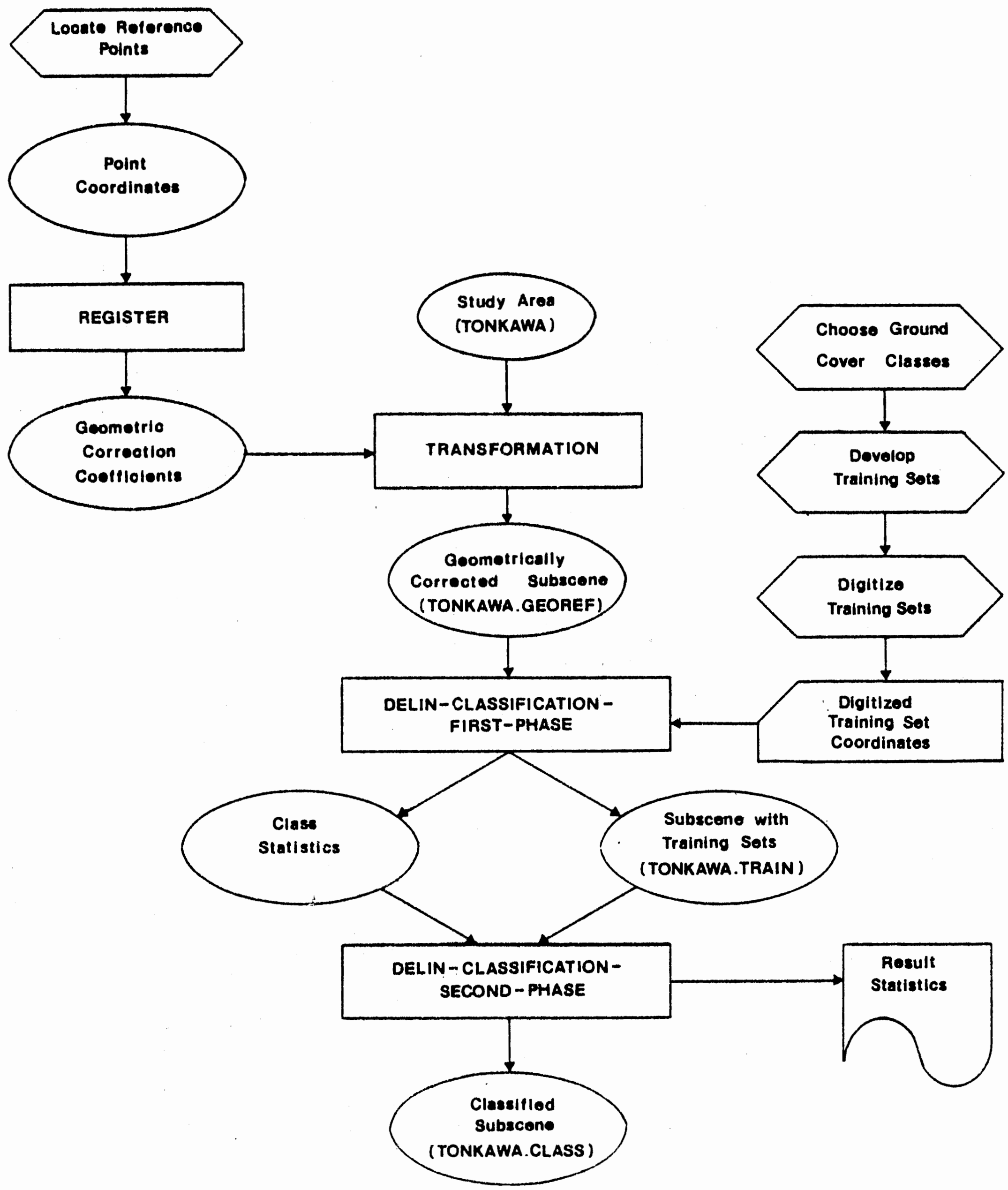

Figure 4. (Continued)

FRAME (Subscene and Histogram)

The purpose of the FRAME program is to copy the digital data which represents only the area of interest (subscene) into a separate dataset in order to eliminate unnecessary data from all further computer processing. A histogram of brightness levels for all four bands of the digital data of the subscene is also produced by the FRAME program.

The portion of the Landsat scene to be copied into the subscene dataset is identified and located for the FRAME program by the coordinates (Landsat scene line and column number) of the upper left pixel of the subscene and the number of lines and columns composing the subscene.

The FRAME program suffers from limitations regarding the size of the subscene to be copied from the original scene and the format of digital data processed by the program. FRAME cannot be successfully used to copy a subscene whose column width completely spans a file and/or overlaps any file boundary with one run of the program. A subscene which is exactly as wide as the file it occupies must be copied as two smaller partial subscenes with the width of each being a multiple of 200. Subscenes which cross file boundaries must be divided at the file boundary into smaller partial subscenes and copied with separate runs of the FRAME program into their respective datasets. The partial subscenes are merged into the complete subscene by the DELIN-merge program. Only the complete GODDARD dataset can be used as the input digital data source for the FRAME program.

In order to fulfill contract agreements of the grant which supported this investigation, the area copied as the initial subscene from the

June 29, 1974, and March 9, 1978, Landsat scenes was the basin of the Southern Great Plains Watershed Research Project; henceforth it is referred to as the "basin subscene". The basin subscene is composed of the Sugar Creek, Spring Creek, Stinking Creek, Tonkawa Creek, Delaware Creek, Ionine Creek, Jack Hollow Creek, Rock Hollow Creek, West Fork Creek, Salt Creek, Bitter Creek, West Fork Creek, East Fork Creek, Spring Creek, Winter Creek, and Little Washita River watersheds which inherently include the study area of this report.

The coordinates of the upper left pixel of the basin subscene were determined from the seven by seven inch black and white prints of band five or seven of the two Landsat scenes. The ratios of the number of columns and lines per millimeter on the prints were used to find the approximate number of columns and lines to the upper left corner of the subscene from the top and left sides of the print. The column number was then rounded down to the nearest multiple of 200 from the first column number of the third file.

The basin subscene was copied as four partial subscenes with four sequential runs of the FRAME program because its column width overlapped file boundaries two, three, and four and completely spanned file three in both the June and March Landsat scenes. The partial subscenes were labeled "FRAME1", "FRAME2", "FRAME3", and "FRAME4" from left to right as they appeared in the basin subscene of both Landsat scenes.

The total column widths for the June 29, 1974, and March 9, 1978, Landsat scenes were 3240 and 3192, respectively and the corresponding file widths were 810 and 798, respectively. The 798 column width of the March scene required a 12 column interval to be skipped between the end of each preceding file and the beginning of the next in order to avoid extraneous data and to correctly identify the coordinates of the upper left pixel of each of the four partial subscenes.

The upper left pixel coordinates and line and column widths for each of the partial subscenes of the basin subscene copied from the June 29, 1974,and March 9, 1978,Landsat scenes are listed in Table V. The FRAME program was used to isolate the basin subscenes instead of the DELIN-subscene program because FRAME produces a histogram which is not provided by DELIN-subscene.

DELIN-merge (Subscene Recombination)

The DELIN-subscene program was used to recombine the four partial subscenes of the basin into one complete subscene. The four partial subscenes were first reduced to two by merging subscenes FRAME1 and FRAME2 into a new subscene labeled "FRAME12" and merging subscenes FRAME3 and FRAME4 into the subscene labeled "FRAME34". The two subscenes FRAME12 and FRAME34 were then combined into the final complete basin subscene and stored in a single dataset labeled "MERGE14".

GREYSCALE (Alphanumberic Line Print)

The GREYSCALE program was used to produce an alphanumeric print representation of Landsat digital data by a computer line printer. The scale of contrast assigned to the print was determined from an evaluation of the histograms produced by the FRAME program.

SMOOTH (Correction of Radiometric Distortion)

The horizontal banding in Landsat imagery which results from radiometric distortion during the scanning of a scene by the Landsat satel-

TABLE V

UPPER LEFT PIXEL COORDINATES AND LINE AND COLUMN WIDTHS FOR EACH PARTIAL SUBSCENE OF THE JUNE AND MARCH "BASIN SUBSCENES"

June 29, 1974

	First Line	Number of Lines	First Column	Number of Columns
FRAME1	1	1100	1221	400
FRAME2	1	1100	1621	810
FRAME3	1	1100	2231	200
FRAME4	1	1100	2431	400

March 9, 1978

	First Line	Number of Lines	First Column	Number of Columns
FRAME1	1	880	1209	400
FRAME2	1	880	1621	600
FRAME3	1	880	2219	200
FRAME4	1	880	2431	600

lite sensors was removed from the June and March basin subscenes by the SMOOTH program.

DELIN-subscene (Subscene Isolation Without Histogram)

The study area subscene labeled "TONKAWA", was copied from the basin subscene by the DELIN-subscene program. DELIN-subscene was used to isolate the study area instead of the FRAME program because DELIN-subscene could copy the entire study area with one run of the program and it is not restricted to digital input data in the GODDARD format, as required in the FRAME program.

The study area was located in the basin subscene by the coordinates of the upper left pixel and the line and column widths of the study area. The coordinates were identified from a GREYSCALE print of the basin subscene.

REGISTER (Geometric Correction, First Phase)

Geometric distortion results from the scanning nature of the satellite sensors, movement of the satellite, rotation of the earth, and stretch of the scene caused by the line printer. The correction of geometric distortion of the GREYSCALE prints of Landsat imagery was accomplished in two phases. Each phase was performed by a separate computer program, of which REGISTER is the first and TRANSFORMATION, the second.

The REGISTER program calculates a set of constants which are used by the TRANSFORMATION program to eliminate the geometric distortion from the Landsat scenes. In order to calculate the constants, the

REGISTER program requires the coordinates (line and column number) of at least nine points from the uncorrected GREYSCALE print of the subscene and the corresponding coordinates from the 7 1/2 minute (1:24,000) topographic maps of the subscene area. Transformation constants are calculated for each set of four consecutive points, and the resulting constants are averaged. To check accuracy, the coordinates for each point are calculated based on the average constants and compared to the original coordinates. Differences less than one (1.0) pixel are considered acceptable.

The intersections of section lines were used as reference points. Section lines on the GREYSCALE prints were distinguished as linears formed by the subtle contrast of grey tones caused by differing agricultural practices throughout the study area. The June training set grid was used to establish the coordinates of the reference points on the topographic map. Sixteen points were selected, well spaced around outer margin of the subscene. The points were organized into groups of four points with one point from each corner. A seventeenth point required by the program was selected near the center of the subscene. The same seventeen points were used for both the June and March study area subscenes.

The intersection of section lines provided excellent reference points for the source of coordinates used to calculate the geometric correction constants. Very good accuracy resulted with the first choice of coordinates used by the REGISTER program from both the June and March data. The largest difference between any calculated and original coordinates of either subscene was .6815 pixel. The average difference for all coordinates of the June and March study area subscenes was .1592 and .1807 pixels, respectively.

TRANSFORMATION (Geometric Correction, Second Phase)

The TRANSFORMATION program was used to apply geometric correction to digital data of the study area subscenes using the constants provided by the REGISTER program. The resulting subscene was labeled "TONKAWA. GEOREF". The accuracy of the geometric correction was checked by overlaying and comparing a 7 1/2 minute (1:24,000) topographic map of the study area with a GREYSCALE print of the geometrically corrected study area subscene. Both the June and March study area subscenes were geographically referenced to the topographic maps with a displacement error of less than one pixel. The GREYSCALE prints of the June and March geometrically corrected study area subscenes are illustrated in Figures 5 and 6, respectively. An overlay (Plate VII) can be placed directly on to Figures 5 and 6 to show the boundaries of the study area within the GREYSCALED subscene.

DELIN-classification-first phase (Training Set Statistics)

The first phase of the DELIN-classification program creates a file which includes an identifier (fifth band) for each pixel that denotes the pixel as belonging to a training set for one of the ground cover classes. Pixels which are not located in any of the training set areas are identified by zeros. The study area is outlined by identifying all pixels outside the area as negative one. A map of the identifiers can be printed to check the location of the training set areas.

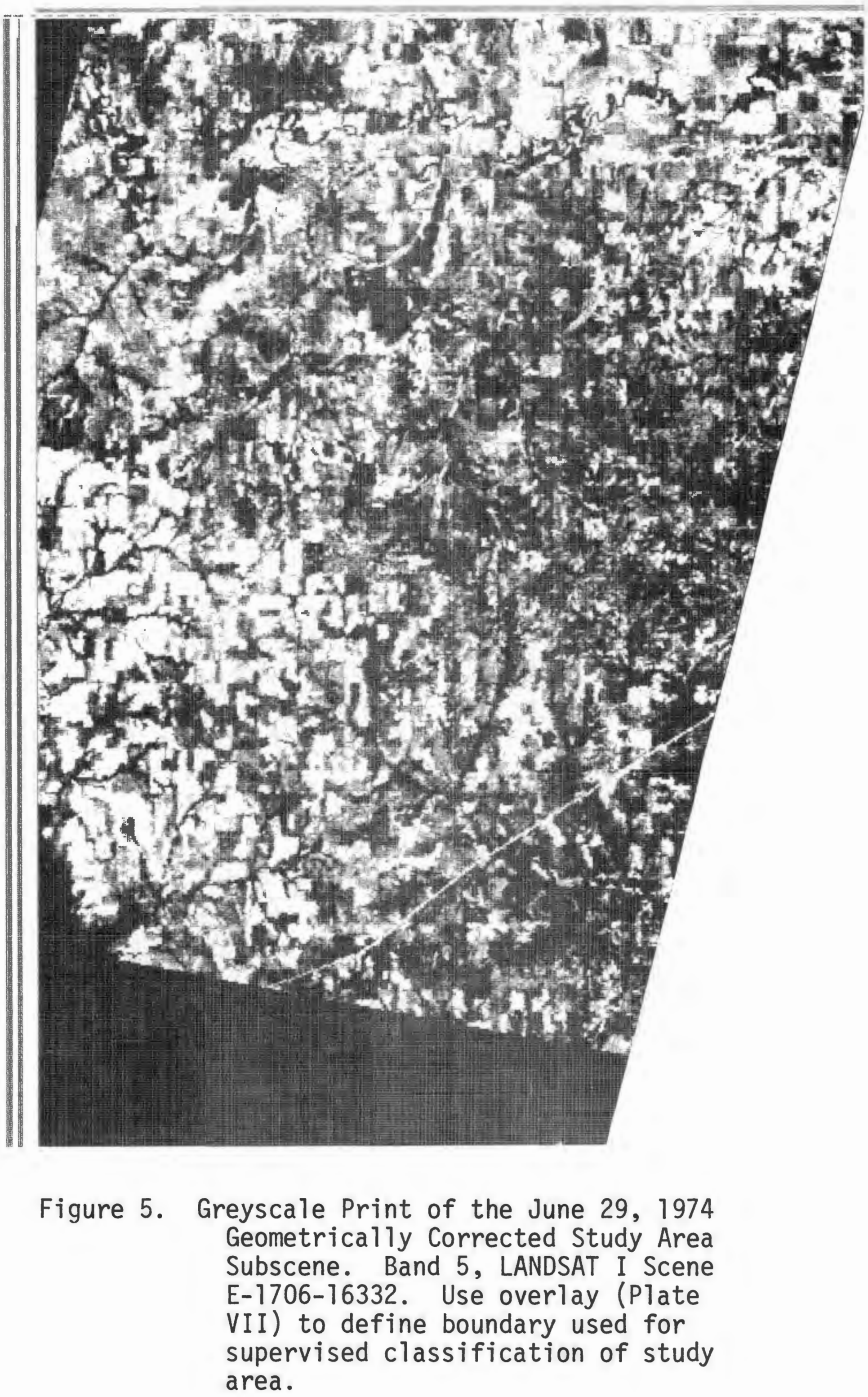

Figure 5. Greyscale Print of the June 29, 1974 Geometrically Corrected Study Area Subscene. Band 5, LANDSAT I Scene E-1706-16332. Use overlay (Plate VII) to define boundary used for supervised classification of study area.

Figure 6. Greyscale Print of the March 9, 1978 Geometrically Corrected Study Area Subscene. Band 5, LANDSAT III Scene E-30004-16290. Use overlay (Plate VII) to define boundary used for supervised classification of study area.

The mean and cross-band covariance matrix are calculated for each training set. These statistics are used by the second phase of classification program. The output file produced by the first phase was labeled "TONKAWA.TRAIN" with additional notations to identify which subscenes (June or March) and training set groups (Soil or IR) were used.

DELIN-classification-second phase (Classification)

The second phase of the DELIN-classification program uses the classical maximum likelihood discrimination technique to classify each pixel. The training set statistics from the first phase govern the assignment of a ground cover class to each pixel. The output file from the first phase is used as input to allow a comparison of the training set class with the class assigned by the maximum likelihood method. A table is printed listing the distribution of the computer assigned classes for the pixels of each training set as well as the distribution of the classification for the entire study area. A file is created which includes an identifier for each pixel that denotes the computer assigned ground cover class. A map of the identifiers can be printed which displays the classification of the entire study area. The output file produced by the second phase was labeled "TONKAWA.CLASS" with additional notations to identify the subscene and training set group.

Classification Procedure

Both phases of the DELIN-classification program were applied to the June and March study area subscenes. The classification procedure used for the subscenes consisted of performing repetitive classifications of the study area using different combinations of bands of digital data with each of the Soil and IR training set groups. These repetitive classifications will subsequently be referred to as "classification treatments". A total of 14 classification treatments were made of the study area. Tables XIII THROUGH XXVI (Appendix C) list the results for the 14 computer classification treatments. The results are presented as the number of pixels assigned to each of the ground cover classes within the entire study area and within each of the training sets.

The different band combinations were used to evaluate the discrimination capability of various individual bands as well as combinations of bands. The four training set groups (Soil and IR for March 9, 1978, and June 29, 1974) were used to evaluate: (1) the two ground truth sources for the vegetated gypsum class and (2) the effect of soil moisture conditions and seasonal vegetation changes upon the classifications of gypsiferous soils.

The method used to apply the first phase of the classification program to the March study area subscene differed slightly from that used for the June subscene. The method used for the March subscene was different because the March training set data consisted only of the changes in training set data from the June to March period. Only the data of the June Soil and IR training set groups was complete for the entire subscene. The method used to obtain a complete March Soil and IR training set group involved substituting March agricultural training sets into the corresponding June training sets. This was accomplished by applying the first phase of the classification program twice to the

March subscene. The first execution of the first phase used the March subscene and the appropriate June training set group (Soil or IR) as the two required input files for the program. The second execution completed the March training set data for the appropriate group by updating the previously processed complete June training set data with the training set changes for the March period. The second execution used the output file (labeled "TONKAWA.TRAIN.JUNE") of the first execution of the program and the corresponding March training group as the two required input files. The output file of the second execution was labeled "TONKAWA.TRAIN" with additional notations to identify the subscene (June or March) and training set group (Soil or IR).

Computer Cost and Execution Time

All the computer processing was executed on the IBM 370/158. The total cost for processing one Landsat scene was approximately 850 dollars. The total CPU time required to collectively process the data was approximately 100 minutes. Performing the automatic data processing on disk instead of tape was found to reduce the real time of program execution by two-thirds.

Unsupervised Classification

An unsupervised classification was produced for the study area using the digital data of the Landsat II scene E2900-16073 of July 10, 1977. The unsupervised classification was produced as part of a seminar held in Slidell, Louisiana at the Earth Resources Laboratory (ERL) facilities of the National Aeronautics and Space Administration (NASA). SEARCH and MAXL31 programs, developed by ERL, were executed on the

Comtal/Varian Image Processing System. A similar system is being established at the Remote Sensing Center, Oklahoma State University.

The SEARCH program chooses ground cover classes by searching for homogeneous blocks of three by three or six by six pixels and grouping the similar blocks. The MAXL31 program uses the maximum likelihood technique to classify each pixel into one of a maximum of 31 classes defined by the SEARCH program. A total of 31 classes were defined for the study area.

In order to print a meaningful graphical production of a map of the study area as classified by the unsupervised classification, the 31 classes were reduced to 10 by grouping those together which appeared to represent the same ground cover. The determination of similarity among the 31 classes was made from an evaluation of a two dimensional plot of the percentage of reflectance exhibited by each class in bands five versus seven.

Graphical displays (electrostatic plots) of the study area were prepared at a scale of 1:57,000 and 1:115,000 by assigning different geometric patterns (bit patterns) to each class. Each pixel was then printed on the electrostatic plot as the bit pattern of the class it represented. Electrostatic plots were not geometrically corrected due to the lack of time.

CHAPTER V

RESULTS

Assessment of Digital Landsat Imagery and Near-Infrared Aerial Photography Investigations

Digital Landsat Imagery

Unsupervised Classification. An examination of the unsupervised classification as represented on the electrostatic plots was made to determine if any bit pattern or combination of patterns approximated the distribution of gypsum outcrops and soils. The bit pattern representing the five pasture classes (five of the original 31 classes) encompassed most of the gypsum areas. New bit patterns were assigned to each of the five classes of the pasture group and another electrostatic plot was prepared for evaluation. Examination of the new plot did not reveal any one or unique combination of these classes which consistently represented the true distribution of gypsum outcrops and soil.

The results of the unsupervised classification of the study area using the July 10, 1977, Landsat scene are not meant to represent a complete evaluation of the capabilities of the unsupervised technique because it was applied to data from only one period of the year. A thorough evaluation would include the investigation of unsupervised classifications of digital data representing a variety of seasonal changes and soil moisture conditions. The success of the unsupervised classification is also limited by the small sizes of most gypsum outcrop and soil sites which are below the 1.1 acre resolution limit of the Landsat satellite sensors. The contrast between the signatures of the vegetated gypsum sites and that of the surrounding surface cover such as pasture apparently are not sufficient for the gypsum signatures to dominate the average reflectance of any 1.1 acre area represented by a pixel.

Supervised Classification. Two statistics were used to evaluate the results of the 14 supervised classification treatments. These statistics were the following:

(1) the percentage of pixels in each training set which were correctly classified and

(2) the percentage of pixels in the total study area which the computer classification program correctly assigned to a particular ground cover class.

Both statistics are needed because the first statistic alone may not accurately reflect the results of the classification. This observation is illustrated in Figure 7. The number of pixels which represent the entire study area are shown by the entire rectangular area (A) in the diagram. The upper circle (B) represents the relative number of pixels in a training set for a specific ground cover class. The lower circle (C) represents the relative number of pixels classified as a particular ground cover class occurring in the total study area. The overlap area (D) common to the two circles represents the correctly classified pixels.

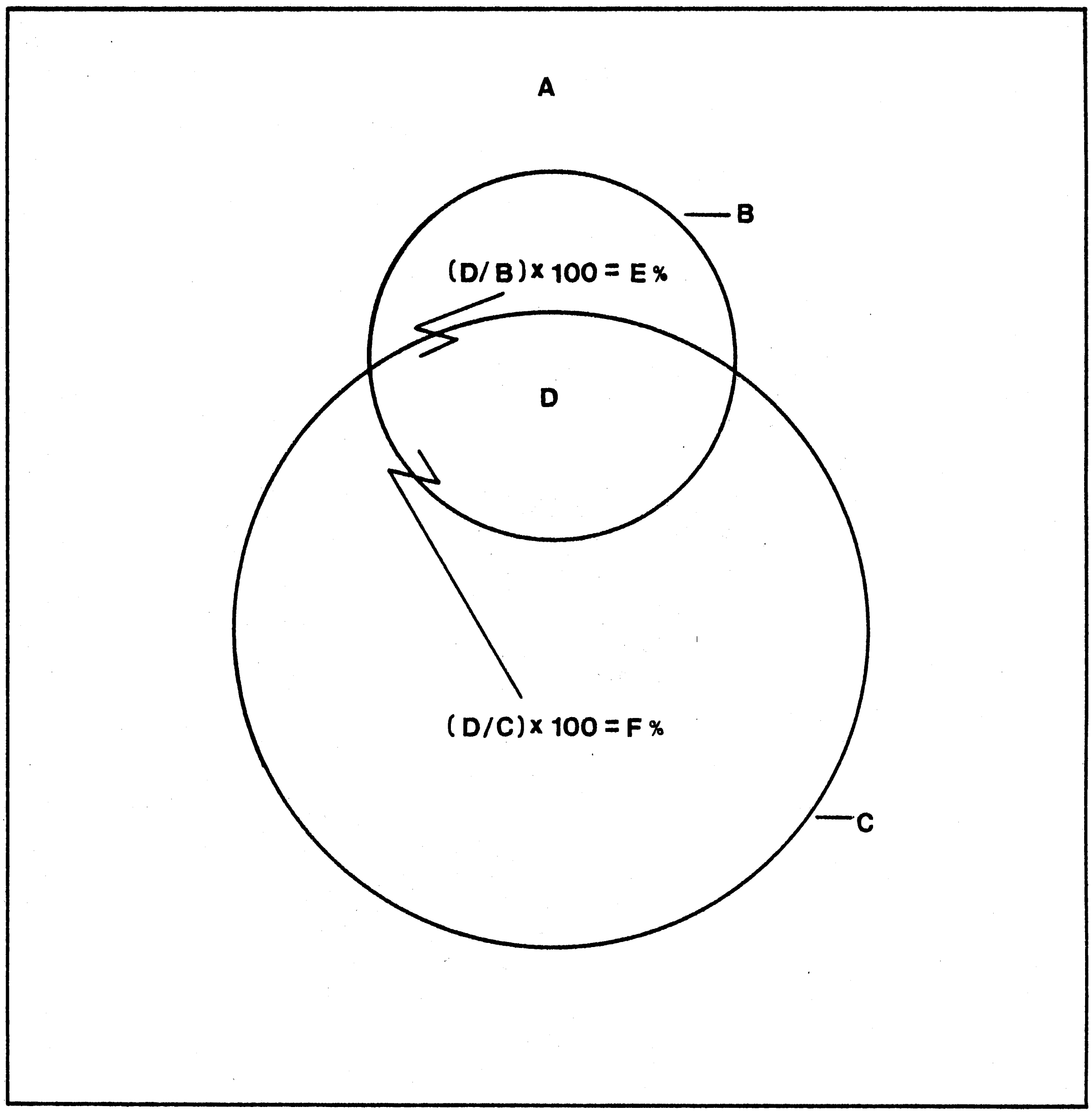

Figure 7. Statistics Used in Final Analysis. A-All Pixels in Total Study Area; B-Training Set Pixels; C-All Pixels Assigned to a Ground Cover Class by the Computer; D-Correctly Classified Pixels; E-Percentage of Training Set Pixels Correctly Classified; F-Percentage of Pixels in C Correctly Classified.

The first statistic, the percentage of pixels in each training set which were correctly classified by the computer, is expressed as the number of pixels in (D) divided by the number of pixels in (B). The second statistic, the percentage of all pixels within the study area correctly assigned to a ground cover class by the computer, is expressed as the number of pixels in (D) divided by the number of pixels in (C). Although the first statistic may be represented by a relatively high percentage, the second statistic might be small due to overclassification by the computer. For example, using Figure 7, the first statistic (D divided by B, multiplied by 100) is large, but the second statistic, the percentage of all pixels correctly assigned to the class by the computer (D divided by C, multiplied by 100) is small. This results in a larger percentage of the study area being incorrectly classified when the difference between (C) and (D) is computed and compared with the total number of pixels in the study area (A).

For most classes, the second statistic (2) cannot be calculated as the percentage of all pixels correctly assigned to a class because the identification of all ground cover throughout the study area was not feasible. For these classes the training set pixels are the only pixels in the study area for which the computer classification can be verified. As a consequence, the second statistic was used for only those classes which are entirely accounted for as training sets in the study area (i.e., gypsum and oil field classes).

The results of the classification treatments for the two vegetated gypsum outcrop and soil classes are listed in Table VI. The results for the exposed gypsiferous soil class are listed in Table VII. The results of the combined vegetated and non-vegetated gypsum classes are

TABLE VI

RESULTS OF THE CLASSIFICATION TREATMENTS FOR VEGETATED GYPSUM OUTCROPS AND SOIL

Bands	Scene	Training Set Group	Gypsum Training Set Symbol	Entire Study Area	Training Set Area		Area Classified As Gypsum by the Computer		Number of Pixels Correctly Classified	Percentage of Training Set Correctly Classified	Percentage of Study Area Assigned to Gypsum Class Correctly Classified
				Number of Pixels	Number of Pixels	As Percent of Study Area (B/A) X 100	Number of Pixels	As Percent of Study Area (C/A) X 100			
				A	B		C		D	E	F
4,5,6,7	June	Soil	1	69,698	2,309	3.3	4,023	5.8	438	19.0	10.9
4,5,6,7	June	IR	2	69,708	448	0.6	7,582	10.9	184	41.1	2.4
4,5,6,7	March	Soil	1	69,702	2,292	3.3	1,062	1.5	93	4.1	8.8
4,5,6,7	March	IR	2	69,702	442	0.6	966	1.4	15	3.4	1.6
4,5	June	IR	2	68,262	449	0.7	3,386	5.0	52	11.6	1.5
4,5	March	IR	2	69,702	442	0.6	1,225	1.8	23	5.2	1.9
4	June	Soil	1	68,263	2,328	3.4	0	0	0	0	0
4	March	Soil	1	69,702	2,292	3.3	212	0.3	22	1.0	10.4
5	June	IR	2	68,262	449	0.7	0	0	0	0	0
5	March	IR	2	69,702	442	0.6	11,212	16.1	123	27.8	1.1
7	June	Soil	1	68,263	2,328	3.4	0	0	0	0	0
7	June	IR	2	69,698	448	0.6	23,659	33.9	216	48.2	0.9
7	March	Soil	1	69,702	2,292	3.3	0	0	0	0	0
7	March	IR	2	69,702	442	0.6	14,009	20.1	132	29.9	0.9

TABLE VII

RESULTS OF THE CLASSIFICATION TREATMENTS FOR EXPOSED (NON-VEGETATED) GYPSIFEROUS SOIL

Bands	Scene	Training Set Group	Gypsum Training Set Symbol	Entire Study Area: Number of Pixels (A)	Training Set Area: Number of Pixels (B)	Training Set Area: As Percent of Study Area (B/A) X 100	Area Classified As Gypsum by the Computer: Number of Pixels (C)	Area Classified As Gypsum by the Computer: As Percent of Study Area (C/A) X 100	Number of Pixels Correctly Classified (D)	Percentage of Training Set Correctly Classified (E)	Percentage of Study Area Assigned to Gypsum Class Correctly Classified (F)
4,5,6,7	June	Soil	3	69,698	98	0.1	4,050	5.8	54	55.1	1.3
4,5,6,7	June	IR	3	69,708	98	0.1	4,108	5.9	54	55.1	1.3
4,5,6,7	March	Soil	3	69,702	95	0.1	3,950	5.7	32	33.7	0.8
4,5,6,7	March	IR	3	69,702	95	0.1	547	0.8	5	5.3	0.9
4,5	June	IR	3	68,262	98	0.1	4,358	6.4	53	54.1	1.2
4,5	March	IR	3	69,702	95	0.1	396	0.6	2	2.1	0.5
4	June	Soil	3	68,263	98	0.1	0	0	0	0	0
4	March	Soil	3	69,702	95	0.1	0	0	0	0	0
5	June	IR	3	68,262	98	0.1	9,261	13.6	47	48.0	0.5
5	March	IR	3	69,702	95	0.1	0	0	0	0	0
7	June	Soil	3	68,263	98	0.1	6,891	10.1	36	36.7	0.5
7	June	IR	3	69,698	98	0.1	6,919	9.9	36	36.7	0.5
7	March	Soil	3	69,702	95	0.1	0	0	0	0	0
7	March	IR	3	69,702	95	0.1	0	0	0	0	0

listed in Table VIII.

The two statistics used to evaluate the classification treatments for the gypsum classes were the following:

(1) the percentage of gypsum training set pixels correctly classified (column E, Tables VI-VIII) and

(2) the percentage of all pixels assigned to the gypsum class(es) by the computer which were correctly classified (column F, Tables VI-VIII).

The calculation of the statistics is illustrated by reference to Figure 8. The figures from the first classification treatment listed in Table VI are used as an example. The letters representing the various parts of the diagram correspond to the letters heading columns which contain the equivalent statistics in Tables VI-VIII.

The training set for the vegetated gypsum class of the June Soil training set group consisted of 2309 pixels (B). The computer assigned 4023 pixels (C) of the study area to the gypsum class of which 438 (D) were correctly classified. The first statistic (E) was calculated as the number of pixels in D divided by the number of pixels in (B). The second statistic (F) was calculated as the number of pixels in (D) divided by the number of pixels in (C).

The June-Soil training set data map is illustrated in Figure 9. The aerial distribution of pixels assigned to the gypsum classes using the June-Soil training sets is shown on the computer classification maps in Figures 10 through 12. The June-IR training set data map is illustrated in Figure 13. The aerial distribution of pixels assigned to the gypsum classes using the June-IR training sets is shown on the classification maps in Figures 14 through 16. When the computer classification

TABLE VIII

RESULTS OF THE CLASSIFICATION TREATMENTS FOR COMBINED VEGETATED AND

NON-VEGETATED GYPSUM CLASSES

Bands	Scene	Training Set Group	Gypsum Training Set Symbols	Entire Study Area	Training Set Area		Area Classified as Gypsum by the Computer		Number of Pixels Correctly Classified	Percentage of Training Set Correctly Classified	Percentage of Study Area Assigned to Gypsum Class Correctly Classified
				Number of Pixels	Number of Pixels	As Percent of Study Area (B/A) X 100	Number of Pixels	As Percent of Study Area (C/A) X 100			
				A	B		C		D	E	F
4,5,6,7	June	Soil	1 + 3	69,698	2,407	3.5	8,073	11.6	546	22.7	6.8
4,5,6,7	June	IR	2 + 3	69,708	546	0.8	11,690	16.8	249	45.6	2.1
4,5,6,7	March	Soil	1 + 3	69,702	2,387	3.4	5,012	7.2	160	6.7	3.2
4,5,6,7	March	IR	2 + 3	69,702	537	0.8	1,513	2.2	21	3.9	1.4
4,5	June	IR	2 + 3	68,262	547	0.8	7,744	11.3	111	20.3	1.4
4,5	March	IR	2 + 3	69,702	537	0.8	1,621	2.3	33	6.1	2.0
4	June	Soil	1 + 3	68,263	2,426	3.6	0	0	0	0	0
4	March	Soil	1 + 3	69,702	2,387	3.4	212	0.3	22	0.9	10.4
5	June	IR	2 + 3	69,262	547	0.8	9,261	13.4	129	23.6	1.4
5	March	IR	2 + 3	69,702	537	0.8	11,212	16.1	135	25.1	1.2
7	June	Soil	1 + 3	68,263	2,426	3.6	6,891	10.1	154	6.3	2.2
7	June	IR	2 + 3	69,698	546	0.8	30,578	43.9	301	55.1	1.0
7	March	Soil	1 + 3	69,702	2,387	3.4	0	0	0	0	0
7	March	IR	2 + 3	69,702	537	0.8	14,009	20.1	154	28.7	1.1

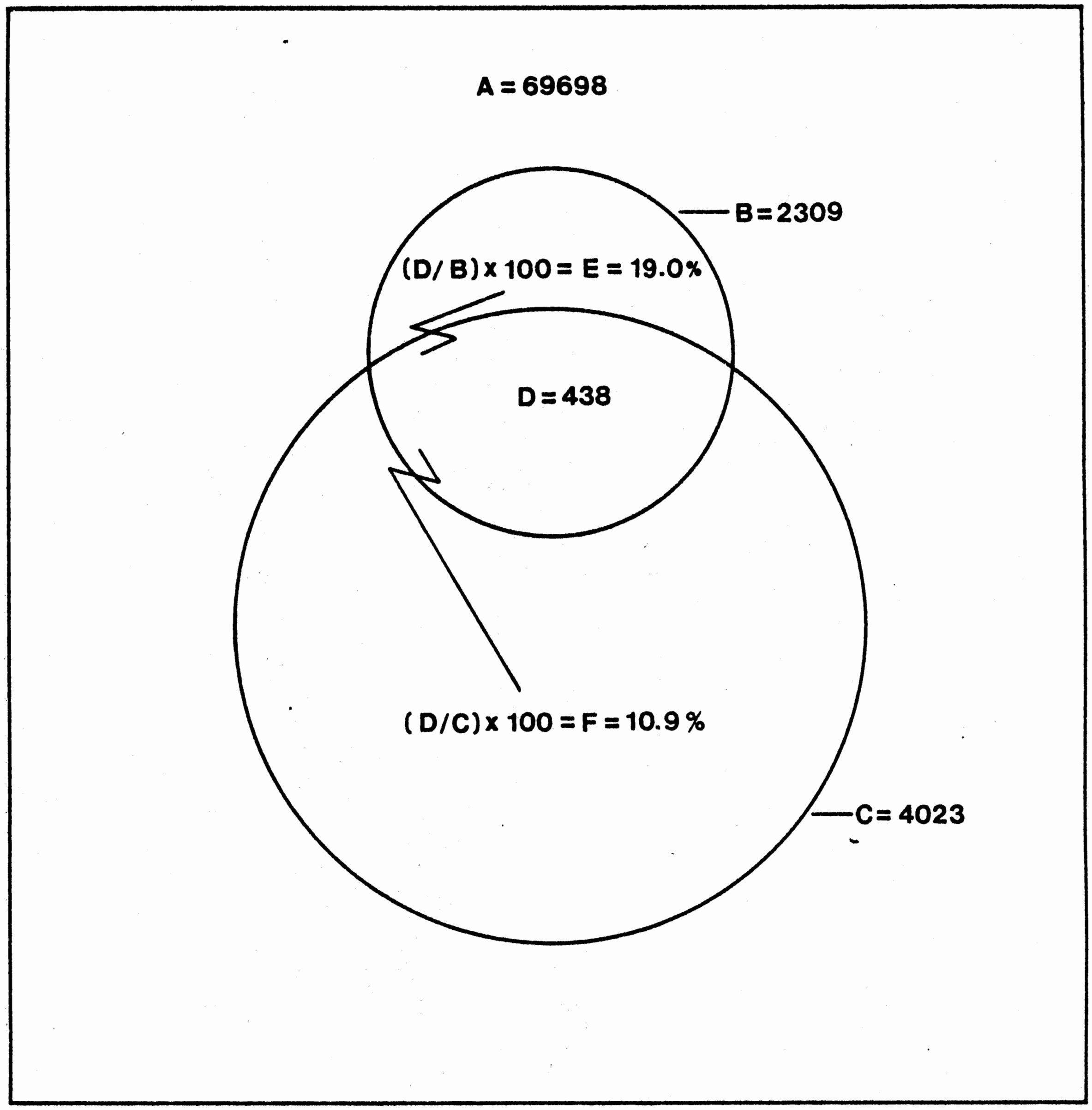

Figure 8. An Example of the Results for the June-Soil Vegetated Gypsum Class. A-All Pixels in Total Study Area; B-Vegetated Gypsum Training Set Pixels; C-All Pixels Assigned to the Vegetated Gypsum Class by the Computer; D-Correctly Classified Pixels; E-Percentage of Gypsum Training Set Pixels Correctly Classified; F-Percentage of Pixels in C Correctly Classified.

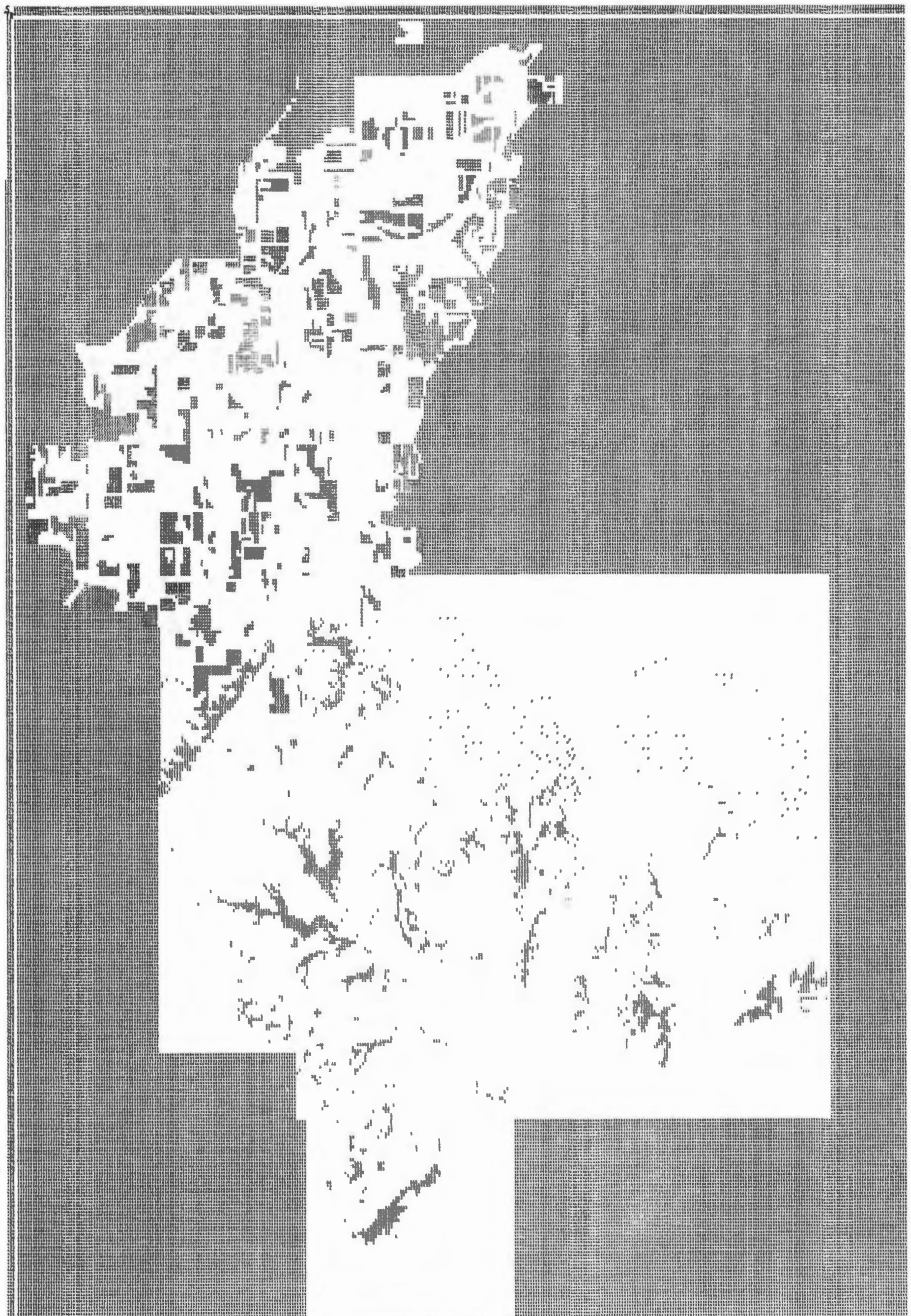

Figure 9. June-Soil Training Set Map. Gypsum training sets are in lower portion of figure (symbols 1 and 3). Oil Well and Storage Tank Site training set is in central portion of figure (symbol F).

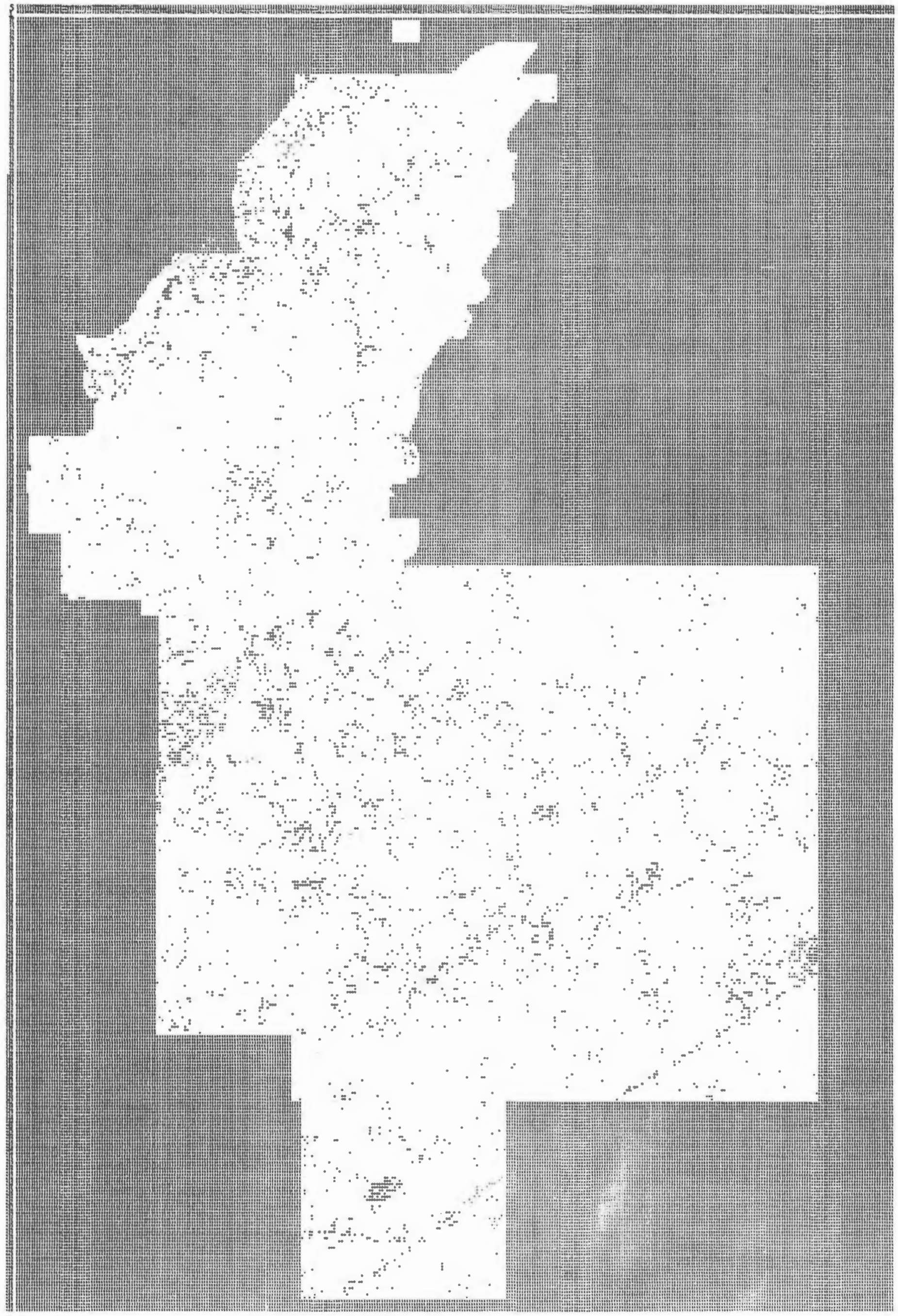

Figure 10. Classification of Vegetated Gypsum Outcrops and Soil (class 1) Using June-Soil Training Sets

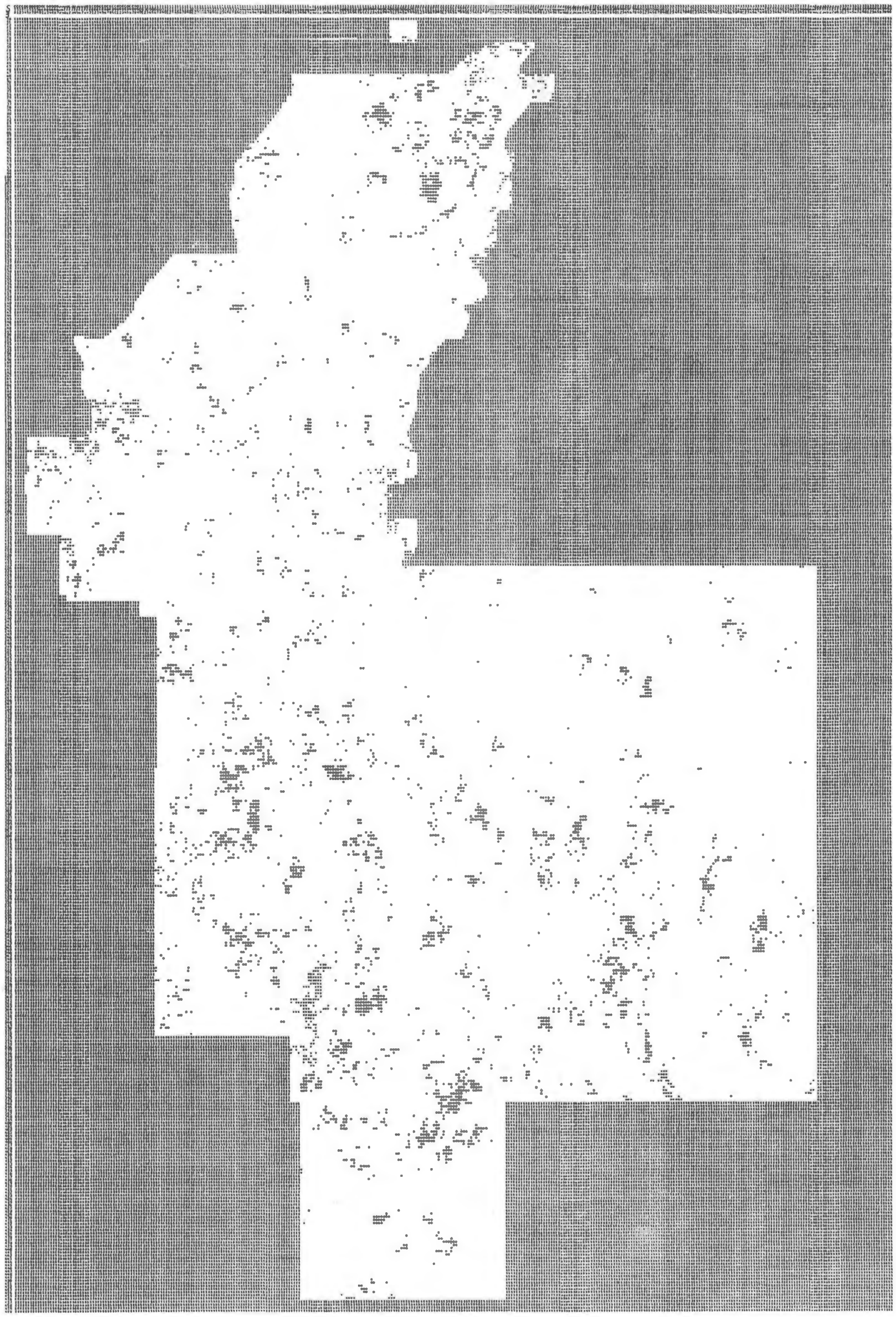

Figure 11. Classification of Exposed Gypsiferous Soil (class 3) Using the June-Soil Training Sets

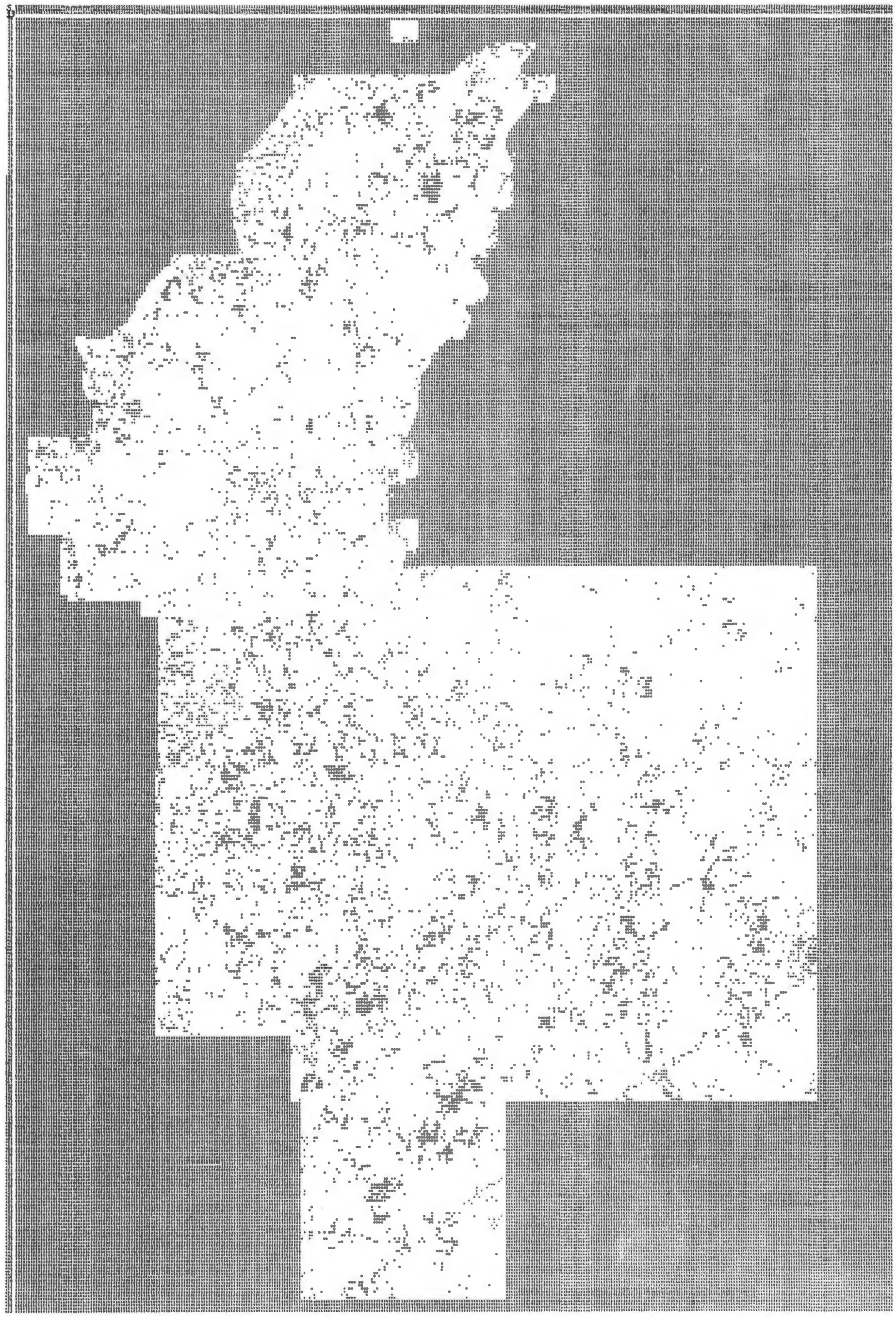

Figure 12. Combined Classifications of Vegetated Gypsum Outcrops and Soil and Exposed Gypsiferous Soil (classes 1 and 3) Using the June-Soil Training Sets

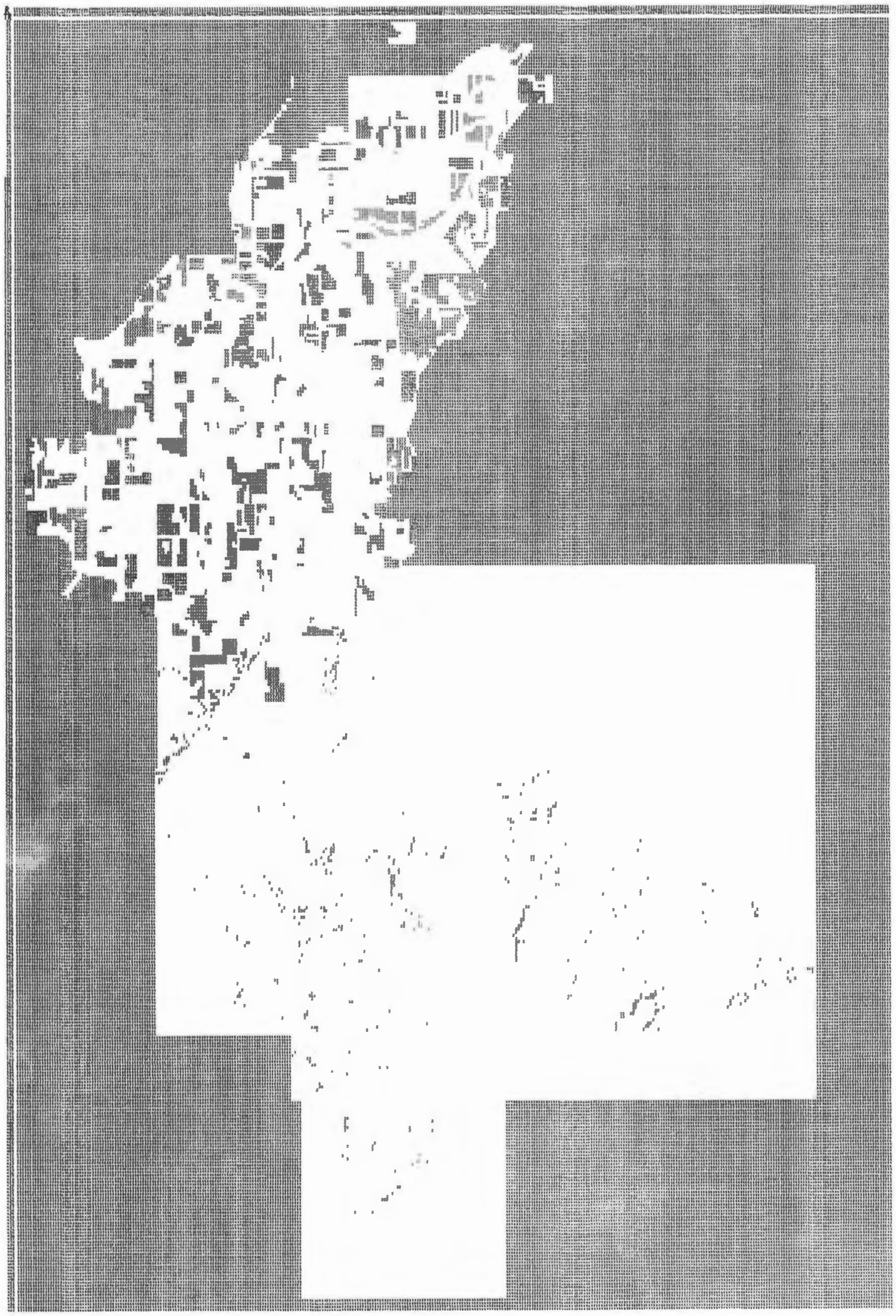

Figure 13. June-IR Training Set Map. Gypsum training sets are in lower portion of figure (symbols 2 and 3).

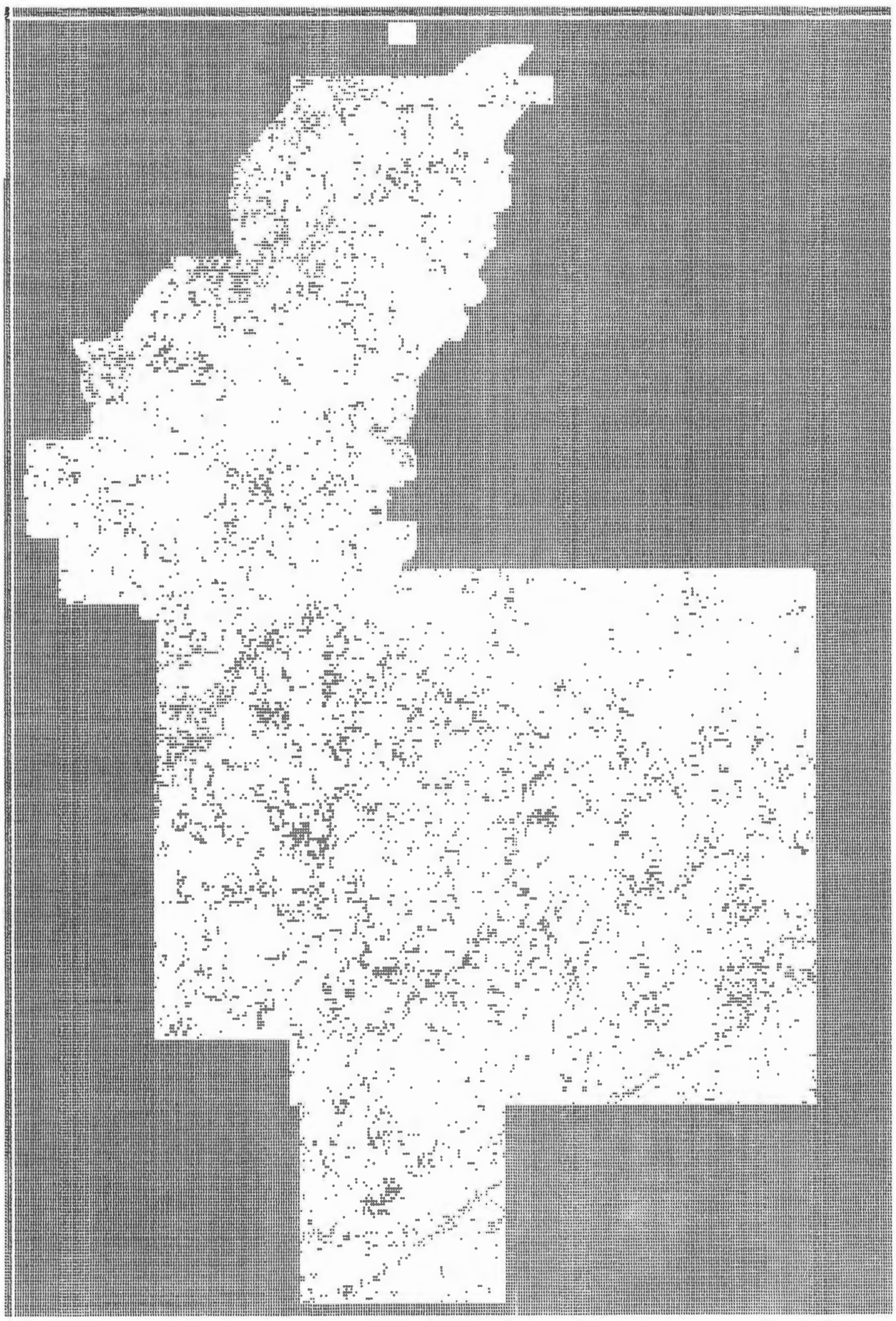

Figure 14. Classification of Vegetated Gypsum Outcrops and Soil (class 2) Using the June-IR Training Sets

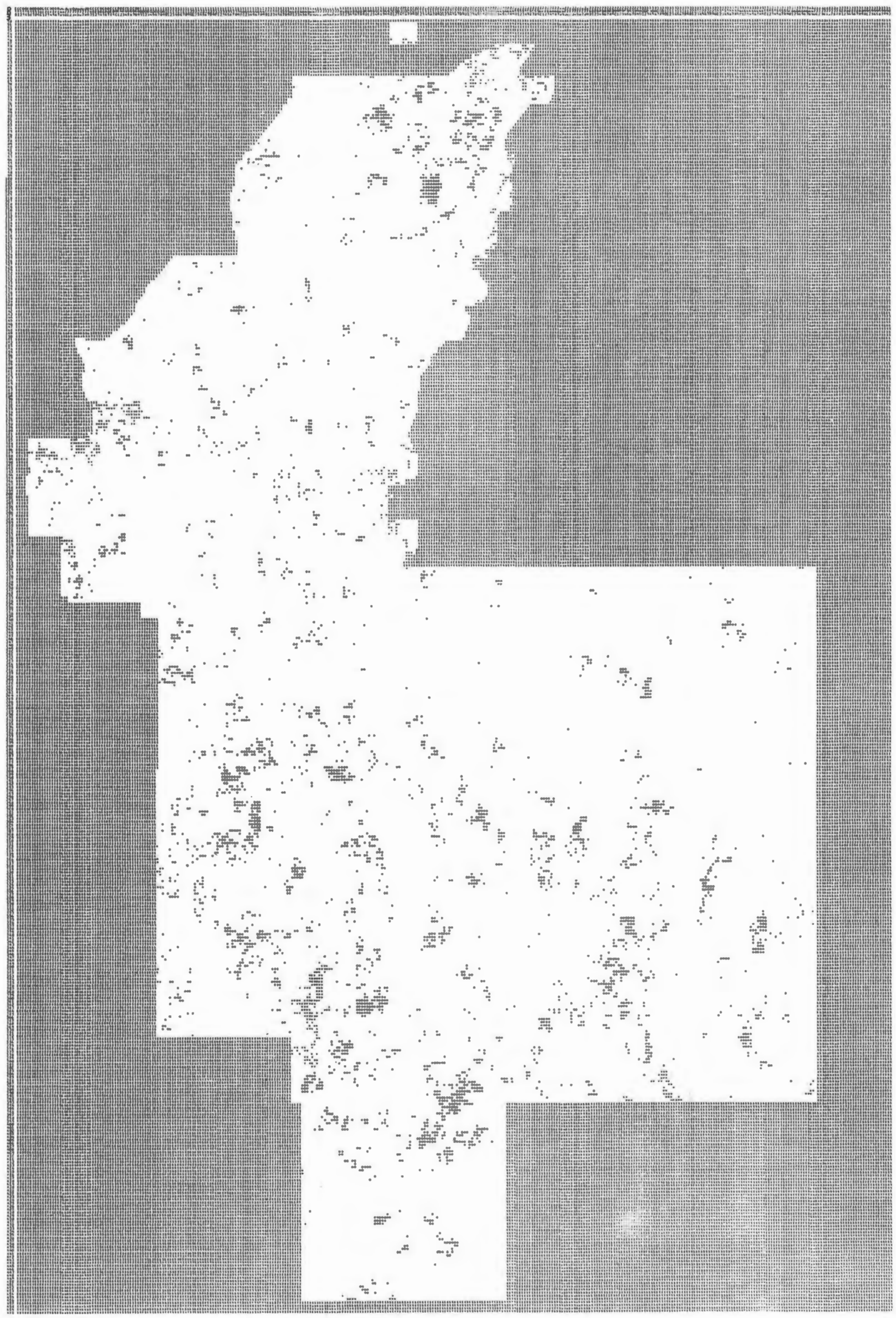

Figure 15. Classification of Exposed Gypsiferous Soil (class 3) Using the June-IR Training Sets

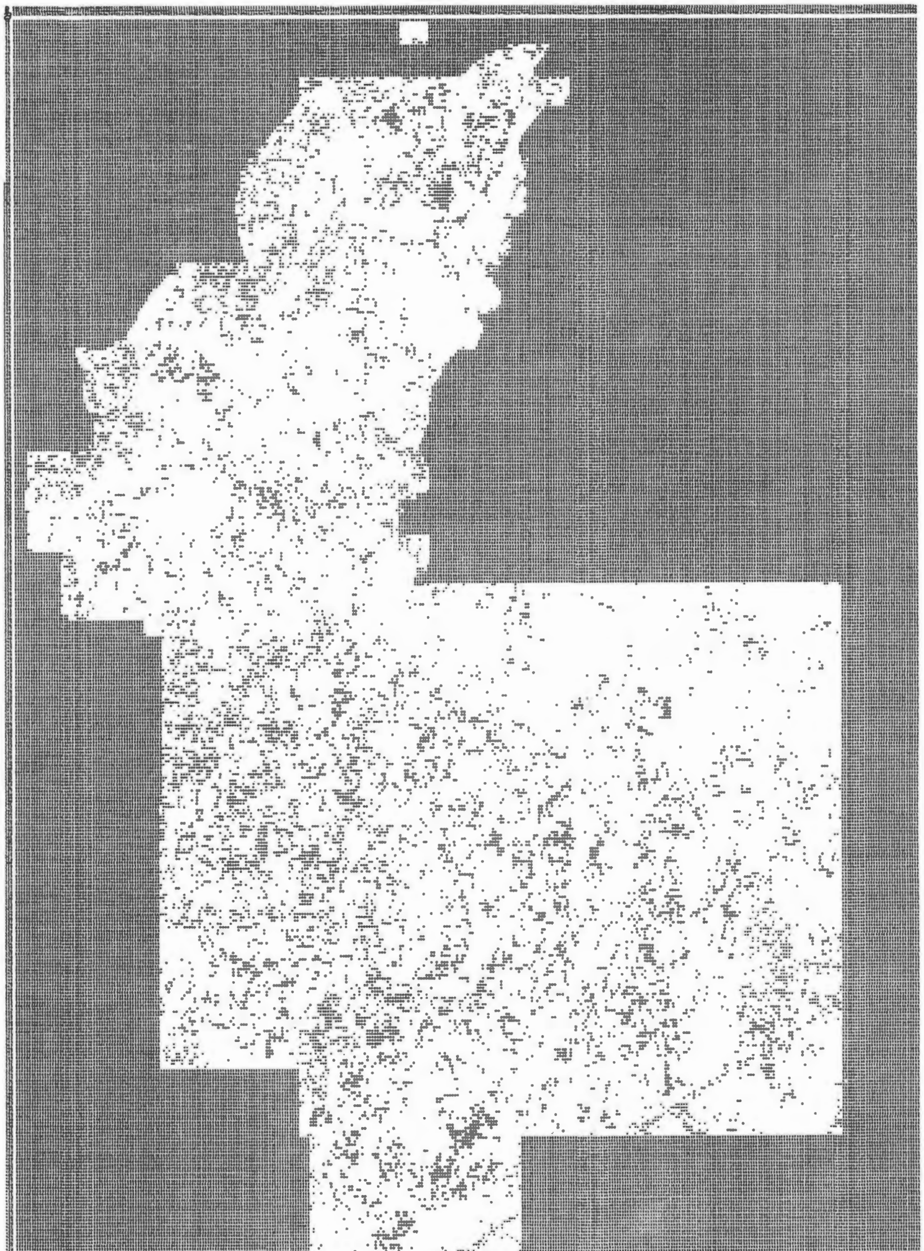

Figure 16. Combined Classification of Vegetated Gypsum Outcrops and Soil and Exposed Gypsiferous Soil (classes 2 and 3) Using the June-IR Training Sets

maps (Figures 10 through 12 and 14 through 16) are compared to the training set data maps (Figures 9 and 13), it becomes evident that the computer classification overestimates the occurrence of the gypsum classes within the total study area (C compared to B in Figures 7 and 8).

The results of the classification treatments for the Oil Well and Storage Tank Site Class are listed in Table IX. The two statistics used to evaluate the classification treatments were the following:

(1) the percentage of Oil Well and Storage Tank Site training set pixels correctly classified (column E, Table IX) and

(2) the percentage of all pixels assigned to the Oil Well and Storage Tank Site class by the computer which were correctly classified (column F, Table IX).

The calculation of the statistics is illustrated by reference to Figure 17. The figures from the first classification treatment of Table IX are used as an example. The letters representing the various parts of the diagram correspond to the letters heading columns which contain the equivalent statistics in Table IX.

There are 173 pixels (B) in the training set for the Oil Well and Storage Tank Site class. The computer assigned 11,546 pixels (C) of the study area to the Oil Well and Storage Tank Site class of which only 49 (D) were correctly classified. The first statistic (E) was calculated as the number of pixels in (D) divided by the number of pixels in (B). The second statistic (F) was calculated as the number of pixels in (D) divided by the number of pixels in (C).

Examination of the tables indicated that the vegetated gypsum outcrops and soil, exposed gypsiferous soil, and oil field well and storage

TABLE IX

RESULTS OF THE CLASSIFICATION TREATMENTS FOR THE OIL WELL AND STORAGE TANK SITE CLASS

Bands	Scene	Training Set Group	Training Set Symbol	Entire Study Area	Training Set Area		Area Classified As Oil Well and Storage Tank Sites by the Computer		Number of Pixels Correctly Classified	Percentage of Training Set Correctly Classified	Percentage of Study Area Assigned to Oil Well and Storage Tank Site Class Correctly Classified
				Number of Pixels	Number of Pixels	As Percent of Study Area (B/A) X 100	Number of Pixels	As Percent of Study Area (C/A) X 100			
				A	B		C		D	E	F
4,5,6,7	June	Soil	F	69,698	173	0.2	11,546	16.6	49	28.3	0.4
4,5,6,7	March	Soil	F	69,702	172	0.2	11,236	16.1	49	28.5	0.4
4	June	Soil	F	68,263	173	0.3	0	0	0	0	0
4	March	Soil	F	69,702	172	0.2	0	0	0	0	0
7	June	Soil	F	68,263	173	0.3	31,397	46.0	127	73.4	0.4
7	March	Soil	F	69,702	172	0.2	16,852	24.2	66	38.4	0.4

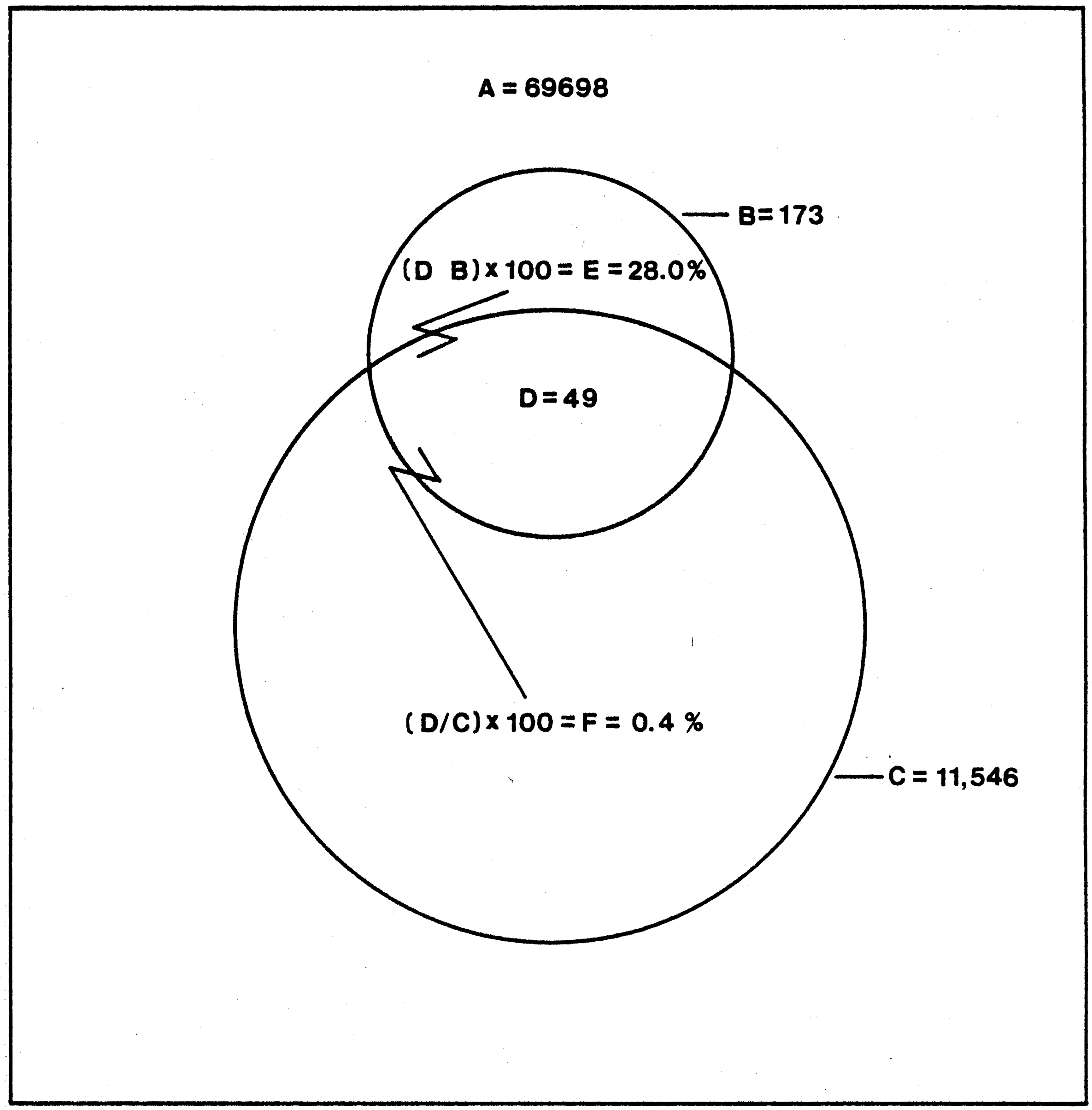

Figure 17. An Example of the Results for the Oil Well and Storage Tank Site Class. A-All Pixels in Total Study Area; B-Oil Well and Storage Tank Site Training Set Pixels; C-All Pixels Assigned to Oil Well and Storage Tank Site Class; D-Correctly Classified Pixels; E-Training Set Pixels Correctly Classified; F-Percentage of Pixels in C Correctly Classified.

tank sites were not classified with a high degree of accuracy using the automatic data processing techniques described in this report (see E and F in Tables VI through IX). In all cases, the computer assigned classes (C on Tables VI through IX) were considerably larger than the training sets (B).

Examination of Tables VI through IX also showed that the degree of accuracy which was achieved with the classification treatments was directly proportional to the number of bands of digital data used for discrimination. The highest accuracy resulted from using all four bands of digital data and the lowest accuracy resulted from using only one band. Therefore, Table X summarizes the results of only those classification treatments (listed in Tables VI through IX) which used all four bands for the discrimination of the gypsum and oil field classes.

An evaluation of Table X revealed that although there are relatively low accuracies with all classification treatments, some trends of consistency in the identification of gypsum are evident. All three gypsum classes were classified with higher accuracies with the June training set groups than with those of March. The higher accuracies probably result from an increase in spectral contrast for the June vegetation due to the seasonal change from dormancy in March to full growth in June. The accuracy of the June and March classification treatments for the Oil Well and Storage Tank class were similar although seasonal variations in vegetation occurred (columns E and F in Table IX).

The percentages of each gypsum training set misclassified as the other ground cover classes are listed in Table XI. The percentages are an expression of the following: [(B-D)/B] x 100 as shown in Figures 7 and 8.

TABLE X

SUMMARY OF RESULTS FOR THE FOUR CLASSIFICATION TREATMENTS WHICH USED FOUR BANDS FOR DISCRIMINATION OF GYPSUM AND OIL FIELD OPERATION SITES

Scene	June		March	
Training Set Group	Soil	IR	Soil	IR
Gypsum Training Sets:				
Vegetated (1)	19.0/10.9*	NA	4.1/8.8*	NA
Vegetated (2)	NA	41.1/2.4*	NA	3.4/1.6*
Exposed (non-vegetated) Gypsiferous Soil (3)	55.1/1.3	55.1/1.3	33.7/0.8	5.3/0.9
Combined Vegetated and Non-vegetated (1 + 3)	22.7/6.8	NA	6.7/3.2	NA
Combined Vegetated and Non-vegetated (2 + 3)	NA	45.6/2.1	NA	3.9/1.4
Oil Well and Storage Tank Site Training Set F	28.3/4.8	NA	28.5/4.0	NA

*Percentage (D/B) of Training Set Correctly Classified/Percentage (D/C) of All Pixels Assigned to the Class by the Computer which were Correctly Classified.

TABLE XI

PERCENTAGES OF EACH GYPSUM TRAINING SET MISCLASSIFIED AS OTHER GROUND COVER CLASSES

Landsat Scene	June 29, 1974				March 9, 1978			
Training Set Group	Soil		IR		Soil		IR	
Training Sets	1	3	2	3	1	3	2	3
Ground Cover Classes								
1*Vegetated Gypsum Outcrops and Soil as Delineated from Soils maps	19	2	NA**	NA	4	0	NA	NA
2 Vegetated Gypsum Outcrops and Soil as Delineated from High Altitude IR Map	NA	NA	41	0	NA	NA	3	0
3 Exposed Gypsiferous Soil	2	55	2	55	2	34	.2	5
4 Town	14	2	12	2	6	0	6.5	0
5 Water	.7	0	.6	0	.3	0	.7	0
6 Dense Woodland	1	1	2	1	1	3	1	3
7 Moderately Dense Woodland	4	1	4	1	2	11	.7	8
8 Sudan	.1	1	0	1	3	0	7	6
9 Alfalfa	6	6	7	7	1	8	2	20
A Peanuts and Cotton	2	4	1	4	4	9	7	14
B May Maize/Maize***	2	6	.6	6	6	2	11	2
C Bare Ground and June Maize/Wheat	4	11	3	13	.1	2	.2	13
D Improved Pasture	5	1	5	2	21	1	29	2
E Unimproved Pasture	23	5	21	7	8	1	12	1
F Oil Field Operation Sites	17	4	NA	NA	23	8	NA	NA
G Barley	NA	NA	NA	NA	4	6	4	6
H Oats	NA	NA	NA	NA	14	13	15	15

*The number or letter of each ground cover class is the same as that used in the classification computer program and computer printout maps.

**Denotes Training Set not included as part of the Training Set Group.

***Class preceding a slash (/) applies only to the June classifications. Class following a slash applies only to the March classifications.

An examination of the table indicates that the vegetated gypsum outcrops and soil were most often misclassified as pasture, oil field operation sites, town, and the agricultural classes, oats and maize. The misclassification results from the spectral similarity of these classes to the gypsum indicator plants. It was observed in this study that the pasture class most closely resembles and almost always encompasses the gypsum plant communities; furthermore, the oil field operation sites are similar to the vegetated gypsum class because they are small in size, surrounded by pasture, and are partially composed of bare rock and soil. The town class resembles the vegetated gypsum class because it partially consists of a mixture of bare rock surfaces (gravel, concrete, and asphalt), grasses, and weeds. These three general ground cover types are also found in the vegetated gypsum class since it is composed of a mixture of vegetation and weathered gypsiferous soils. Vegetated gypsum may be misclassified as the agricultural classes oats and maize because of the similarity of these crops to the gypsum indicator plants and/or the possible lack of homogeneity in the agricultural training sets. The agricultural training sets were based on reported data.

The exposed gypsiferous soil class (3) was misclassified most often as bare ground using the June training set groups and as alfalfa, oats, cotton, and bare ground using the March training set groups. Cotton and oat fields would be predominantly bare ground in March. The misclassification of exposed gypsiferous soil as alfalfa probably results from the lack of homogeneous agricultural training sets. A field of alfalfa in March would not resemble bare soil.

Oil field well and storage tank sites were most often misclassified as pasture or woodland. The misclassification probably results from the small size of the oil field operation sites. The small size and lack of brightness contrast would allow the surrounding pasture or woodland to dominate the average spectral signature of any pixel which might include a well or storage tank site.

The percentages of each of the other training sets which were misclassified as gypsum is listed in Table XII. The classes which had the highest percentage of misclassification as gypsum were town, pasture, alfalfa, and bare ground. The misclassification of these classes as gypsum supports the earlier conclusion that there is an apparent similarity of their spectral signatures to those of gypsum indicator plants and exposed gypsiferous soils.

Thus, the most probable reasons for the failure of the vegetated gypsum outcrops and soil, exposed gypsiferous soil, and oil field well and storage tank sites to be accurately classified by the automatic data processing techniques used in this investigation are:

(1) Subtle spectral contrast exist between the areas of gypsum surface cover or oil field operation sites and the surrounding vegetation.

(2) The size of most gypsum outcrops and soil sites and oil field operation sites is below the resolution limits of the Landsat imagery (less than 1.1 acres).

Near-Infrared Aerial Photography

Vegetated gypsum outcrops and soil and non-vegetated gypsiferous soil were easily distinguished on the high and low altitude color near-infrared and low altitude black and white near-infrared photography. The vegetated gypsum outcrops and soil were easily discriminated and

TABLE XII

PERCENTAGE OF EACH TRAINING SET MISCLASSIFIED AS GYPSUM

Landsat Scene	June 29, 1974				March 9, 1978			
Training Set Group	Soil		IR		Soil		IR	
Gypsum Class	1	3	2	3	1	3	2	3
Training Sets								
1*Vegetated Gypsum Outcrops and Soil as Delineated From SCS Soil Maps		2	NA**	NA		2	NA	NA
2 Vegetated Gypsum Outcrops and Soil as Delineated from High Altitude IR Map	NA	NA		2	NA	NA		.2
3 Bare Gypsum Soil	2	NA	0	NA	0	NA	0	NA
4 Town	14	0	25	0	1	0	1	1
5 Water	0	0	0	0	0	0	0	0
6 Dense Woodland	1	0	1.5	0	.5	.25	.2	0
7 Moderately Dense Woodland	.5	1	2	1	.2	3	0	.1
8 Sudan	0	3	0	3	0	4	0	0
9 Alfalfa	5	18	15	16	0	13	.4	2
A Peanuts and Cotton	2	5	2	5	.3	2	.6	0
B May Maize/Maize***	5	1	10	5	1	2	1	0
C Bare Ground and June Maize/Wheat	5	16	7	16	1	19	2	.4
D Improved Pasture	6	3	14	3	1	1	.7	0
E Unimproved Pasture	7	3	18	2	1	.5	.8	.1
F Oil Field Well and Storage Tank Sites	5	2	NA	NA	.6	2	0	0
G Barley	NA	NA	NA	NA	0	1	0	0
H Oats	NA	NA	NA	NA	0	0	0	0

*The number or letter of each ground surface cover class is the same as that used in the classification computer program and computer printout maps.

**Denotes Training Set not included as part of the Training Set Group.

***Class preceding a slash (/) applies only to the June classifications. Class following a slash applies only to the March classifications.

accurately delineated from all other types of ground cover on the high and low altitude color near-infrared photography by the unique spectral signatures yielded by the gypsum indicator plants. The vegetated gypsum outcrops and soil could not be consistently discriminated and delineated on the low altitude black and white near-infrared photographs because unique spectral signatures were not registered on the black and white film for the gypsum indicator plants using the methods of photography described in this report. Exposed gypsiferous soils could not be discriminated from other bare soils on the high and low altitude color and low altitude black and white near-infrared photography.

The quality of the small scale (1:120,000) NASA high altitude color near-infrared transparencies was better than that of the large scale (1:24,000) low altitude hand-held camera color near-infrared photomosaic. In spite of its lower quality, the low altitude photography was superior to the high altitude photography for discriminating and mapping vegetated gypsum outcrops and soil because of its higher resolution. Smaller areas of gypsum indicator plants were resolved, distinguished, and delineated on the low altitude color near-infrared photomosaic than on the high altitude color near-infrared transparencies. Nine hundred and ten acres of vegetated gypsum outcrops and soil were mapped from the low altitude color near-infrared photography as compared to 500 acres from the high altitude color near-infrared photography. The 910 acres approximates the actual acreage of vegetated gypsum outcrops and soils mapped within the study area.

Summary of Significant Results

The most significant results of this investigation of the potential of Near-Infrared Aerial Photography and Landsat Digital Imagery as data bases for point and non-point pollution source maps are the following.

Landsat Digital Imagery-Supervised

1. Vegetated gypsum outcrops and soil, exposed gypsiferous soil and oil field well and storage tank sites were not accurately classified using automatic data processing techniques applied to Landsat digital data as described in this report.
2. The vegetated gypsum outcrops and soil were more successfully classified with imagery from the growing season (June) of the year than with imagery from the dormant season (March).

Landsat Digital Imagery-Unsupervised

1. Vegetated gypsum outcrops and soil and exposed gypsiferous soil were not successfully classified using the unsupervised technique in this study.

Near-Infrared Aerial Photography

1. Vegetated gypsum outcrops and soil can be easily distinguished consistently discriminated, and accurately mapped using high and low altitude color near-infrared photography.
2. Exposed gypsiferous soil can occasionally be easily distinguished but not consistently discriminated nor mapped from high and low altitude color near-infrared and low altitude

black and white near-infrared photography.

3. Color near-infrared aerial photography is superior to black and white near-infrared photography for discriminating vegetated gypsum outcrops and soil.

4. Low altitude color near-infrared photography is more applicable than high altitude color near-infrared photography for mapping vegetated gypsum outcrops and soil because of its higher resolution.

Recommendations for Future Studies

Investigations by Rowan (1974 and 1977), Raines (1978), and Donovan (1979) have shown that ratio techniques applied to Landsat digital data have been successful in enhancing subtle differences in reflectance between similar types of vegetation and rocks. Since one of the reasons for the inability of the automatic data processing techniques used in this study to successfully discriminate the gypsum outcrops and soil was the possibility of insufficient contrast between the spectral signatures of the gypsum indicator plants and surrounding pasture, it is recommended that appropriate ratio techniques be developed and applied to the digital data of the June 29, 1974,and March 9, 1978,Tonkawa study area subscenes. It is suspected that the June scene will provide more success because of its superiority over the March scene as used in this study.

Donovan (1979) reported that the ratio of bands 6/5 was best for separation of general types of ground surface cover such as water, vegetation, rock, and soil. He also reported that the 5/4 ratio was the most useful for discrimination among soil and rock while the 6/7 ratio was best suited for discriminating among vegetation types. Raines (1978) noted that the 5/6 ratio was also useful for discriminating subtle vegetation changes that were associated with variations in bedrock lithology. Ratio techniques were not used in this investigation because the necessary computer software was not available.

In addition to the ratio of bands from the same scene, the ratio of bands or combinations of bands from the June and March subscenes is also suggested. The ratio of subscenes representative of different periods of the year could take advantage of seasonal vegetation changes in order to enhance the contrast between similar types of vegetation and soils.

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APPENDIX A

SOURCE LISTINGS FOR COMPUTER PROGRAMS

GRID

```
C  GRID
C
 GRID: PROCEDURE OPTIONS(MAIN);
 DECLARE COL FIXED DECIMAL(15,0);
 DECLARE  TOP FIXED DECIMAL (10,0);
 DECLARE A CHARACTER(120) ;
 DECLARE B CHARACTER(120) ;
 DECLARE LINE FIXED DECIMAL(9,0);
 DECLARE REP FIXED DECIMAL(4,0);
 DECLARE LINES,PAGES FIXED DECIMAL  (5,0);
 OPEN FILE(SYSPRINT) LINESIZE(132) PAGESIZE(500);
 GET SKIP EDIT(LINES,PAGES)((2)F(5,0));
 COL = 0 ;
 A=(12)'----:----|'  ;
 B=(12)'1234567890' ;
 REP=LINES/5;
 DO I=1 TO PAGES;
 LINE=0      ;
  PUT PAGE;
     DO J=10 TO 120 BY 10;
       TOP = J + ((I * 120) - 120);
       PUT SKIP(0) EDIT (TOP)(COLUMN(J+1),F(10,0));
     END;
 DO K=1 TO REP ;
          DO L=1 TO 4;
          LINE=LINE +1 ;
          PUT SKIP EDIT(LINE,A)(F(9,0),X(1),A(120)) ;
          END ;
 LINE=LINE +1 ;
 PUT SKIP EDIT (LINE,B) (F(9,0),X(1),A(120));
 END ;
 END ;
 END GRID ;
```

GODDARD

```
C   GODDARD
C
       GODDRD:  PROCEDURE OPTIONS(MAIN);
      DCL TAPE1 FILE RECORD SEQUENTIAL ENV(U(3296));
      DCL TAPE2 FILE RECORD SEQUENTIAL ENV(U(3296));
      DCL TAPE3 FILE RECORD SEQUENTIAL ENV(U(3296));
      DCL TAPE4 FILE RECORD SEQUENTIAL ENV(U(3296));
      DCL ESTAPE FILE RECORD SEQUENTIAL ENV(U(3296));
           DCL X BINARY FIXED(15,0) ;
      DCL LINE CHAR(3296) VAR, REC CHAR(40), LABEL CHAR(624) ;
      DCL SWITCH LABEL ;
              ON ERROR SNAP BEGIN ;
               PUT SKIP LIST(ONCODE,KOUNT)   ;
               LINE=(3296)'0'   ;
               GO TO SWITCH  ;
                   END;
      OPEN FILE(ESTAPE) OUTPUT;
      OPEN FILE (TAPE1) INPUT;
      ON ENDFILE (TAPE1) GO TO EN2;
      KOUNT=0;
      READ FILE (TAPE1) INTO (REC);
      PUT LIST (REC);
      WRITE FILE (ESTAPE) FROM (REC);
      READ FILE (TAPE1) INTO (LABEL);
           PUT SKIP(4) LIST(SUBSTR(LABEL,1,144));
           DO II=145 TO 624 BY 10 ;
            X= UNSPEC(SUBSTR(LABEL,II,2)) ;
            XX=X ;
            PUT SKIP(2) EDIT(XX,SUBSTR(LABEL,II+2,8)) (F(10,2),X(5),A) ;
           END ;   PUT PAGE ;
      WRITE FILE (ESTAPE FROM (LABEL);
           SWITCH=L1   ;
      DO1:  DO I=1 TO 3000;
      READ FILE (TAPE1) INTO (LINE);
      IF LENGTH (LINE)<1000 THEN GO TO EN1;
           L1:  KOUNT=KOUNT + 1 ;
      WRITE FILE (ESTAPE) FROM (LINE);
      EN1:  END DO1;
      EN2:  PUT SKIP(5) LIST ('KOUNT=',KOUNT);
      CLOSE FILE(TAPE1)   ;
      OPEN FILE (TAPE2) INPUT;
      ON ENDFILE (TAPE2) GO TO EN4;
           SWITCH=L2   ;
      DO3:  DO I=1 TO 3000;
      READ FILE (TAPE2) INTO (LINE);
      IF LENGTH (LINE)<1000 THEN GO TO EN3;
      WRITE FILE (ESTAPE) FROM (LINE);
       L2:  KOUNT=KOUNT+1;
      EN3:  END DO3;
      EN4:  PUT SKIP(5) LIST('KOUNT NOW=',KOUNT);
      CLOSE FILE(TAPE2) ;
    NXT:  OPEN FILE(TAPE3) INPUT   ;
      ON ENDFILE (TAPE3) GO TO EN6;
           SWITCH=L3   ;
      DO5:  DO I=1 TO 3000;
      READ FILE (TAPE3) INTO (LINE);
      IF LENGTH(LINE)<1000 THEN GO TO EN5;
        L3:  KOUNT=KOUNT+1   ;
      WRITE FILE (ESTAPE) FROM (LINE);
      EN5:  END DO5;
      EN5:  PUT SKIP(5) LIST('KOUNT=', KOUNT);
      CLOSE FILE(TAPE3)   ;
      OPEN FILE (TAPE4) INPUT;
      ON ENDFILE(TAPE4) GO TO EN8;
           SWITCH=L4   ;
      DO7:  DO I=1 TO 3000;
      READ FILE(TAPE4) INTO(LINE);
      IF LENGTH(LINE)<1000 THEN GO TO EN7;
        L4:  KOUNT=KOUNT+1   ;
      WRITE FILE(ESTAPE) FROM(LINE);
      EN7:  END DO7;
      EN8:  PUT SKIP(5) LIST('TOTAL=',KOUNT);
      CLOSE FILE(TAPE4)   ;
      CLOSE FILE(ESTAPE)   ;
      END GODDRD;
```

FRAME

```
C   FRAME
C
    FRAME: PROCEDURE OPTIONS(MAIN) ;
      DCL SYSPRINT FILE PRINT;
      OPEN FILE(SYSPRINT) LINESIZE(132) PAGESIZE(2500) ;
      DCL ERTSX FILE RECORD SEQUENTIAL ENV(U(3296));
            SCPAT FILE RECORD SEQUENTIAL ENV(U(3240)),
            FRAMEX FILE RECORD SEQUENTIAL ENV(U(3240)) ;
      DCL (DISTRIB(4,0:127),MEAN(4),SD(4),START(4),STOP(4),
            FLINE,LASTL,FPT,LPT,XDAT(4)) FLOAT DEC(6) ;
      DCL DATRX FILE STREAM INPUT;
      DCL (SUM(4),SUM2(4)) FLOAT DEC(12) ;
      DCL LINE CHAR (3296) VAR, DATA(800) FLOAT DEC(6) ;
      GET FILE(DATRX) EDIT(LINE)(A(70)) ;
      GET SKIP FILE(DATRX) EDIT(FIRST_LINE,ND_LINES,FIRST_PT,
            NO_PTS)((4)F(5,0));
      FLINE=FIRST_LINE; LASTL=FIRST_LINE+NO_LINES-1;
      FPT=FIRST_PT ;  LPT=FIRST_PT+NO_PTS-1 ;
      XX=0.0; DO I=1 TO 4  ;
            START(I)=FPT-XX; STOP(I)=LPT-XX ;
            IF START(I)>810 THEN START(I)=0.0;
            IF START(I)=0&STOP(I)>810 THEN STOP(I)=0.0 ;
            IF STOP(I)>810 THEN STOP(I)=810 ;
            IF STOP(I)>0&START(I)<1 THEN START(I)=1.0 ;
            IF START(I)<0 THEN START(I)=0 ;
            IF STCP(2)<0 THEN STOP(I)=0 ;
            XX=XX+810 ;
            END
      PUT PAGE ; PUT SKIP LIST(START);
            PUT SKIP LIST(STOP) ; PUT PAGE ;
      OPEN FILE(ERTSX) INPUT ; <K=0 ;
      OPEN FILE(SCRAT) OUTPUT;  READ FILE(ERTSX) IGNORE(2) ;
      DO I=1 TO 4 ;
      SUM(I)=0.0 ; SUM2(I)=0.0 ; DO J=0 TO 127 ;
            DISTRIB(I,J)=0 ;
      END; END;
      NSKIP=2340-(NO_LINES) ; COUNT=0.0 ;  CK=0.0 ;
    DO1: DO I=1 TO 4 ;
      IF START(I)=0 & CK=0 THEN DO ;
            READ FILE(ERTSX) IGNORE(2340) ;
            GO TO EN1; END ;
      IF START(I)=0 & CK=1 THEN GO TO EN1;
      IF CK=0 ATHEN READ FILE(ERTSX) IGNORE(FLINE-1) ;
            ELSE READ FILE(ERTSX) IGNORE(NSKIP) ;
      CK=1 ;
    DO2:  DO J=1 TO NO LINES  ; READ FILE(ERTSX) INTO(LINE)  ;
            KNT=FLOOR((START(I)/2)-.3)*8+1 ;
    DO3: DO K=START(I) TO STOP(I) BY 2 ;
    DO4: DO L=0,1 ;  KK5=1 ;
    DU5: DO M=0,2,4,6 ;
      IXX=UNSPEC(SUBSTR(LINE,KNT+L+M,1)) ;
      XX=IXX ; SUM(KK5)=SUM(KK5)+XX ;
      SUM2(KK5)=SUM2(KK5)+XX*XX ;
      DISTRIB(KK5,IXX)=DISTRIB(KK5,IXX)+1 ;
      KK=KK+1 ;
      KK5=KK5+1 ;
      DATA(55)=IXX;
    EN5: END DO5 ;
      IF KK>=800 THEN DO;
            KK=0 ; WRITE FILE(SCRAT) FROM(DATA) ; END ;
      COUNT=COUNT+1 ;
    EN4: END DO4 ;
      KNT=KNT+8 ;
    EN3: END DO3 ;
      /* WRITE FILES HERE */
      IF KK=0 THEN GO TO EN2;
      DO LL=KK TO 800 ;  DATA(LL)=0 ; END ;
      WRITE FILE(SCRAT) FROM(DATA) ;
            KK=0 ;
    EN2: END DO2 ;
    EN1: END DO1 ;
      CLOSE FILE(ERTSX) ; CLOSE FILE(SCRAT);
      ON ENDFILE(SCRAT) GU TO DUTX ;
      OPEN FILE(SCRAT) INPUT; OPEN FILE(FRAMEX) OUTPUT ;
      XDAT(1)=FLINE ; XDAT(2)=FPT ; XDAT(3)=NO_LINES; XDAT(4)=NO_PTS ;
```

```
    WRITE FILE(FRAMEX) FROM(XDAT) ;
    DO I=1 TO 4 ;
     SD(I)=SUM2(I)-SUM(I)*SUM(I)/COUNT ;
    IF SD(I)<0.0 THEN SD(I)=0.0 ;
    SD(I)=SQRT((SD(I)/COUNT-1)) ;
    MEAN(I)=SUM(I)/COUNT ; END ;
    WRITE FILE(FRAMEX) FROM(MEAN) ;
    WRITE FILE(FRAMEX) FROM(SD) ;
    WRITE FILE(FRAMEX) FROM(DISTRIB) ;
    DO I=1 TO 10000 ;
    READ FILE(SCRAT) INTO(DATA) ;
    WRITE FILE(FRAMEX) FROM(DATA) ;
    END ;
  OUTX: DO I=1 TO 4;
    PUT SKIP(4) EDIT('GROUP',I,' MEAN =',MEAN(I),' S.D. =',SD(I))
    (A,F(4,0)(8,4),A,F(8,5)) ;
    END ;
    PUT PAGE ;
    DO I=0 TO 127 ; PUT SKIP EDIT('NUMBER',I,(DISTRIB(J,I)
         DO J=1 TO 4 ))  (A,F(4,0),(4)F(14,0)) ;
    END;
  END FRAME ;
```

GREYSCALE

```
C   GREYSCALE
C
     EPLOTX: PROCEDURE OPTIONS(MAIN) ;
       DCL SYSPRINT FILE PRINT ;
       OPEN FILE(SYSPRINT) LINESIZE(132) PAGESIZE(2500) ;
       DCL ERTSX FILE RECORD SEQUENTIAL ENV(U(3240)) ;
       DCL CARD CHAR(80);
       DCL LINE(8) CHAR(100),BLINE CHAR(100) INITIAL((100)' '),
           TOP(4) CHAR(100),STR(10) CHAR(1) INITIAL('0','1',
           '2','3','4','5','6','7','8','9') ;
       DCL (DATA(800),GET(4)) FLOAT DEC(6) ;
       DCL MARK1(21) CHAR(1) INITIAL('0','0','0','0','0','0','0',
         '0','0','0','0','M','A','X','Z','1',')','+','=','-',' ');
       DCL MARK2(11) CHAR(1) INITIAL('X','X','X','X','X','+','+',
         '+','+','=','-');
       DCL MARK3(6) CHAR(1) INITIAL('H','H','H','H','=','-');
       DCL MARK4(4) CHAR(1) INITIAL('B','B','B','C') ;
       DCL (MEAN,SD)(4) FLOAT DEC(4);
       NNX=4;  READ FILE(ERTSX) INTO(GET); READ FILE(ERTSX) INTO(MEAN);
       READ FILE(ERTSX) INTO(SD) ; READ FILE(ERTSX) IGNORE(1) ;
       LINE1=GET(1) ; IPT1=GET(2);  NOLINES=GET(3);  NOPTS=GET(4) ;

       DCL BOT(0:3),(FAC,PUTTOP)(0:3),XINC(4), INXX FILE STREAM INPUT;
       GET SKIP(2) FILE(INXX) EDIT(BOT)((4)F(5,0));
       GET SKIP(1) FILE(INXX) EDIT(FAC)((4)F(5,0));
           PUTTOP(*)=FAC(*);
       DO I=0 TO 3; FAC(I)=21.0/(FAC(I)-BOT(I)); END;
       GET SKIP(1) FILE(INXX) EDIT(XINC)((4)F(5,0));
       GET SKIP(1) FILE(INXX) EDIT(CARD)(A(80));
       CLOSE FILE(INXX);
       DO I77=1 TO 4;
       INC=XINC(I77)-1.0;  IF INC>-1&INC<4 THEN DO;
    AGN:
           ITIME=1 ;  NNX=1000 ;
    STAR: NUM1=IPT1+(ITIME-1)*100 ;
       TOP(1)=' '; TOP(2)=' '; TOP(3)=' '; TOP(4)=' ';
       KNT=1 ;
       DO I=NUM1 TO NUM1+99 ;
       IF I<1000 THEN GO TO NX1 ;
       SUBSTR(TOP(1),KNT,1)=STR(FLOOR(I/1000)+1) ;
    NX1: IF I<100 THEN GO TO NX2 ;
       IX=FLOOR(I/100)-10*FLOOR(I/1000)+1 ;
       SUBSTR(TOP(2),KNT,1)=STR(IX) ;
    NX2: IX=FLOOR(I/10)-10*FLOOR(I/100)+1 ;
       SUBSTR(TOP(3),KNT,1)=STR(IX) ;
       IX=I-FLOOR(I/10)*10+1 ;
       SUBSTR(TOP(4),KNT,1)=STR(IX) ;
       KNT=KNT+1 ;  END ;
       ON ENDFILE(ERTSX) GO TO ERRT ;
       PUT PAGE ;
       PUT SKIP EDIT(CARD)(A);
       PUT SKIP EDIT('BANDS TO BE PRINTED',XINC)(A,(4)F(5,0));
       PUT SKIP(0) EDIT('BAND BEING PRINTED:',XINC(I77))
                               (COL(70),A,F(5,0));
       PUT SKIP(1);
                   DO I=1 TO 4 ;
                   PUT SKIP EDIT(TOP(I))(X(20),A) ;
                    END; PUT SKIP;
       PUT SKIP(1) EDIT('SCENE VALUES      TOP',PUTTOP(INC),
       '   BOTTOM',BOT(INC),'    SCALE',FAC(INC))
         ((3)(A,F(10,2)));  PUT SKIP;

       IGN1=FLOOR((ITIME/2)-0.2) ; IGN2=CEIL(NOPTS/200)-1-IGN1 ;
       NNX=NNX+400 ;  IF NNX>401 THEN NNX=1 ;
       DO I=LINE1 TO LINE1 + NOLINES ;
       READ FILE(ERTSX) IGNORE(IGN1) ;
       READ FILE(ERTSX) INTO(DATA) ;
       READ FILE(ERTSX) IGNORE(IGN2) ;
       DO KO=1 TO 8;  LINE(KO)=BLINE ; END ;
       KNT=NNX+INC ;
        DO J=1 TO 100 ;
       IFAC=(DATA(KNT)-BOT(INC))*FAC(INC) ;
       IF IFAC>20 THEN GO TO ENN1 ;
       IF IFAC<2 THEN DO ; IFAC=2 ;
           SUBSTR(LINE(8),J,1)='A' ; END ;
```

```
      SUBSTR(LINE(1),J,1)=MARK1(IFAC) ;
      IF IFAC<12 THEN SUBSTR(LINE(2),J,1)=MARK2(IFAC) ;
      IF IFAC<9 THEN SUBSTR(LINE(3),J,1)='''' ;
      IF IFAC<8 THEN SUBSTR(LINE(4),J,1)='.' ;
      IF IFAC<7 THEN SUBSTR(LINE(5),J,1)=MARK3(IFAC) ;
      IF IFAC<5 THEN SUBSTR(LINE(6),J,1)=MARK4(IFAC) ;
      IF IFAC<3 THEN SUBSTR(LINE(7),J,1)='V' ;

      ENN1:  KNT=KNT+4 ;  END ;
    PUT SKIP EDIT('LINE',I,'|',LINE(1),'|')(A,F(6,0),X(9),A,A,A);
      DO KO=2 TO 8 ;
      IF LINE(KO)¬=BLINE THEN
      PUT SKIP(0) EDIT(LINE(KO)) (COLUMN(21),A) ;
      END ;
      END ;
         ERRT: CLOSE FILE(ERTSX) ;
      ITIME=ITIME+1 ;  READ FILE(ERTSX) IGNORE(4) ;
      IF NOPTS+99>ITIME*100 THEN GO TO STAR ;
          END; /* END THEN-DO */   END; /* END DO I77 */
   END EPLOTX ;
```

SMOOTH

```
C   SMOOTH
C
      ABC: PROCEDURE OPTIONS(MAIN);
      DCL (XIN,XOUT) FILE RECORD SEQUENTIAL,
      (DATA(200,4),GET(4)) FLOAT DEC(6);

    DCL (SXX(6,4),SD(6,4),COUNT(6,4)) FLOAT DEC(16),
          (TABLES(6,4,0:127)) FLOAT DEC(6),DIS(0:127,4);

     ON ENDFILE(XIN) GO TO OUT;
    READ FILE(XIN) INTO(GET); READ FILE(XIN) IGNORE(3);
      ISKIP=CEIL(GET(4)/200.0)-1.0;
          SXX,SD,COUNT=0.0; KNT=1;
    STAR: READ FILE(XIN) INTO(DATA);
      READ FILE(XIN) IGNORE(ISKIP);
      DO J=1 TO 4;
           SXX(KNT,J)=SXX(KNT,J)+SUM(DATA(*,J));
           SD(KNT,J)=SD(KNT,J)+SUM(DATA(*,J)*DATA(*,J));
      COUNT(KNT,J)=COUNT(KNT,J)+200.0;
      END;

          KNT=KNT+1; IF KNT=7 THEN KNT=1;
    GO TO STAR;

    OUT: CLOSE FILE(XIN);
          SD(*,*)=SD(*,*)-(SXX(*,*)*SXX(*,*)/COUNT(*,*));
          SD(*,*)=SQRT(SD(*,*)/(COUNT(*,*)-1.0));
          SXX(*,*)=SXX(*,*)/COUNT(*,*);

          DO I=1 TO 6;
          PUT SKIP(2) EDIT((SXX(I,J),SD(I,J),COUNT(I,J) DO J=1 TO 4))
               ((4)(F(8,2),F(8,2),F(8,0),X(5)));
          END;
          PUT SKIP(5);
    DO I=0 TO 127; XI=I; DO J=1 TO 4; DO K=1 TO 6;
    TABLES(K,J,I)=(SD(1,J)*(XI-SXX(K,J))+SD(K,J)*SXX(1,J))/SD(K,J);
    END; END; END;

          DO I=0 TO 127;
          PUT SKIP(1) EDIT(((TABLES(K,J,I) DO J=1 TO 4) DO K=1 TO 6))
               ((24)F(5,1)); END;

          WRITE FILE(XOUT) FROM(GET);
      GET(*)=SXX(1,*); WRITE FILE(XOUT) FROM(GET);
      GET(*)=SD(1,*); WRITE FILE(XOUT) FROM(GET);
      WRITE FILE(XOUT) FROM(GET);

    ON ENDFILE(XIN) GO TO DONE; ISKIP=ISKIP+1;
    READ FILE(XIN) IGNORE(4); KNT=1;

    STAR2:
    DO IT=1 TO ISKIP; READ FILE(XIN) INTO(DATA);
          IF KNT=1 THEN GO TO NXT2;
          DO I=1 TO 200; DO J=1 TO 4;
               IF DATA(I,J)<1.0 | DATA(I,J)>256.0 THEN GO TO NXT3;
               DATA(I,J)=TABLES(KNT,J,DATA(I,J));
    NXT3: END; END;
    NXT2: WRITE FILE(XOUT) FROM(DATA);
               KNT=KNT+1; IF KNT=7 THEN KNT=1; GO TO STAR2;
    DONE: PUT PAGE;

      CLOSE FILE(XIN),FILE(XOUT);
     END ABC;
```

REGISTER

```
C   REGISTER
C
      REGSTR:  PROCEDURE OPTIONS(MAIN);
      DEFAULT RANGE(A:H,O:Z) FLOAT BIN    VALUE (FLOAT BIN(53)),
              RANGE(I:N)  FIXED BIN VALUE (FIXED BIN(15));
      DECLARE VEC FILE RECORD SEQUENTIAL;
      DECLARE VECTOR FILE RECORD SEQUENTIAL;
      DECLARE(
                TERMS
                ,COUNT
                ,SEQ(3)
                                        ) FIXED BIN(15);
      DECLARE NUM(4) FLOAT BIN(53);
      PUT PAGE EDIT('PROGRAM REGSTR','FEW VOMO 790511')
        (COL(30), A, COL(100), A);
      ON ENDFILE(SYSIN) GO TO THATS_ALL;
      OPEN FILE(VEC) OUTPUT;
    FIRST:
      PUT SKIP(4);
      PUT LIST ('DO YOU WANT TO LOAD THE FILES?');
      PUT SKIP;
      DECLARE ANS CHAR(3);
      NUM=0.0      ;
      GET EDIT(ANS) (A(3));
      PUT LIST(ANS);
      PUT SKIP(2);
      IF ANS¬='YES' THEN GO TO NXT;
      PUT LIST('HOW MANY PAIRS OF POINTS DO YOU WANT TO LOAD?');
      PUT SKIP;
      GET LIST(N);
      NUM(1) = N ;
      WRITE FILE(VECTOR) FROM(NUM);
      PUT LIST(N);
      PUT SKIP(2);
      DO I=1 TO N;
      GET SKIP LIST(NUM);
      WRITE FILE(VECTOR) FROM(NUM);
      PUT SKIP EDIT('NUM(',I,',*) = ',NUM)(A,F(2,0),A,(4)F(7,1));
      END;
      CLOSE FILE(VECTOR);
      DECLARE SX(22);
      DECLARE N2(4);
      READ FILE(VECTOR) INTO(NUM) ;
      PUT SKIP(4);
      N2=0;
      DO I=1 TO N;
      READ FILE(VECTOR) INTO(NUM);
      PUT EDIT(NUM,NUM-N2,NUM(1)-NUM(3),NUM(2)-NUM(4))((10) F(10,1));
      PUT SKIP;
      N2=NUM;
      END;
      PUT SKIP(2);
      CLOSE FILE(VECTOR) ;
      SX=0;
      GET SKIP;
    NXT: PUT LIST('NOW GIVE THE COLUMNS OF X,XN,YN');
      PUT LIST('ON TRNSFM, X=OLD COORDNTS, XN,YN ARE NEW COORDNTS');
      A=0;
      B=0;
      GET LIST(SEQ);
      PUT SKIP EDIT('COLUMN SEQUENCE',SEQ)(A,(3)F(3,0));
      SX=0;
      DECLARE A(5,5),B(5);
      PUT SKIP(4);
    READ:
      READ FILE(VECTOR) INTO(NUM) ;
      NUMX = NUM(1);
      PUT LIST('HOW MANY TERMS?');
      PUT SKIP;
      GET LIST(TERMS);
      PUT LIST(TERMS);
      PUT SKIP(4);
      N=TERMS;
      COUNT=0;
      DO JJ=1 TO NUMX-TERMS BY TERMS;
```

```
LP1: DO I=1 TO TERMS;
    READ FILE(VECTOR) INTO(NUM) ;
    X=NUM(SEQ(2));
    Y=NUM(SEQ(3));
    B(I)=NUM(SEQ(1));
    A(I,1)=1;
    A(I,2)=X;
    A(I,3)=Y;
    KNT=1;
    DO J=4 TO TERMS;
    A(I,J)=X**KNT*Y**KNT;
    KNT=KNT+1;
    END LP1;
    PUT SKIP(2);
    TOL=0;
LP2: DO J=1 TO N;
    BIG=0;
LP3: DO I=J TO N;
    IF ABS(BIG)>=ABS(A(I,J)) THEN GO TO END3;
    BIG=A(I,J);
    IMAX=I;
END3: END LP3;
    IF ABS(BIG)>TOL THEN GO TO SW;
    PUT LIST('SINGULAR MATRIX');
    GO TO LP0;
SW: DO K=J TO N;
    T=A(J,K);
    A(J,K)=A(IMAX,K);
    A(IMAX,K)=T;
    A(J,K)=A(J,K)/BIG;
    END SW;
    T=B(IMAX);
    B(IMAX)=B(J);
    B(J)=T/BIG;
    IF J=N THEN GO TO LP6;
    J1=J+1;
LP4: DO IX=J1 TO N;
LP5: DO JX=J1 TO N;
    A(IX,JX)=A(IX,JX)-A(IX,J)*A(J,JX);
    END LP5;
    B(IX)=B(IX)-B(J)*A(IX,J);
    END LP2;
LP6: DO J=N-1 TO 1 BY -1;
    DO K=N TO J+1 BY -1;
    B(J)=B(J)-A(J,K)*B(K);
    END LP6;
    PUT EDIT(B(1),B(2),B(3),B(4))((4) F(10,3));
    PUT SKIP;
    DO I=1 TO TERMS;
    SX(I)=SX(I)+B(I);
    END;
    COUNT=COUNT+1;
LP0: END;
    DO I=1 TO TERMS;
    SX(I)=SX(I)/COUNT;
    END;
    CLOSE FILE(VECTOR) ;
    READ FILE(VECTOR) INTO(NUM) ;
    NN = NUM(1);
    DO K=1 TO NN;
    READ FILE(VECTOR) INTO(NUM) ;
    X=NUM(SEQ(2));
    Y=NUM(SEQ(3));
    SUM=SX(1);
    SUM=SUM+SX(2)*X;
    SUM=SUM+SX(3)*Y;
    KNT=1;
    DO I=4 TO TERMS;
    SUM=SUM+SX(I)*X**KNT*Y**KNT;
    KNT=KNT+1;
    END;
    PUT SKIP(2);
    PUT SKIP EDIT(SUM,NUM(SEQ(1)),NUM(SEQ(1))-SUM,X,Y)((5) F(10,4)) ;
    END;
    CLOSE FILE(VECTOR) ;
```

```
      SX(22)=TERMS;
      PUT SKIP(4);
      PUT LIST('POINT (COLUMN) THEN LINE (ROW) COEFFICIENTS');
      PUT SKIP;
      PUT LIST(SX);
      WRITE FILE(VEC) FROM(SX);
      PUT PAGE;
      GO TO FIRST;
   THATS_ALL:  CLOSE FILE(VEC);
    END REGSTR;
```

TRANSFORMATION

```
C   TRANSFORMATION
C
        TRANSFM:  PROCEDURE OPTIONS(MAIN);
     DCL ERTS FILE RECORD SEQUENTIAL,
         HOLD FILE ENV(REGIONAL(1) F(6400)),
         COEF FILE RECORD SEQUENTIAL,
         DATX FILE RECORD SEQUENTIAL ENV(F(80)),
         ERTS2 FILE RECORD SEQUENTIAL,

        (TLINE,BLINE,FST_PT,LST_PT) FLOAT DEC(6),
        (PCOF,LCOF)(22) FLOAT DEC(16),CARD CHAR(80),
        (DATA(800),EDAT(2,4000),GET(4),SUM(4)) FLOAT DEC(6),
        SDAT(3200) FIXED BINARY(15,0);

        READ FILE(DATX) INTO(CARD); READ FILE(DATX) INTO(CARD);
        TLINE=SUBSTR(CARD,1,5); BLINE=SUBSTR(CARD,6,5);
        FST_PT=SUBSTR(CARD,11,5); LST_PT=SUBSTR(CARD,16,5);
        IF LST_PT-FST_PT>799 THEN LST_PT=FST_PT+799;

        NOLINES=BLINE-TLINE+1; NOPOINTS=LST_PT-FST_PT+1;
        NTOP=TLINE; OPEN FILE(HOLD) DIRECT OUTPUT;
        CLOSE FILE(HOLD); OPEN FILE(HOLD) DIRECT UPDATE;

        SDAT=1000.0; EDAT=1000.0;

        DO I=0 TO NOLINES;
        REWRITE FILE(HOLD) FROM(SDAT) KEY(I); END;

        OPEN FILE(ERTS) INPUT; READ FILE(ERTS) INTO(GET);
        READ FILE(ERTS) INTO(SUM);
        LINE_NO1=GET(1); POINT_NO1=GET(2);
        ON ENDFILE(ERTS) GO TO OUT; READ FILE(ERTS) IGNORE(2);

        OPEN FILE(COEF) INPUT;
        READ FILE(COEF) INTO(PCOF); READ FILE(COEF) INTO(LCOF);
        CLOSE FILE(COEF);

        NPTERMS=PCOF(22); NLTERMS=LCOF(22);
        XX=LCOF(1)+LCOF(2)*TLINE+LCOF(3)*LST_PT;
        DO K=4 TO NLTERMS;
        XX=XX+LCOF(K)*TLINE**(K-3)*LST_PT**(K-3); END;
        LINE1=FLOOR(XX)-1.0;
        XX=LCOF(1)+LCOF(2)*TLINE+LCOF(3)*FST_PT;
        DO K=4 TO NLTERMS;
        XX=XX+LCOF(K)*TLINE**(K-3)*FST_PT**(K-3); END;

        IF FLOOR(XX)<LINE1 THEN INROLL=1; ELSE INROLL=-1;

        PUT SKIP(1) EDIT('GET',GET)(A,(4)F(10,2));
        PUT SKIP(2) EDIT('POINT COEFFICIENTS',PCOF)(A,SKIP,
        (2)((11)F(10,4),SKIP));
        PUT SKIP(4) EDIT('LINE COEFFICIENTS',LCOF)(A,SKIP,
        (2)((11)F(10,4),SKIP));
        PUT SKIP(4) EDIT('TOP LINE',TLINE,'BOTTOM LINE',BLINE,
        'LEFT POINT',FST_PT,'RIGHT POINT',LST_PT)
        ((4)(A,F(5,0),X(4)));
        PUT PAGE;

        NH=CEIL(GET(4)/200.0);
        IF NH>5 THEN DO;
        PUT LIST('TOO MANY ERTS POINTS'); GO TO OUT; END;

        IF LINE1-1<LINE_NO1 THEN DO;
        LINE1=LINE_NO1-1; GO TO XOT; END;

        DO I=LINE_NO1 TO LINE1-1;
        READ FILE(ERTS) IGNORE(NH);
        END;

    XOT: LINE1=LINE1-1;
        KNT=0; DO JO=1 TO NH;
             READ FILE(ERTS) INTO(DATA);
        DO I=1 TO 800; EDAT(2,I+KNT)=DATA(I); END;
           KNT=KNT+800;
                END;
```

```
NXT0: LINE1=LINE1+1;
    DO XK1=TLINE TO BLINE;
    XX1=LCOF(1)+LCOF(2)*XK1+LCOF(3)*FST_PT;
    DO L=4 TO NLTERMS;
    XX1=XX1+LCOF(L)*XK1**(L-3)*FST_PT**(L-3); END;
    IF XX1>LINE1 THEN GO TO NXT00;
    END;
NXT00:
    DO XK2=TLINE TO BLINE;
    XX2=LCOF(1)+LCOF(2)*XK2+LCOF(3)*LST_PT;
    DO L=4 TO NLTERMS;
    XX2=XX2+LCOF(L)*XK2**(L-3)*LST_PT**(L-3); END;
    IF XX2>LINE1 THEN GO TO NXT;
    END;
NXT:
    NLEFT=LST_PT; NRIGHT=FST_PT; INC=-1;
    TOPLINE=XK1; BOTLINE=XK2;
    IF XK2<XK1 THEN DO;
    NLEFT=FST_PT; NRIGHT=LST_PT; INC=1;
    TOPLINE=XK2; BOTLINE=XK1;
                     END;

    IF INROLL¬=INC THEN DO;
    LINE1=LINE1-1; INROLL=INC;
    GO TO STAR;            END;

    KNT=0;
    DO JO=1 TO NH; READ FILE(ERTS) INTO(DATA);
      DO I=1 TO 800;
        EDAT(1,I+KNT)=EDAT(2,I+KNT); EDAT(2,I+KNT)=DATA(I);
      END;
     KNT=KNT+800;
    END;

STAR:
    PUT SKIP(2) EDIT('READ ERTS',LINE1,'BOTTOM LINE',BOTLINE,
    'TOP LINE',TOPLINE,'START',NLEFT)((4)(A,F(6,0),X(2)));
    NX000=NLEFT;

    XL1=LINE1; XL2=LINE1+1;

DO1: DO LINXX=BOTLINE TO TOPLINE BY -1;
    IF LINXX>BLINE THEN GO TO EN1;
    READ FILE(HOLD) INTO(SDAT) KEY(LINXX-NTOP+1);

DO2: DO PTSXX=NX000 TO NRIGHT BY INC;
    MMMM=((PTSXX-FST_PT+1.0)*4.0-3.0);
    IF MMMM<1 | MMMM>NOPOINTS*4 THEN GO TO EN2;
    IF SDAT(MMMM)¬=1000.0 THEN GO TO EN2;

    XX=LCOF(1)+LCOF(2)*LINXX+LCOF(3)*PTSXX;
    DO L=4 TO NLTERMS;
    XX=XX+LCOF(L)*LINXX**(L-3)*PTSXX**(L-3); END;
    IF XX<XL1 THEN GO TO EN2;
    IF XX>XL2 THEN GO TO NXT1;
    XXLINE=XX;
    XX=PCOF(1)+PCOF(2)*PTSXX+PCOF(3)*LINXX;
    DO L=4 TO NPTERMS;
    XX=XX+PCOF(L)*LINXX**(L-3)*PTSXX**(L-3); END;
    XXPOINT=XX;

    XP1=FLOOR(XXPOINT); XP2=XP1+1.0;
    PLFAC=XP2-XXPOINT; PRFAC=1.0-PLFAC;
    LTFAC=XL2-XXLINE; LBFAC=1.0-LTFAC;
    NNNN=(FLOOR(XXPOINT)-POINT_NO1+1.0)*4.0-3.0;
    IF NNNN<1 | NNNN>4000 THEN GO TO NXT1;
    DO JJJ=0 TO 3;
    SDAT(MMMM+JJJ)=(EDAT(1,NNNN+JJJ)*PLFAC*LTFAC+
                    EDAT(2,NNNN+JJJ)*PLFAC*LBFAC+
                    EDAT(1,NNNN+JJJ+4)*PRFAC*LTFAC+
                    EDAT(2,NNNN+JJJ+4)*PRFAC*LBFAC)*100.0 ;
    END;
    IF ABS(PTSXX-NRIGHT)<2 & LINXX=BLINE THEN DO;
       REWRITE FILE(HOLD) FROM(SDAT) KEY(LINXX-NTOP+1);
```

```
            GO TO OUT;                             END;
        EN2: END DO2;
        NXT1: REWRITE FILE(HOLD) FROM(SDAT) KEY(LINXX-NTOP+1);
            NX000=PTSXX-(5*INC);
        EN1: END DO1;
            GO TO NXT0;
        OUT: CLOSE FILE(ERTS);

            GET(1)=TLINE; GET(2)=FST_PT;
            GET(3)=NOLINES; GET(4)=NOPOINTS;
             OPEN FILE(ERTS2) OUTPUT;

              WRITE FILE(ERTS2) FROM(GET);
               DO I=1 TO 3; WRITE FILE(ERTS2) FROM(SUM); END;

            DO I=1 TO NOLINES; READ FILE(HOLD) INTO(SDAT) KEY(I);
             DO J=1 TO 800;
                DATA(J)=SDAT(J)/100;
                    END;
            WRITE FILE(ERTS2) FROM(DATA);

            IF NOPOINTS<201 THEN GO TO NXT2;

            KNT=800;
            DO K=2 TO CEIL(NOPOINTS/200);
            DO J=1 TO 800;
               DATA(J)=SDAT(J+KNT)/100;
                 END;
            KNT=KNT+800;
            WRITE FILE(ERTS2) FROM(DATA);
            END;

        NXT2: END;
            CLOSE FILE(HOLD),FILE(ERTS2);
        END TRANSFM;
```

DELIN

```
/* PROGRAM DELIN V3M1 791015 */
/*        DELINEATION PROGRAM          */
/*
          PROGRAM TO SELECT A SCENE FROM LANDSAT CATA.
                  FOR ENVIRONMENTAL INSTITUTE,
                      CKLAHOMA STATE UNIVERSITY.
                  BY FRED WITZ.

             THIS PROGRAM COPIES A RECTANGULAR SUBSCENE
          FROM LANDSAT DATA AND DELINEATES AN AREA BY MARKING
          EXCLUDED PIXELS WITH A SPECIAL CODE. OPTIONS ARE
          PROVIDED TO MERGE TWO INPUT FILES CONTAINING ADJACENT
          INFORMATION AND TO OUTPUT ONLY SELECTED PIXELS.  INPUT,
          OUTPUT AND INTERMEDIATE INFORMATION CAN BE PRINTED.

          FILES USED:
              INPUT    STANDARD LNDSAT DATA FOR SINGLE INPUT
                       IN IBM FOUR BYTE FLOATING POINT FORMAT.
              INPUT1   STANDARD LANDSAT DATA FOR MERGE (LEFT SIDE)
              INPUT2   STANDARD LANDSAT DATA FOR MERGE (RIGHT SIDE).
              OUTPUT   SELECTED AREA WITH SCENE DELINEATED
                       IN SAME FORMAT AS INPUT.

          CONTROL INPUT SUMMARY:
              (FOR DETAILS SEE PROGRAM DESCRIPTION)
------------------------------------------------------------------
PARAMETER CARDS (ANY ORDER)
          OP:      VALUES:
FORMAT    A(10)    F(5, 0) EXCEPT CODE: E(10, 0)
------------------------------------------------------------------
          STAT     NBANDSTAT, BANDSTAT ...          (MUST PRECEDE DISCRIM)
          INPUT    LRECLIN1, NCOLROWIN1, NBANDIN    (REQUIRED)
          MERGE    LRECLIN2, NCOLROWIN2, ROWOFF2, COLOFF2
          ADD
          DISCRIM NCLASS
              (DATA STARTING IN COLUMN 1, FORMAT F(10) )
              CLASS, WEIGHT, N             (N NOT USED)
              MEAN ...
              COVARIANCE ...
              ...
          MAP      BANDMAP, NCOLMAP, NOVP, NSYM
              (DATA STARTING IN COLUMN 8, FORMAT 3A1, (COL(11), 50A1) )
              SYMBOL(IOVP, J) FOR J = -2 TO NSYM, IOVP = 1 TO NOVP
          SINGLE   NBANDCOPY, BANDCOPY ...
          COPY     LRECLOUT, NBANDCOPY, BANDCOPY ...
          STATOUT

          WINDOW   ROWA, ROWB, COLA, COLB
          OFFSET   ROWOFF, COLOFF
          MOVE
OR        PATTERN CHECK  (MUST BE LAST)
              (DATA STARTING IN COLUMN 1)
              (FORMAT F(5) FOLLOWED BY FREE FORM)
              ROWDB, CLASSD(1), COLDB(1), CLASSD(2), COLDB(2), ...
              ...
              (END OF FILE)
------------------------------------------------------------------
          HEADIN   LRECLIN1H     (SAME AS HEADIN1)
          HEADIN1  LRECLIN1H
          HEADIN2  LRECLIN2H
          HEADOUT  LRECLOUTH
------------------------------------------------------------------
          LIST
          NOLIST         (TURN OFF LIST)
          PRINTINV           (MUST PRECEDE DISCRIM )
          PRINTSTAT
          PRINTIN   IPRIN, NBANDPRIN1, BANDPRIN1 ...      (SAME AS PRINTIN1)
          PRINTIN1  IPRIN, NBANDPRIN1, BANDPRIN1 ...
          PRINTIN2  IPRIN, NBANDPRIN2, BANDPRIN2 ...
          PRINT     IPRIN, NBANDPR    , BANDPR     ...
          PRINTCODE IPRIN,NBANDPRCODE,BANDPRCODE...
          PRINTOUT  IPRIN, NBANDPROUT, BANDPROUT ...
          PRINTHEAD
          TEST      I, MERRO, MERR, MWARN
```

```
          (I=1 NO OUTPUT, I=2 NO INPUT)
          (TEST MUST FOLLOW COPY, SINGLE, OR STATOUT TO SUPPRESS OUT)

-----------------------------------------------------------
*/
/*//////////////////////////////////////////////////////////////////////*/

DELIN:  PROC OPTIONS(MAIN);
        DEFAULT RANGE(A:Z)
            STATIC
            ;

        DCL VERSION CHAR(20) INIT('V3M1 791015');

        DCL (
            ABS,
            CEIL, MAX, MIN, MOD, LOG,
            ONCHAR, ONSOURCE, STRING, SUBSTR
            )       BUILTIN;
                                /* FILES */
        DCL (
            INPUT1   INPUT,   /* SINGLE OR LEFT INPUT */
            INPUT2   INPUT,   /* MERGE DATA (RIGHT SIDE) */
            OUTPUT   OUTPUT   /* OUTPUT SCENE */
            )        FILE SEQUENTIAL;
        DCL PUNCH    FILE STREAM OUTPUT ENV(RECSIZE(80) );
        DCL SYSIN    FILE STREAM INPUT;
        DCL STATIN   FILE STREAM INPUT;
        DCL (
            SYSPRINT, PRINT1, PRINT2, PRINT3, PRINT4, PRINT5
            )        FILE STREAM PRINT;
        DCL (
            MAPOUT1, MAPOUT2, MAPOUT3, MAPOUT4, MAPOUT5
            ) FILE OUTPUT SEQUENTIAL
             ENV(F CTLASA RECSIZE(132) BLKSIZE(132) );
                                /* CONTROLLED */
        DCL (
            RECIN1(LENIN1),               /* SINGLE OR LEFT INPUT */
            RECIN2(LENIN2),               /* RIGHT INPUT FOR MERGE */
            REC( NCOLROW, NBAND),         /* WORKING RECORD (ROW) */
            RECOUT(LENOUT),               /* OUTPUT RECORD */
                                /* HEADER RECORDS */
            RECIN1A(LENIN1A), RECIN1B(LENIN1B),
            RECIN1C(LENIN1C), RECIN1D(LENIN1D),
            RECIN2A(LENIN2A), RECIN2B(LENIN2B),
            RECIN2C(LENIN2C), RECIN2D(LENIN2D),
            RECOUTA(LENOUTA), RECOUTB(LENOUTB),
            RECOUTC(LENOUTC), RECOUTD(LENOUTD)
            )        FLOAT BIN(21) CONTROLLED;

                                /* STATIC */

                                /* FILE VARIABLES */
        DCL PPRINT(5)    FILE VARIABLE
                     INIT(PRINT1, PRINT2, PRINT3, PRINT4, PRINT5);
                                /* SET TO SYPRINT, PRINT1, PRINT2 ... */
        DCL (
            PRINTIN1, PRINTIN2, PRINT, PRINTCODE, PRINTOUT
            )    FILE VARIABLE INIT(SYSPRINT);
        DCL MMAPOUT(10) FILE VARIABLE INIT(
                MAPOUT1, MAPOUT2, MAPOUT3, MAPOUT4, MAPOUT5
                );
                                /* STRUCTURES */
        DCL 1 MAPLINE    STATIC,
                2 CC          CHAR(1) INIT(' '),
                2 ROWMAP      PIC'ZZZZ9',
                2 FILL        CHAR(1) INIT(' '),
                2 MAPROW(125) CHAR(1) INIT( (125) (' ') );
                                /* CHARACTER */
        DCL
            SYMBOL(10, -2:150)  CHAR(1),
            DIGIT(0:9)          CHAR(1),
            CHAR                CHAR(1),
            OP2      CHAR(10),
            OP       CHAR(10) INIT(''); /* OP CODE: TYPE OF CARD */
```

```
                          /* FLOAT */
          DCL (
              CCC(20, 20), TT(20),
              TTT(0:30, 20)   INIT( (620) 0.),
              TTTT(0:30, 20, 20) INIT( (12400) 0.),
              CII, CJI, DFN, DFV, DFC, T
              )        FLOAT BIN(53);
          DCL (
              AA(30), BBB(30, 20), CCCC(30, 20, 20),
              XX(20), YY(20),
              CCLASS(0:30) INIT(-2),
              CLASS, WEIGHT,
              X, Z, ZMIN
              )        FLOAT BIN(21);
                          /* INTEGER */
          DCL (
              BANDSTAT, BANDCOPY,
              BANDPRIN1, BANDPRIN2, BANDPR, BANDPRCODE, BANDPROUT
              ) (20) FIXED BIN(31) INIT(
                 1, 2, 3, 4, 5, 6, 7, 8, 9, 10,
                 11, 12, 13, 14, 15, 16, 17, 18, 19, 20);
          DCL (
              CLASSD(100), COLDB(100),   /* PATTERN CLASS, LAST PIXEL */
                          /* COUNTERS */
              NNT(-1:30)   INIT( (32) 0),
              NNNCLASS(-1:30, -1:30)   INIT( (1024) 0),
                          /* LIMITS (DIMENSIONS) */
              MCOLD     INIT(100),
              MBAND     INIT(20),
              MCLASS    INIT(30),
              MPRINT    INIT(5),
              MNMAP     INIT(5),
              MCOLMAP   INIT(125),
              MSYM      INIT(150),
              MOVP      INIT(10),
              MWARN     INIT(1000),
              MERR      INIT(1000),   /* NUMBER OF ERRORS BEFORE ABORT */
              MERRD     INIT(10)      /* NUMBER OF DATA ERRORS
                                          SUPPRESSING PROCESSING */
              )        FIXED BIN(31);

                          /* INPUT PARAMETERS WITH ZERO DEFAULT */
          DCL (
              COL1,
              COLA, COLB,        /* FIRST, LAST COLUMN OF WINDOW */
              COLOFF,            /* COLUMN OFFSET FOR DATA */
                                 /* PHYSICAL RECORD LENGTH IN BYTES */
                                 /*  DOES NOT INCLUDE 4 BYTES FOR RECFM=V */
              LRECLIN1, LRECLIN2, LRECLOUT,
                                 /* HEADER RECORD LENGTH IN BYTES */
                                 /*  >0 : FIXED LENGTH, =0 : STANDARD */
                                 /*  LENGTHS, <0 : USE LRECL */
              LRECLIN1H, LRECLIN2H, LRECLOUTH,
                                 /* NUMBER OF BANDS */
              NBANDSTAT, NBANDCOPY, NBANDIN, NBANDOUT,
              NBANDPRIN1, NBANDPRIN2, NBANDPR, NBANDPRCODE, NBANDPROUT,
                                 /* NUMBER OF COLUMNS IN ROW */
              NCOLROWIN1, NCOLROWIN2,
                                 /* COUNTERS */
              NRECIN1, NRECIN2, NRECOUT, NROW, NROWIN, NROWOUT,
              ROW1,
              ROWA, ROWB,        /* FIRST, LAST ROW OF WINDOW */
              ROWOFF,            /* ROW OFFSET FOR DATA */
              NERR, NWARN
              )        FIXED BIN(31) INIT(0);

                          /* INPUT PARAMETERS WHICH ARE ALWAYS SET */
          DCL (
              COLOFF2,           /* COLUMN OFFSET FOR MERGE */
                                 /*  <0 : REDUCTION IN NCOLROWIN1 */
              NCLASS,
              BANDMAP,           /* BAND USED FOR MAP */
              NCOLMAP, NSYM, NOVP,        /* SIZES FOR MAP */
              ROWDA, ROWDB,      /* FIRST LAST ROW OF TEMPLATE DATA */
              ROWOFF2            /* ROW OFFSET FOR MERGE */
```

```
                                /*  >0 : MORE RECORDS IGNORED */
                                /*  <0 : FEWER RECORDS IGNORED */
                  )        FIXED BIN(31);
                                /* CALCULATED PARAMETERS */
             DCL (
                  LASTLOCIN1, LASTLOCIN2, LASTLOCOUT,
                  LENIN1, LENIN1A, LENIN1B, LENIN1C, LENIN1D,
                  LENIN2, LENIN2A, LENIN2B, LENIN2C, LENIN2D,
                  LENOUT, LENOUTA, LENOUTB, LENOUTC, LENOUTD,
                  LOCA, LOCB, LOCB2, LOCBOUT,
                  NBAND, NCOLD,
                  NCOLIN1, NCOLIN2, NCOLOUT, NCOLROW, NCOLROWIN, NCOLROWOUT,
                  NMAP,
                  NRECIN1A, NRECIN2A
                  )        FIXED BIN(31);
                                /* TEMPORARY VARIABLES */
             DCL (
                  BAND, COL, COLDA, I, ICOL, J, JBAND, LOC, LOCIN, LOCOUT,
                  ICLASS, IMAP, JCLASS, K, KCLASS, NT,
                  ROW
                  )        FIXED BIN(31);
                                /* BIT (LOGICAL) */
             DCL BPPRINT(5)  BIT(1) INIT( (5) ('0'B) );
             DCL (
                  BINPUT,       /* INPUT FILE TO BE PROCESSED */
                  BMERGE,              /* MERGE OPTION */
                  BADD,         /* ADD ONE BAND TO INPUT */
                  BPATT,   /* READ BOUNDARY AND TRAINING SET PATTERN */
                  BCHECK,       /* CHECK TRAINING SET FOR OVERLAP */
                  BDISCRIM,     /* PERFORM DISCRIMINATION */
                  BSTAT,        /* COLLECT STATISTICS */
                  BMAP,         /* PRINT MAP OF AREA AND TRAINING SETS */
                  BCOPY,        /* PRODUCE OUTPUT OF SELECTED BANDS */
                  BOUT,         /* OUTPUT FILE WILL BE USED */
                  BSINGLE,      /* FORMAT SELECTED BANDS, PIXELS SEPARATE */
                  BSTATOUT,     /* PUNCH STATISTICS */
                  BPUNCH,       /* PUNCH WILL BE USED */

                  BHEADIN1,            /* INPUT1 CONTAINS HEADS */
                  BHEADIN2,            /* INPUT2 CONTAINS HEADS */
                  BHEADOUT,            /* OUTPUT FILE IS TO CONTAIN HEADERS */
                  BPRINTINV,    /* PRINT DETERMINANT AND INVERSE COVARIANCE */
                  BCHECKINV,           /* PRINT PRODUCT OF COVAR AND INVERSE */
                  BPRINTHEAD,          /* OPTION TO PRINT HEADERS FOR ALL FILES */
                  BPRINTIN1,           /* PRINT INPUT1 (LEFT HALF) */
                  BPRINTIN2,           /* PRINT INPUT2 (RIGHT HALF) */
                  BPRINT,              /* PRINT DATA BEFORE SELECTION */
                  BPRINTCODE,          /* PRINT ROW AFTER CODING */
                  BPRINTOUT,           /* PRINT OUTPUT */
                  BPRINTSTAT, /* PRINT STATISTICS */
                  BANY, BDONE,         /* TEMP */
                  FALSE
                  )         BIT(1) INIT('0'B);
             DCL (
                  BIN,                 /* ALLOW INPUT - SET OFF BY TEST */
                  BLIST,               /* PRINT DATA CARDS (SCENE SELECTION) */
                  TRUE
                  )         BIT(1) INIT('1'B);

                                /* FORMATS */
 FMT_HEAD:        FORMAT(COL(1), A, COL(1), F(5,0),
                   999(COL(11), 12 F(10,2) ) );
 FMT_REC:         FORMAT(COL(1), A, COL(1), F(5,0),
                   999(COL(11), 30 F(4) ) );

                                /* INTERRUPT EXITS */
             ON ENDFILE(SYSIN) BEGIN;
                  CALL NOTE(0, 'END OF CONTROL INPUT');
                  GO TO @MOVE;
                  END;
             ON ENDFILE(INPUT1) BEGIN;
                  CALL NOTE(3, 'END OF INPUT FILE BEFORE END OF WINDOW');
                  GO TO @CLOSE;
                  END;
             ON ENDFILE(INPUT2) BEGIN;
```

```
                CALL NOTE(3, 'END OF INPUT2 FILE BEFORE END OF WINDOW');
                GO TO @CLOSE;
                END;
            ON CONVERSION BEGIN;
                IF ONSOURCE='' THEN ONSOURCE='0';
                ELSE DO;
                    CALL NOTE(3, 'INVALID CHARACTER '''
                     || ONCHAR || ''' IN FIELD ''' || ONSOURCE ||
                     ''' OF FOLLOWING DATA');
                    ONCHAR = '0';
                    END;
                END;
            OPEN FILE(SYSPRINT) LINESIZE(132) PAGESIZE(60);
            PUT EDIT('PROGRAM DELIN', VERSION, '')
                (COL(30), A, COL(100), A, SKIP(2), A);
/*///////////////////////////////////////////////////////////////////////*/
                                        /* PARAMETER INPUT LOOP */
@LOOP_PARM:
            GET EDIT(OP) (COL(1), A(10) );
            PUT EDIT('CARD', OP) (SKIP(2), A(4), COL(11), A(10) );

            IF OP = 'INPUT      ' THEN GO TO @INPUT      ;
            IF OP = 'MERGE      ' THEN GO TO @MERGE      ;
            IF OP = 'ADD        ' THEN GO TO @ADD        ;
            IF OP = 'MOVE       ' THEN GO TO @MOVE       ;
            IF OP = 'PATTERN    ' THEN GO TO @PATT       ;
            IF OP = 'PATT       ' THEN GO TO @PATT       ;
            IF OP = 'DISCRIM    ' THEN GO TO @DISCRIM    ;
            IF OP = 'STAT       ' THEN GO TO @STAT       ;
            IF OP = 'MAP        ' THEN GO TO @MAP        ;
            IF OP = 'COPY       ' THEN GO TO @COPY       ;
            IF OP = 'SINGLE     ' THEN GO TO @SINGLE     ;
            IF OP = 'STATOUT    ' THEN GO TO @STATOUT    ;
            IF OP = 'WINDOW1    ' THEN GO TO @WINDOW1    ;
            IF OP = 'WINDOW     ' THEN GO TO @WINDOW     ;
            IF OP = 'OFFSET     ' THEN GO TO @OFFSET     ;
            IF OP = 'HEADIN     ' THEN GO TO @HEADIN1    ;
            IF OP = 'HEADIN1    ' THEN GO TO @HEADIN1    ;
            IF OP = 'HEADIN2    ' THEN GO TO @HEADIN2    ;
            IF OP = 'HEADOUT    ' THEN GO TO @HEADOUT    ;
            IF OP = 'LIST       ' THEN GO TO @LIST       ;
            IF OP = 'NOLIST     ' THEN GO TO @NOLIST     ;
            IF OP = 'PRINTINV   ' THEN GO TO @PRINTINV   ;
            IF OP = 'PRINTHEAD  ' THEN GO TO @PRINTHEAD  ;
            IF OP = 'PRINTIN    ' THEN GO TO @PRINTIN1   ;
            IF OP = 'PRINTIN1   ' THEN GO TO @PRINTIN1   ;
            IF OP = 'PRINTIN2   ' THEN GO TO @PRINTIN2   ;
            IF OP = 'PRINT      ' THEN GO TO @PRINT      ;
            IF OP = 'PRINTCODE  ' THEN GO TO @PRINTCODE  ;
            IF OP = 'PRINTOUT   ' THEN GO TO @PRINTOUT   ;
            IF OP = 'PRINTSTAT  ' THEN GO TO @PRINTSTAT  ;
            IF OP = 'TEST       ' THEN GO TO @TEST       ;

            DO I = 2 TO 8;
                GET EDIT(OP2) (A(10) );
                PUT EDIT(OP2) (A(10) );
                END;
            PUT EDIT(' DELETED CARD') (A);
            IF SUBSTR(OP, 1, 1) ¬= ' '
                THEN CALL NOTE(3, 'INVALID PARAMETER CODE');
            GO TO @LOOP_PARM;

                                        /* INPUT */
@INPUT:
            GET EDIT(LRECLIN1, NCOLROWIN1, NBANDIN) (F(5,0) );
            PUT EDIT(LRECLIN1, NCOLROWIN1, NBANDIN) (F(5,0) );
            BINPUT = TRUE;
            GO TO @LOOP_PARM;
                                        /* MERGE */
@MERGE:
            GET EDIT(LRECLIN2, NCOLROWIN2, ROWOFF2, COLOFF2) (F(5,0) );
            PUT EDIT(LRECLIN2, NCOLROWIN2, ROWOFF2, COLOFF2) (F(5,0) );
            BMERGE = TRUE;
            GO TO @LOOP_PARM;
```

```
/*////////////////////////////////////////////////////////////////////////*/

@ADD:
        BADD = TRUE;
        GO TO @LOOP_PARM;
@PATT:
        GET EDIT(I) (F(5) );
        PUT EDIT(I) (F(5) );
        BPATT = TRUE;
        BCHECK = I>=0;
        GO TO @MOVE;
@DISCRIM:
        GET EDIT(NCLASS) (F(5) );
        PUT EDIT(NCLASS) (F(5) );
        BDISCRIM = TRUE;
        IF NCLASS=0 THEN CALL NOTE(3, 'NUMBER OF CLASSES REQUIRED');
        IF ¬BSTAT THEN CALL NOTE(3,'STAT MUST PRECEDE DISCRIM');
        ELSE DO ICLASS = 1 TO NCLASS;
            GET FILE(STATIN) EDIT(CCLASS(ICLASS), WEIGHT, I)
             (COL(1), 3 F(10) );
            IF BLIST THEN PUT EDIT('CARD', CCLASS(ICLASS), WEIGHT, I)
             (SKIP(3), A, COL(11), F(10), F(10,4), F(10) );
            GET FILE(STATIN)
             EDIT( (BBB(ICLASS, J) DO J = 1 TO NBANDSTAT) )
             (COL(1), 10 F(10) );
            IF BLIST THEN PUT EDIT('CARD',
             (BBB(ICLASS, J) DO J = 1 TO NBANDSTAT) )
             (SKIP(2), A, 9(COL(11), 10 F(10, 5) ) );
            IF BLIST THEN PUT SKIP(2);
            DO J = 1 TO NBANDSTAT;
                GET FILE(STATIN)
                 EDIT( (CCC(J, K) DO K = 1 TO NBANDSTAT) )
                 (COL(1), 10 F(10) );
                IF BLIST THEN PUT EDIT('CARD',
                 (CCC(J, K) DO K = 1 TO NBANDSTAT) )
                 (COL(1), A, 9 (COL(11), 10 F(10, 5) ) );
                END; /* J */
            T = 1.;
            IF BCHECKINV THEN DO J = 1 TO NBANDSTAT;
                DO K = 1 TO NBANDSTAT;
                    CCCC(ICLASS, J, K) = CCC(J, K);
                    END; /* K */
                END; /* J */
            DO I = 1 TO NBANDSTAT;
                CII = CCC(I, I);
                CCC(I, I) = 1.;
                T = T*CII;
                DO K = 1 TO NBANDSTAT;
                    CCC(I, K) = CCC(I, K)/CII;
                    END; /* K */
                DO J = 1 TO I-1, I+1 TO NBANDSTAT;
                    CJI = CCC(J, I);
                    CCC(J, I) = 0.;
                    DO K = 1 TO NBANDSTAT;
                        CCC(J, K) = CCC(J, K) - CJI*CCC(I, K);
                        END; /*K */
                    END; /* J */
                END; /* I */
            IF WEIGHT = 0. THEN WEIGHT = 1.;
            AA(ICLASS) = LOG(ABS(T)/(WEIGHT*WEIGHT) );
            IF BPRINTINV THEN DO;
                PUT EDIT('CLASS', CCLASS(ICLASS), 'WEIGHT', WEIGHT,
                 '    DETERMINANT', T, '    PENALTY', AA(ICLASS),
                 'BAND', (BANDSTAT(J) DO J = 1 TO NBANDSTAT) )
                 (SKIP(3), COL(18), A, F(3), SKIP(2), A, F(10, 5),
                 2 (A, E(15, 7) ), SKIP(2), A, 9 (COL(6), 10 F(10) ) );
                PUT EDIT('MEAN', (BBB(ICLASS, J)DO J = 1 TO NBANDSTAT))
                 (SKIP(2), A, 9 (COL(11), 10 F(10, 5) ) );
                PUT EDIT('INVERSE COVARIANCE') (SKIP(2), A);
                DO J = 1 TO NBANDSTAT;
                    PUT EDIT(BANDSTAT(J),
                     (CCC(J, K) DO K = 1 TO NBANDSTAT) )
                     (COL(4), F(3), 9 (COL(11), 10 F(10, 3) ) );
                    END; /* J */
                END; /* BPRINTINV */
```

```
            IF BCHECKINV THEN DO I = 1 TO NBANDSTAT;
                DO K = 1 TO NBANDSTAT;
                    CII = 0.;
                    DO J = 1 TO NBANDSTAT;
                        CII = CII + CCC(I, J)*CCCC(ICLASS, J, K);
                        END; /* J */
                        XX(K) = CII;
                    END; /* K */
                PUT EDIT('CHECK', (XX(K) DO K = 1 TO NBANDSTAT) )
                 (SKIP(2), A, 9(COL(11), 10 F(10, 6) ) );
                END; /* I */
            DO J = 1 TO NBANDSTAT;
                DO K = 1 TO NBANDSTAT;
                    CCCC(ICLASS, J, K) = CCC(J, K);
                    END; /* K */
                END; /* J */
            END; /* ICLASS */
        GO TO @LOOP_PARM;
@STAT:
        GET EDIT(NBANDSTAT) (F(5) );
        PUT EDIT(NBANDSTAT) (F(5) );
        GET EDIT( (BANDSTAT(J) DO J = 1 TO NBANDSTAT) ) (F(5) );
        PUT EDIT( (BANDSTAT(J) DO J = 1 TO NBANDSTAT) ) (F(5) );
        IF NBANDSTAT = 0 THEN CALL NOTE(3, 'NBANDSTAT REQUIRED');
        ELSE BSTAT = TRUE;
        GO TO @LOOP_PARM;
@MAP:
        GET EDIT(BANDMAP, NCOLMAP, NOVP, NSYM) (F(5) );
        PUT EDIT(BANDMAP, NCOLMAP, NOVP, NSYM) (F(5) );
        IF NCOLMAP <= 0 THEN NCOLMAP = 100;
        IF NCOLMAP > MCOLMAP THEN DO;
            CALL NOTE(2, 'NCOLMAP REDUCED TO MAXIMUM');
            NCOLMAP = MCOLMAP;
            END;
        IF NSYM > 0 THEN DO;
            IF NSYM > MSYM THEN NSYM = MSYM;
            IF NOVP <= 0 THEN NOVP = 1;
            IF NOVP > MOVP THEN NOVP = MOVP;
            DO IOVP = 1 TO NOVP;
                GET SKIP EDIT( (SYMBOL(IOVP, I) DO I = -2 TO NSYM) )
                 (COL(8), 3 A(1), 9(COL(11), 50 A(1) ) );
                PUT SKIP EDIT( (SYMBOL(IOVP, I) DO I = -2 TO NSYM) )
                 (COL(8), 3 A(1), 9(COL(11), 50 A(1) ) );
                END;     /* IOVP */
            END; /* NSYM */
        ELSE DO;
            NSYM = 30;
            NOVP = 1;
            STRING(SYMBOL) = '*/ 123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ';
            END;
        BMAP = TRUE;
        GO TO @LOOP_PARM;
@COPY:
        GET EDIT(LRECLOUT, NBANDCOPY) (F(5,0) );
        PUT EDIT(LRECLOUT, NBANDCOPY) (F(5,0) );
        GET EDIT( (BANDCOPY(J) DO J = 1 TO NBANDCOPY) ) (F(5) );
        PUT EDIT( (BANDCOPY(J) DO J = 1 TO NBANDCOPY) ) (F(5) );
        IF BSINGLE THEN CALL NOTE(3, 'CONFLICTING OUTPUT ACTION');
        ELSE BCOPY, BOUT=TRUE;
        GO TO @LOOP_PARM;
@SINGLE:
        GET EDIT(NBANDCOPY) (F(5) );
        PUT EDIT(NBANDCOPY) (F(5) );
        GET EDIT( (BANDCOPY(J) DO J = 1 TO NBANDCOPY) ) (F(5) );
        PUT EDIT( (BANDCOPY(J) DO J = 1 TO NBANDCOPY) ) (F(5) );
        IF BCOPY   THEN CALL NOTE(3, 'CONFLICTING OUTPUT ACTION');
        ELSE BSINGLE, BPUNCH = TRUE;
        GO TO @LOOP_PARM;
@STATOUT:
        BSTATOUT, BPUNCH = TRUE;
        GO TO @LOOP_PARM;
                            /* WINDOW */
@WINDOW1:
        GET EDIT(ROW1, COL1) (F(5) );
        PUT EDIT(ROW1, COL1) (F(5) );
```

```
                GO TO @LOOP_PARM;
        @WINDOW:
                GET EDIT(ROWA, ROWB, COLA, COLB) (F(5,0) );
                PUT EDIT(ROWA, ROWB, COLA, COLB) (F(5,0) );
                IF ROWA ¬= 0 THEN ROWA = ROWA + ROWOFF;
                IF ROWB ¬= 0 THEN ROWB = ROWB + ROWOFF;
                IF COLA ¬= 0 THEN CCLA = COLA + COLOFF;
                IF COLB ¬= 0 THEN COLB = COLB + COLOFF;
                GO TO @LOOP_PARM;
                                                /* OFFSET */
        @OFFSET:
                GET EDIT(ROWOFF, COLOFF) (F(5) );
                PUT EDIT(ROWOFF, COLOFF) (F(5) );
                GO TO @LOOP_PARM;
        @HEADIN1:
                GET EDIT(LRECLIN1H) (F(5,0) );
                PUT EDIT(LRECLIN1H) (F(5,0) );
                BHEADIN1 = TRUE;
                GO TO @LOOP_PARM;
        @HEADIN2:
                GET EDIT(LRECLIN2H) (F(5,0) );
                PUT EDIT(LRECLIN2H) (F(5,0) );
                BHEADIN2 = TRUE;
                GO TO @LOOP_PARM;
        @HEADOUT:
                GET EDIT(LRECLOUTH) (F(5,0) );
                PUT EDIT(LRECLOUTH) (F(5,0) );
                BHEADOUT = TRUE;
                GO TO @LOOP_PARM;
                                                /* LIST */
        @LIST:
                BLIST = TRUE;
                GO TO @LOOP_PARM;
        @NOLIST:
                BLIST = FALSE;
                GO TO @LOOP_PARM;
        @PRINTINV:
                GET EDIT(I) (F(5) );
                PUT EDIT(I) (F(5) );
                BPRINTINV = TRUE;
                IF I > 0 THEN BCHECKINV = TRUE;
                GO TO @LOOP_PARM;
        @PRINTHEAD:
                BPRINTHEAD = TRUE;
                GO TO @LOOP_PARM;
                                                /* PRINTIN1 */
        @PRINTIN1:
                CALL GETPR(PRINTIN1, NBANDPRIN1, BANDPRIN1);
                BPRINTIN1 = TRUE;
                GO TO @LOOP_PARM;
                                                /* PRINTIN2 */
        @PRINTIN2:
                CALL GETPR(PRINTIN2, NBANDPRIN2, BANDPRIN2);
                BPRINTIN2 = TRUE;
                GO TO @LOOP_PARM;
                                                /* PRINT */
        @PRINT:
                CALL GETPR(PRINT, NBANDPR, BANDPR);
                BPRINT = TRUE;
                GO TO @LOOP_PARM;
                                                /* PRINTCODE */
        @PRINTCODE:
                CALL GETPR(PRINTCODE, NBANDPRCODE, BANDPRCODE);
                BPRINTCODE = TRUE;
                GO TO @LOOP_PARM;
                                                /* PRINTOUT */
        @PRINTOUT:
                CALL GETPR(PRINTOUT, NBANDPROUT, BANDPROUT);
                BPRINTOUT = TRUE;
                GO TO @LOOP_PARM;
        @PRINTSTAT:
                BPRINTSTAT = TRUE;
                GO TO @LOOP_PARM;
                                                /* TEST */
        @TEST:
```

```
          GET EDIT(I) (F(5) );
          PUT EDIT(I) (F(5) );
          IF I>=1 THEN BOUT, BPUNCH = FALSE;
          IF I>=2 THEN BIN = FALSE;
          GET EDIT(I) (F(5) );
          PUT EDIT(I) (F(5) );
          IF I¬=0 THEN MERRD = I;
          GET EDIT(I) (F(5) );
          PUT EDIT(I) (F(5) );
          IF I¬=0 THEN MERR = I;
          GET EDIT(I) (F(5) );
          PUT EDIT(I) (F(5) );
          IF I¬=0 THEN MWARN = I;
          GO TO @LOOP_PARM;

/*//////////////////////////////////////////////////////////////////////*/

GETPR:    PROC(PRINT, NBANDPR, BANDPR);
               DEFAULT RANGE(A:Z)
                    FIXED BIN
                    STATIC
                    ;
               DCL
                    PRINT     FILE VARIABLE,
                    (
                    NBANDPR,
                    BANDPR(20),
                    IPRIN
                    )         FIXED BIN(31);
               GET EDIT(IPRIN, NBANDPR) (F(5,0) );
               PUT EDIT(IPRIN, NBANDPR) (F(5,0) );
               GET EDIT((BANDPR(J) DO J = 1 TO NBANDPR) ) (F(5,0) );
               PUT EDIT((BANDPR(J) DO J = 1 TO NBANDPR) ) (F(5,0) );
               IF IPRIN > 0 THEN
                    IF IPRIN <= MPRINT THEN DO;
                         PRINT = PPRINT(IPRIN);
                         BPPRINT(IPRIN) = TRUE;
                         END;
                    ELSE CALL NOTE(2, 'INVALID PRINTER');
               END;  /* GETPR */

/*//////////////////////////////////////////////////////////////////////*/

                                   /* MOVE */
@MOVE:
                                   /* PARAMETER DEFAULTS AND CHECKING */

                                   /* INPUT */
          IF ¬BINPUT THEN IF BMERGE|BDISCRIM|BSINGLE
            THEN DO;
               CALL NOTE(1,
                'INPUT ASSUMED FOR MERGE, DISCRIM, OR SINGLE');
               BINPUT = TRUE;
               END;
            ELSE DO; /* ¬BINPUT */
               IF ¬BPATT THEN DO;
                    CALL NOTE(1, 'NO INPUT, NO PATTERN, NO WORK');
                    GO TO @STOP;
                    END; /* ¬BPATT */
               IF ROWB<=ROWA | COLB<=COLA THEN CALL NOTE(3,
                'MISSING OR INVALID WINDOW (OR MISSING INPUT');
               COLOFF = COLOFF - (COLA - 1);
               NCOLROW = COLB - COLA + 1;
               BADD = TRUE;
               NBAND = 1;
               GO TO @NOINPUT;
               END;
          IF NBANDIN = 0 THEN DO;
               CALL NOTE(1, '4 BANDS ASSUMED');
               NBANDIN = 4;
               END;
          IF LRECLIN1 = 0 THEN DO;
               CALL NOTE(1, 'INPUT LRECL ASSUMED TO BE 3200');
               LRECLIN1 = 3200;
               END;
```

```
                              /* MERGE */
          IF BMERGE THEN DO;
              IF LRECLIN2 = 0 THEN LRECLIN2 = LRECLIN1;
              LENIN2 = LRECLIN2/4;
              LASTLOCIN2 = LENIN2 - NBANDIN;
              END;
                              /* ADD */
          IF BADD THEN NBAND = NBANDIN + 1;
          ELSE NBAND = NBANDIN;
                              /* HEADIN2 */
          IF BHEADIN2&¬BMERGE THEN DO;
              CALL NOTE(2, 'NO MERGE - HEADIN2 IGNORED');
              BHEADIN2 = FALSE;
              END;

                              /* PRINTIN1, 2 */
          IF NBANDPRIN1 = 0 THEN NBANDPRIN1 = NBANDIN;
          IF BMERGE THEN DO;
              IF NBANDPRIN2 = 0 THEN NBANDPRIN2 = NBANDIN;
              END;
          ELSE DO;
              IF BPRINTIN2 THEN CALL NOTE(2,
               'NO MERGE OPERATION - PRINTIN2 IGNORED');
              END;
                              /* PRINT */
          IF NBANDPR = 0 THEN NBANDPR = NBANDIN;

/*//////////////////////////////////////////////////////////////////////////*/

          IF NERR>0 THEN IF BIN|BOUT|BPUNCH THEN DO;
              CALL NOTE(1, 'FILE PROCESSING SUPPRESSED DUE TO ERRORS');
              BIN, BOUT, BPUNCH = FALSE;
              END;
                              /* OPEN FILES, ALLOCATE, READ HEADERS */
          DO I = 1 TO MPRINT;
              IF BPPRINT(I) THEN OPEN FILE(PPRINT(I) ) LINESIZE(132) ;
              END;

                              /* OPEN INPUT */
          IF BIN THEN DO;
              IF BMERGE THEN OPEN FILE(INPUT1), FILE(INPUT2);
              ELSE OPEN FILE(INPUT1) TITLE('INPUT');
              IF BHEADIN1 THEN DO;
                  IF LRECLIN1H = 0 THEN DO;
                      LENIN1A = 4;
                      LENIN1B, LENIN1C = NBANDIN;
                      LENIN1D = 128*NBANDIN;
                      END;
                  ELSE DO;
                      IF LRECLIN1H < 0 THEN LRECLIN1H = LRECLIN1;
                      LENIN1A, LENIN1B, LENIN1C, LENIN1D = LRECLIN1H/4;
                      END;
                  ALLOCATE RECIN1A, RECIN1B, RECIN1C, RECIN1D;
                  READ FILE(INPUT1) INTO(RECIN1A);
                  READ FILE(INPUT1) INTO(RECIN1B);
                  READ FILE(INPUT1) INTO(RECIN1C);
                  READ FILE(INPUT1) INTO(RECIN1D);
                  NRECIN1 = 4;
                  IF BPRINTHEAD THEN DO;
                      PUT FILE(PRINTIN1) EDIT('INPUT1 HEADER',
                       1, RECIN1A) (R(FMT_HEAD) );
                      PUT FILE(PRINTIN1) EDIT('INPUT1 HEADER',
                       2, RECIN1B) (R(FMT_HEAD) );
                      PUT FILE(PRINTIN1) EDIT('INPUT1 HEADER',
                       3, RECIN1C) (R(FMT_HEAD) );
                      PUT FILE(PRINTIN1) EDIT('INPUT1 HEADER',
                       4, RECIN1D) (R(FMT_HEAD) );
                      END;
                  IF ROW1 = 0 THEN ROW1 = RECIN1A(1);
                  IF ROWB = 0 THEN DO;
                      CALL NOTE(1, 'LAST ROW SET FROM HEADER');
                      ROWB = ROW1 - 1 + RECIN1A(3);
                      END;
                  ELSE IF ROWB > ROW1 - 1 + RECIN1A(3) THEN DO;
                      CALL NOTE(2, 'LAST ROW PAST END OF FILE');
```

```
                    ROWB = ROW1 - 1 + RECIN1A(3);
                    END;
                IF COL1 = 0 THEN COL1 = RECIN1A(2);
                IF NCOLROWIN1 = 0 THEN DO;
                    CALL NOTE(1,
                     'INPUT1 ROW LENGTH TAKEN FROM HEADER');
                    NCOLROWIN1 = RECIN1A(4);
                    END;
                END;  /* BHEADIN1 */
            IF BHEADIN2 THEN DO;
                IF LRECLIN2H = 0 THEN DO;
                    LENIN2A = 4;
                    LENIN2B, LENIN2C = NBANDIN;
                    LENIN2D = 128*NBANDIN;
                    END;
                ELSE DO;
                    IF LRECLIN2H < 0 THEN LRECLIN2H = LRECLIN2;
                    LENIN2A, LENIN2B, LENIN2C, LENIN2D = LRECLIN2H/4;
                    END;
                ALLOCATE RECIN2A, RECIN2B, RECIN2C, RECIN2D;
                READ FILE(INPUT2) INTO(RECIN2A);
                READ FILE(INPUT2) INTO(RECIN2B);
                READ FILE(INPUT2) INTO(RECIN2C);
                READ FILE(INPUT2) INTO(RECIN2D);
                NRECIN2 = 4;
                IF BPRINTHEAD THEN DO;
                    PUT FILE(PRINTIN2) EDIT('INPUT2 HEADER',
                     1, RECIN2A) (R(FMT_HEAD) );
                    PUT FILE(PRINTIN2) EDIT('INPUT2 HEADER',
                     2, RECIN2B) (R(FMT_HEAD) );
                    PUT FILE(PRINTIN2) EDIT('INPUT2 HEADER',
                     3, RECIN2C) (R(FMT_HEAD) );
                    PUT FILE(PRINTIN2) EDIT('INPUT2 HEADER',
                     4, RECIN2D) (R(FMT_HEAD) );
                    END;
                IF BHEADIN1 THEN IF ROWOFF2 = 0 THEN DO;
                    CALL NOTE(1,
                     'MERGE ROW OFFSET CALCULATED FROM HEADERS');
                    ROWOFF2 = RECIN2A(1) - RECIN1A(1);
                    END;
                ELSE IF RECIN1A(1) + ROWOFF2 ¬= RECIN2A(1) THEN
                    CALL NOTE(2,
                     'MERGE ROW OFFSET INCONSISTANT WITH HEADERS');
                IF NCOLROWIN2 = 0 THEN DO;
                    CALL NOTE(1,
                     'INPUT2 ROW LENGTH TAKEN FROM HEADER');
                    NCOLROWIN2 = RECIN2A(4);
                    END;
                END;  /* BHEADIN2 */
            END;  /* BIN */

/*//////////////////////////////////////////////////////////////////////*/

                              /* MORE INPUT CALCULATIONS */
        LENIN1 = LRECLIN1/4;
        NCOLIN1 = LENIN1/NBANDIN;
        LASTLOCIN1 = LENIN1 - NBANDIN;
        IF NCOLROWIN1 = 0 THEN DO;
            CALL NOTE(2, 'INPUT1 - RECORD LENGTH USED FOR ROW LENGTH');
            NCOLROWIN1 = NCOLIN1;
            END;
        IF BMERGE THEN DO;
            LENIN2 = LRECLIN2/4;
            NCOLIN2 = LENIN2/NBANDIN;
            LASTLOCIN2 = LENIN2 - NBANDIN;
            IF NCOLROWIN2 = 0 THEN DO;
                CALL NOTE(2,
                 'INPUT2 - RECORD LENGTH USED FOR ROW LENGTH');
                NCOLROWIN2 = NCOLIN2;
                END;
            IF COLOFF2 <= 0 THEN COLOFF2 = NCOLROWIN1 + COLOFF2;
            IF COLOFF2 > NCOLROWIN1 THEN CALL NOTE(3,
              'INPUT2 - COLUMN OFFSET BEYOND INPUT1');
            NCOLROWIN = COLOFF2 + NCOLROWIN2;
            END;
```

```
        ELSE DO; /* NOT BMERGE */
            NCOLROWIN = NCOLROWIN1;
            END;
                                /* WINDOW1 */
        IF ROW1 = 0 THEN ROW1 = 1;
        IF COL1 = 0 THEN COL1 = 1;
                                /* WINDOW */
        IF ROWA = 0 THEN ROWA = ROW1;
        IF ROWB = 0 THEN DO;
            CALL NOTE(1, 'LAST ROW NOT GIVEN - ENTIRE INPUT ALLOWED');
            ROWB = 32000;
            END;
        IF COLA = 0 THEN COLA = COL1;
        IF COLB <= 0 THEN DO;
            CALL NOTE(1,'LAST COLUMN NOT GIVEN - ENTIRE INPUT COPIED');
            NCOLROW = NCOLROWIN;
            COLB = COLA + NCOLROW - 1;
            END;
        ELSE DO;
            NCOLROW = COLB - COLA + 1;
            IF NCOLROW > NCOLROWIN THEN CALL NOTE(3,
             'WINDOW EXCEEDS INPUT LENGTH');
            END;
                                /* OFFSET */
        COLOFF = COLOFF - (COLA-1);
                                /* MORE INPUT CALCULATIONS */
        I = (NCOLROWIN1 + NCOLIN1 - 1)/NCOLIN1;
        NRECIN1A = (ROWA - ROW1)*I;
        LOCA = (COLA - COL1)*NBANDIN;
        IF BMERGE THEN DO;
            IF ROWOFF2 > ROWA - ROW1 THEN CALL NOTE(3,
             'ROW OFFSET FOR INPUT2 IS PAST WINDOW');
            I = (NCOLROWIN2 + NCOLIN2 - 1)/NCOLIN2;
            NRECIN2A = (ROWA - ROW1 - ROWOFF2)*I;
            LOCB = (COLOFF2 - 1)*NBANDIN;
            LOCB2 = (COLB - COL1 - COLOFF2)*NBANDIN;
            END;
        ELSE DO;
            LOCB = (COLB - COL1)*NBANDIN;
            END;
@NOINPUT:
                                /* COPY OR SINGLE */
        IF NBANDCOPY = 0 THEN NBANDCOPY = NBAND;
        NBANDOUT = NBANDCOPY;
                                /* PRINTOUT */
        IF BPRINTOUT THEN IF NBANDPROUT = 0 THEN NBANDPROUT = NBANDOUT;
                                /* COPY */
        IF BCOPY THEN DO;
            NCOLROWOUT = NCOLROW;
            IF LRECLOUT = 0 THEN DO;
                CALL NOTE(1, 'WINDOW USED FOR OUTPUT LRECL');
                LRECLOUT = NCOLROWOUT*NBANDOUT*4;
                END;
            ELSE IF LRECLOUT < NCOLROWOUT*NBANDOUT*4 THEN CALL NOTE(1,
             'OUTPUT ROW WILL SPAN RECORDS');
            LENOUT = LRECLOUT/4;
            NCOLOUT = LENOUT/NBANDOUT;
            LASTLOCOUT = LENOUT - NBANDOUT;
            LOCBOUT = (NCOLROWOUT - 1)*NBANDOUT;
            END;  /* BCOPY */
        ELSE IF BHEADOUT THEN DO;
            CALL NOTE(2, 'NO COPY, HEADOUT IGNORED');
            BHEADOUT = FALSE;
            END; /* BHEADOUT */

/*//////////////////////////////////////////////////////////////////////*/

        IF NERR>0 THEN IF BIN|BOUT|BPUNCH THEN DO;
            CALL NOTE(1, 'FILE PROCESSING SUPPRESSED DUE TO ERRORS');
            BIN, BOUT, BPUNCH = FALSE;
            END;
        IF BOUT THEN OPEN FILE(OUTPUT);
        IF BHEADOUT THEN DO;
            IF LRECLOUTH = 0 THEN DO;
                LENOUTA = 4;
```

```
                    LENOUTB, LENOUTC = NBANDOUT;
                    LENOUTD = 128*NBANDOUT;
                    END;
                ELSE DO;
                    IF LRECLOUTH < 0 THEN LRECLOUTH = LRECLOUT;
                    LENOUTA, LENOUTB, LENOUTC, LENOUTD = LRECLOUTH/4;
                    END;
                ALLOCATE RECOUTA, RECOUTB, RECOUTC, RECOUTD;
                RECOUTA = 0.;
                RECOUTB = 0.;
                RECOUTC = 0.;
                RECOUTD = 0.;
                RECOUTA(1) = ROWA;
                RECOUTA(2) = COLA;
                RECOUTA(3) = ROWB - ROWA + 1;
                RECOUTA(4) = NCOLROWOUT;
                IF BHEADIN1 THEN DO;
                    LOCOUT = 0;
                    IF NBANDOUT > LENOUTB THEN CALL NOTE(2,
                     'HEADERS EXCEED OUTPUT LRECL - ZEROS USED');
                    ELSE DO JBAND = 1 TO NBANDCOPY;
                        BAND = BANDCOPY(JBAND);
                        IF BAND <= NBANDIN THEN DO;
                            RECOUTB(JBAND) = RECIN1B(BAND);
                            RECOUTC(JBAND) = RECIN1C(BAND);
                            LOCIN = (BAND - 1)*128;
                            IF NBANDOUT*128 <= LENOUTD THEN DO I= 1 TO 128;
                                LOCOUT = LOCOUT + 1;
                                LOCIN = LOCIN + 1;
                                RECOUTD(LOCOUT) = RECIN1D(LOCIN);
                                END; /* I */
                            END; /* BAND */
                        END;  /* JBAND */
                    IF NBANDOUT*128 > LENOUTD THEN CALL NOTE(2,
                     'HEADER 4 EXCEEDS OUTPUT LRECL - ZEROS USED');
                    END;  /* BHEADIN1 */
                ELSE CALL NOTE(1,
                 'NO INPUT HEADERS - ZEROS USED FOR HEADER 2-4');
                IF BPRINTHEAD THEN DO;
                    PUT FILE(PRINTOUT) EDIT('OUTPUT HEADER',
                     1, RECOUTA) (R(FMT_HEAD) );
                    PUT FILE(PRINTOUT) EDIT('OUTPUT HEADER',
                     2, RECOUTB) (R(FMT_HEAD) );
                    PUT FILE(PRINTOUT) EDIT('OUTPUT HEADER',
                     3, RECOUTC) (R(FMT_HEAD) );
                    PUT FILE(PRINTOUT) EDIT('OUTPUT HEADER',
                     4, RECOUTD) (R(FMT_HEAD) );
                    END;  /* BPRINTHEAD */
                IF BOUT THEN DO;
                    WRITE FILE(OUTPUT) FROM(RECOUTA);
                    WRITE FILE(OUTPUT) FROM(RECOUTB);
                    WRITE FILE(OUTPUT) FROM(RECOUTC);
                    WRITE FILE(OUTPUT) FROM(RECOUTD);
                    NRECOUT = 4;
                    END;  /* BOUT */
                END;  /* BHEADOUT */

/*//////////////////////////////////////////////////////////////////////*/

                              /* PRINT FILE SUMMARY */
            PUT FILE(SYSPRINT) EDIT( (40) '-', 'RECORD', 'ROW',
             'BYTES WORDS COLUMNS   COLUMNS', (40) '-')
             (PAGE, A, COL(17), A, COL(34), A, COL(10), A, COL(1), A);
            IF BINPUT THEN IF BMERGE THEN PUT FILE(SYSPRINT) EDIT(
             'INPUT1', LRECLIN1, LENIN1, NCOLIN1, NCOLROWIN1,
             'INPUT2', LRECLIN2, LENIN2, NCOLIN2, NCOLROWIN2,
             'TOTAL', NCOLROWIN)
             (2 R(FMT_SUMM), COL(1), A, COL(32), F(5,0) );
            ELSE PUT FILE(SYSPRINT) EDIT(
             'INPUT', LRECLIN1, LENIN1, NCOLIN1, NCOLROWIN1)
             (R(FMT_SUMM) );
            IF BCOPY THEN PUT FILE(SYSPRINT) EDIT(
             'OUTPUT', LRECLOUT, LENOUT, NCOLOUT, NCOLROWOUT, (40)'-')
             (R(FMT_SUMM) );
            ELSE PUT FILE(SYSPRINT) EDIT('ROW', NCOLROW, (40)'-')
```

```
          (COL(1), A, COL(32), F(5) );
FMT_SUMM:    FORMAT(COL(1), A, COL(10), 2 F(5,0), F(7,0),
               COL(32), F(5,0) );
          PUT SKIP(3);

/*//////////////////////////////////////////////////////////////////////*/

          IF NERR>0 THEN IF BIN|BOUT|BPUNCH THEN DO;
               CALL NOTE(1, 'FILE PROCESSING SUPPRESSED DUE TO ERRORS');
               BIN, BOUT, BPUNCH = FALSE;
               END;
                                   /* ALLOCATE, POSITION FILES */
          IF BIN THEN DO;
               IF BINPUT THEN DO;
                    IF BMERGE THEN ALLOCATE RECIN1, RECIN2, REC;
                    ELSE ALLOCATE RECIN1, REC;
                    READ FILE(INPUT1) IGNORE(NRECIN1A);
                    NRECIN1 = NRECIN1 + NRECIN1A;
                    END; /* BINPUT */
               ELSE ALLOC REC;
               IF BMERGE THEN DO;
                    READ FILE(INPUT2) IGNORE(NRECIN2A);
                    NRECIN2 = NRECIN2 + NRECIN2A;
                    END;
               IF BCOPY THEN DO;
                    ALLOCATE RECOUT;
                    RECOUT = 0.;
                    END; /* BCOPY */
               END; /* BIN */
          IF BPUNCH THEN OPEN FILE(PUNCH) LINESIZE(80);

/*//////////////////////////////////////////////////////////////////////*/

                                   /* FINAL SETUP */

                                   /* MAP */
          IF BMAP THEN DO;
               IF BANDMAP<=0 | BANDMAP>NBAND THEN BANDMAP = NBAND;
               NMAP = (NCOLROW + NCOLMAP - 1)/NCOLMAP;
               STRING(MAPLINE) = '';
               STRING(DIGIT) = ' 123456789';
               IF NMAP > MNMAP THEN DO;
                    CALL NOTE(2, 'MAP WIDTH REDUCED TO MAXIMUM');
                    NMAP = MNMAP;
                    END;
               LOC = COLA - 1;
               DO IMAP = 1 TO NMAP;
                    OPEN FILE(MMAPOUT(IMAP) );
                    DO I = 1000, 100, 10, 1;
                         DO J = 1 TO MIN(NCOLMAP, COLB - LOC);
                              MAPROW(J) = DIGIT(MOD( (LOC+J)/I, 10) );
                              END; /* J */
                         DO J = COLB - LOC + 1 TO NCOLMAP;
                              MAPROW(J) = ' ';
                              END; /* J */
                         WRITE FILE(MMAPOUT(IMAP) ) FROM(MAPLINE);
                         DIGIT(0) = '0';
                         END; /* I */
                    DIGIT(0) = ' ';
                    MAPROW = ' ';
                    WRITE FILE(MMAPOUT(IMAP) ) FROM(MAPLINE);
                    LOC = LOC + NCOLMAP;
                    END; /* IMAP */
               END; /* BMAP */
                                   /* PRINTCODE */
          IF NBANDPRCODE = 0 THEN NBANDPRCODE = NBAND;
          ROWDA = ROWA;
          ROWDB = ROWB;
          ON ENDFILE(SYSIN) BEGIN;
               CALL NOTE(0, 'END OF PATTERN DATA');
               GO TO @CLOSE;
               END;
          IF NERR>0 THEN IF BIN|BOUT|BPUNCH THEN DO;
               CALL NOTE(1, 'FILE PROCESSING SUPPRESSED DUE TO ERRORS');
               BIN, BOUT, BPUNCH = FALSE;
```

```
                 END;
/*//////////////////////////////////////////////////////////////////////*/
                                       /* CARD INPUT LOOP */
@LOOP_CARD:
          IF BPATT THEN DO;
               GET SKIP LIST(ROWDB);
               NCOLD = 0;
               COLDA = COLA;
               DO ICOL = 1 TO MCOLD WHILE(COLDA<=COLB);
                    GET LIST(CLASSD(ICOL), COLDB(ICOL) );
                    IF COLDB(ICOL)=0 THEN COLDA = COLB + 1;
                    ELSE COLDA = COLDB(ICOL) + 1;
                    NCOLD = ICOL;
                    END; /* ICOL */
               IF BLIST THEN PUT EDIT('CARD',
                ROWDB, (CLASSD(I), COLDB(I) DO I = 1 TO NCOLD) )
                (COL(1), A, COL(11), F(5), 999(COL(16), 15 F(5) ) );
               COLDA = COLA;
               DO ICOL = 1 TO NCOLD;
                    COL = COLDB(ICOL);
                    IF COL = 0 THEN COL = COLB;
                    IF COL<COLDA THEN DO;
                         CALL NOTE(3, 'COLUMN OVERLAP IN DATA '' ... '
                           || COLDA || CLASSD(ICOL) || COL
                           || ' ... ''');
                         COL = COLDA;
                         END;
                    IF COL>COLB THEN DO;
                         CALL NOTE(3, 'COLUMN BEYOND WINDOW');
                         COL = COLB;
                         END; /* IF */
                    COLDA = COL + 1;
                    COLDB(ICOL) = COL + COLOFF;
                    END; /* ICOL */
               IF ROWDB = 0 THEN ROWDB = ROWB;
               ELSE ROWDB = ROWDB + ROWOFF;
               IF ROWDB<ROWDA THEN DO;
                    CALL NOTE(3, 'ROW OVERLAP OR SEQUENCE ERROR');
                    GO TO @LOOP_CARD;
                    END; /* IF */
               IF ROWDB>ROWB THEN DO;
                    CALL NOTE(3, 'ROW BEYOND WINDOW');
                    ROWDB = ROWB;
                    END; /* IF */
               END; /* BPATT */
          IF NERR>MERRD THEN IF BIN THEN DO;
               CALL NOTE(1, 'FILE PROCESSING SUPPRESSED DUE TO ERRORS');
               BIN = FALSE;
               END; /* IF */

/*//////////////////////////////////////////////////////////////////////*/

                                       /* FILE INPUT LOOP */
@PROCESS:
          IF BIN THEN DO ROW = ROWDA TO ROWDB;
               IF BADD THEN REC(*, NBAND) = 0.;
               COL = 0;
               IF BINPUT THEN DO ICOL = 1 TO NCOLROWIN1 BY NCOLIN1;
                    LOCIN = (ICOL - 1)*NBANDIN;
                    READ FILE(INPUT1) INTO(RECIN1);
                    NRECIN1 = NRECIN1 + 1;
                    IF BPRINTIN1 THEN PUT FILE(PRINTIN1) EDIT(
                     'INPUT RECORD', NRECIN1,
                     ( (RECIN1(LOC + BANDPRIN1(J) ) DO J = 1 TO NBANDPRIN1)
                     DO LOC = 0 TO LASTLOCIN1 BY NBANDIN) ) (R(FMT_REC) );
                    DO LOC = MAX(LOCA - LOCIN, 0)
                    TO MIN(LOCB - LOCIN, LASTLOCIN1) BY NBANDIN;
                         COL = COL + 1;
                         DO J = 1 TO NBANDIN;
                              REC(COL, J) = RECIN1(LOC + J);
                              END;  /* J */
                         END;  /* LOC */
                    END; /* ICOL, BINPUT */

               IF BMERGE THEN DO ICOL = 1 TO NCOLROWIN2 BY NCOLIN2;
```

```
        LOCIN = (ICOL - 1)*NBANDIN;
        READ FILE(INPUT2) INTO(RECIN2);
        NRECIN2 = NRECIN2 + 1;
        IF BPRINTIN2 THEN PUT FILE(PRINTIN2) EDIT(
         'INPUT2 RECORD', NRECIN2,
         ( (RECIN2(LOC + BANDPRIN2(J) ) DO J = 1 TO NBANDPRIN2)
         DO LOC = 0 TO LASTLOCIN2 BY NBANDIN) ) (R(FMT_REC) );
        DO LOC = 0 TO MIN(LOCA2-LOCIN, LASTLOCIN2) BY NBANDIN;
            COL = COL + 1;
            DO J = 1 TO NBANDIN;
                REC(COL, J) = RECIN2(LOC + J);
                END;  /* J */
            END;  /* LOC */
        END;  /* ICOL */
    NROW = NROW + 1;
    IF BPRINT THEN PUT FILE(PRINT) EDIT('INPUT ROW', ROW,
     ( (REC(I, BANDPR(J) ) DO J = 1 TO NBANDPR)
     DO I = 1 TO NCOLROW) ) (R(FMT_REC) );

IF BPATT THEN DO;
    COLDA = 1;
    DO ICOL = 1 TO NCOLD;
        ICLASS = CLASSO(ICOL);
        IF ICLASS > -2 THEN DO COL = COLDA TO COLDB(ICOL);
            IF BCHECK THEN
              IF REC(COL, NBAND)¬=0. & REC(COL, NBAND)¬=ICLASS
                THEN REC(COL, NBAND) = -2.;
              ELSE REC(COL, NBAND) = ICLASS;
            ELSE REC(COL, NBAND) = ICLASS;
            END; /* COL */
        COLDA = COLDB(ICOL) + 1;
        END; /* ICOL */
    END; /* BPATT */

IF BDISCRIM THEN DO COL = 1 TO NCOLROW;
            JCLASS = REC(COL, NBAND);
            IF JCLASS ¬= -1. THEN DO;
                IF JCLASS < -1 THEN JCLASS = 0;
                ZMIN = 1E30;
                KCLASS = 0;
                DO J = 1 TO NBANDSTAT;
                    XX(J) = REC(COL, BANDSTAT(J) );
                    END; /* J */
                DO ICLASS = 1 TO NCLASS;
                    Z = AA(ICLASS);
                    DO J = 1 TO NBANDSTAT;
                        YY(J) = XX(J) - BBB(ICLASS, J);
                        END; /* J */
                    DO J = 1 TO NBANDSTAT;
                        T = 0.;
                        DO K = 1 TO NBANDSTAT;
                            T = T + CCCC(ICLASS, J, K)*YY(K);
                            END; /* K */
                        Z = Z + YY(J)*T;
                        END; /* J */
                    IF Z<ZMIN THEN DO;
                        ZMIN = Z;
                        KCLASS = ICLASS;
                        END; /* Z<ZMIN */
                    END; /* ICLASS */
                NNNCLASS(JCLASS, KCLASS)
                 = NNNCLASS(JCLASS, KCLASS) + 1;
                REC(COL, NBAND) = CCLASS(KCLASS);
                END; /* JCLASS¬=-1 */
    END; /* COL, BDISCRIM */
    IF BPRINTCODE THEN PUT FILE(PRINTCODE) EDIT(
        'CODED ROW', ROW,
        ( (REC(I, BANDPRCODE(J) ) DO J = 1 TO NBANDPRCODE)
         DO I = 1 TO NCOLROW) ) (R(FMT_REC) );
    IF BSTAT THEN DO COL = 1 TO NCOLROW;
            ICLASS = REC(COL, NBAND);
            IF ICLASS > NCLASS THEN ICLASS = -2;
            IF ICLASS < -1 THEN NNT(-1) = NNT(-1) + 1;
            IF ICLASS ¬= -1 THEN DO;
                IF ICLASS <= -2 THEN ICLASS = 0;
```

```
            NNT(ICLASS) = NNT(ICLASS) + 1;
            DO J = 1 TO NBANDSTAT;
                T, TT(J) = REC(COL, BANDSTAT(J) );
                TTT(ICLASS, J) = TTT(ICLASS, J) + T;
                DO K = 1 TO J;
                    TTTT(ICLASS, J, K) =
                     TTTT(ICLASS, J, K) + T*TT(K);
                    END; /* K */
                END; /* J */
            END; /* ICLASS ¬= -1 */
END; /* COL, BSTAT */
IF BMAP THEN DO IOVP = 1 TO NOVP UNTIL(BDONE);
    IF IOVP = 1 THEN DO;
        ROWMAP = ROW;
        MAPLINE.CC = ' ';
        END;
    ELSE DO;
        STRING(ROWMAP) = '';
        MAPLINE.CC = '+';
        END;
    LOC = 0;
    BDONE = TRUE;
    DO IMAP = 1 TO NMAP;
        BANY = FALSE;
        DO J = 1 TO MIN(NCOLMAP, NCOLROW - LOC);
            I = REC(LOC + J, BANDMAP);
           IF I<-2 | I>NSYM THEN I = -2;
            MAPROW(J), CHAR = SYMBOL(IOVP, I);
           IF CHAR ¬= ' ' THEN BANY = TRUE;
            END; /* J */
        DO J = NCOLROW - LOC + 1 TO NCOLMAP;
            MAPROW(J) = ' ';
            END; /* J */
        IF IOVP=1 | BANY THEN
         WRITE FILE(MMAPOUT(IMAP) ) FROM(MAPLINE);
        IF BANY THEN BDONE = FALSE;
        LOC = LOC + NCOLMAP;
        END; /* IMAP */
    END; /* IOVP, BMAP */
IF BCOPY THEN DO;
    COL = 0;
    DO ICOL = 1 TO NCOLROWOUT BY NCOLOUT;
        LOCOUT = (ICOL - 1)*NBANDOUT;
        DO LOC = 0 TO MIN(LOCROUT - LOCOUT, LASTLOCOUT)
         BY NBANDOUT;
            COL = COL + 1;
            DO J = 1 TO NBANDCOPY;
                RECOUT(LOC + J) = REC(COL, BANDCOPY(J) );
                END;  /* J */
            END;  /* LOC */
        NRECOUT = NRECOUT + 1;
        IF BPRINTOUT THEN PUT EDIT('OUTPUT RECORD',NRECOUT,
         ( (RECOUT(LOC + BANDPROUT(J) )
         DO J = 1 TO NBANDPROUT)
         DO LOC = 0 TO LASTLOCOUT BY NBANDOUT) )
         (R(FMT_REC) );
        IF BOUT THEN WRITE FILE(OUTPUT) FROM(RECOUT);
        END;  /* ICOL */
    END; /* BCOPY */
ELSE IF BSINGLE THEN DO;
    NROWOUT = NROWOUT + 1;
    IF BPRINTOUT THEN PUT FILE(PRINTOUT) EDIT
     ('ROW', NROWOUT, '  PUNCH', '  COL')
     (COL(1), A, F(5), A, COL(1), A);
    DO COL = 1 TO NCOLROW;
        IF REC(COL, NBAND) ¬= -1. THEN DO;
            NRECOUT = NRECOUT + 1;
            IF BPRINTOUT THEN PUT FILE(PRINTOUT) EDIT(
             COL, (REC(COL, BANDPROUT(J) )
             DO J = 1 TO NBANDPROUT) )
             (COL(1), F(5), 9 (COL(11), 10 F(10,5) ) );
            IF BPUNCH THEN PUT FILE(PUNCH) EDIT(
             ( (REC(COL, BANDCOPY(J) ) )
             DO J = 1 TO NBANDCOPY) )
             (COL(1), 10 F(10,5) );
```

```
                  END; /* REC ¬= 1. */
               END; /* COL */
            END; /* BSINGLE */
         END; /* ROW */
      ROWDA = ROWDB + 1;
      IF ROWDB<ROWB THEN GO TO @LOOP_CARD;
      CALL NOTE(0, 'PROCESSING COMPLETED');
      GO TO @CLOSE;

/*/////////////////////////////////////////////////*/

NOTE:  PROC(LEVEL, MSG);
/*
      THIS SUBROUTINE PRINTS AN ERROR OR WARNING MESSAGE
      IT ALSO COUNTS THE NUMBER OF ERRORS AND WARNINGS.
*/

         DCL MSG        CHAR(*);
         DCL LEVEL      FIXED BIN;

FMT_ERR:  FORMAT(SKIP(2), 3 A, SKIP(1), A);
         IF LEVEL = 0 THEN PUT EDIT(MSG, '.', '', ' ') (R(FMT_ERR));
         ELSE IF LEVEL = 1 THEN PUT EDIT('* NOTE - ', MSG, '. *',
         ' ') (R(FMT_ERR) );
         ELSE IF LEVEL = 2 THEN DO;
            PUT EDIT('** WARNING - ', MSG, '. **', ' ')
             (R(FMT_ERR) );
            NWARN = NWARN + 1;
            IF NWARN > MWARN THEN GO TO @ABORT;
            END;
         ELSE IF LEVEL = 3 THEN DO;
            PUT EDIT('*** ERROR - ', MSG, '. ***', ' ')
             (R(FMT_ERR) );
            NERR = NERR + 1;
            IF NERR > MERR THEN GO TO @ABORT;
            END;
         END; /* NOTE */

/*/////////////////////////////////////////////////*/

@ABORT:
      CALL NOTE(0, 'EXECUTION TERMINATED DUE TO ERRORS');
      GO TO @STOP;

@CLOSE:
      IF BDISCRIM THEN DO;
         JCLASS = -1;
         DO J = 0 TO MCLASS;
            DO K = 0 TO NCLASS;
               NNNCLASS(-1, K) = NNNCLASS(-1, K) + NNNCLASS(J, K);
               NNNCLASS(J, -1) = NNNCLASS(J, -1) + NNNCLASS(J, K);
               END; /* K */
            NNNCLASS(-1, -1) = NNNCLASS(-1, -1) + NNNCLASS(J, -1);
            IF NNNCLASS(J, -1) > 0 THEN JCLASS = J;
            END; /* J */
         PUT EDIT('NUMBER OF PIXELS', 'OLD', 'NEW CLASS',
         '   CLASS    TOTAL    ERROR',(CCLASS(K) DO K = 1 TO NCLASS))
         (PAGE, COL(16), A, SKIP(2), A, COL(32), A, COL(1), A,
         9 (COL(25), 10 F(8) ) );
         PUT EDIT('     TOTAL', (NNNCLASS(-1, K) DO K = -1 TO NCLASS))
         (SKIP(2), A, 2 F(8), 9 (COL(25), 10 F(8) ) );
         PUT EDIT('     OTHER', (NNNCLASS(0, K) DO K = -1 TO NCLASS) )
         (SKIP(2), A, 2 F(8), 9 (COL(25), 10 F(8) ) );
         DO J = 1 TO JCLASS;
            PUT EDIT(J, (NNNCLASS(J, K) DO K = -1 TO NCLASS) )
             (SKIP(2), 3 F(8), 9 (COL(25), 10 F(8) ) );
            END; /* J */
         END; /* BDISCRIM */

      IF BPRINTSTAT THEN PUT EDIT('STATISTICS', NNT(-1), ' ERRORS')
       (PAGE, COL(17), A, SKIP(2), COL(12), F(8), A);
      IF BSTAT THEN DO ICLASS = 1 TO MCLASS;
         NT = NNT(ICLASS);
         IF NT > 0 THEN DO;
            NNT(0) = NNT(0) + NT;
```

```
                DO J = 1 TO NBANDSTAT;
                    TTT(0, J) = TTT(0, J) + TTT(ICLASS, J);
                    DO K = 1 TO NBANDSTAT;
                        TTTT(0,J,K) = TTTT(0,J,K) + TTTT(ICLASS,J,K);
                        END; /* K */
                    END; /* J */
                END; /* NT */
            END; /* ICLASS, BSTAT */
        IF BSTAT THEN DO ICLASS = 0 TO MCLASS;
            NT = NNT(ICLASS);
            IF ¬NT > 0 THEN IF NT < 5
              THEN DO;
                CALL NOTE(2, 'SMALL CLASS IGNORED');
                PUT EDIT('N =', NT)(COL(40), A, F(3) );
                END; /* NT < 5 */
              ELSE DO; /* NT >= 5 */
                DFM = NT;
                DFV, DFC = DFM - 1.;
                DO J = 1 TO NBANDSTAT;
                    T, TT(J) = TTT(ICLASS, J);
                    CCC(J, J) = (TTTT(ICLASS, J, J) - T*T/DFM)/DFV;
                    DO K = 1 TO J-1;
                        CCC(J,K), CCC(K,J) =
                        (TTTT(ICLASS, J, K) - T*TT(K)/DFM)/DFC;
                        END; /* K */
                    END; /* J */
                DO J = 1 TO NBANDSTAT;
                    TT(J) = TT(J)/DFM;
                    END; /* J */
                IF BPRINTSTAT THEN DO;
                    PUT EDIT('CLASS', ICLASS, '    COUNT', NT,
                     'BAND', (BANDSTAT(J) DO J = 1 TO NBANDSTAT) )
                     (SKIP(4), COL(11), A, F(3), A, F(8),
                     SKIP(2), A, 9 (COL(6), 10 F(10) ) );
                    PUT EDIT('MEANS', (TT(J) DO J = 1 TO NBANDSTAT) )
                     (COL(1), A, 9 (COL(11), 10 F(10, 5) ) );
                    PUT EDIT('COVARIANCE') (SKIP(2), A);
                    DO J = 1 TO NBANDSTAT;
                        PUT EDIT(BANDSTAT(J),
                         (CCC(J,K) DO K = 1 TO NBANDSTAT) )
                         (COL(4), F(3), 9 (COL(11), 10 F(10, 5) ) );
                        END; /* J */
                    END; /* BPRINTSTAT */
                IF BSTATOUT & ICLASS>0 THEN DO;
                    IF BPRINTOUT THEN PUT FILE(PRINTOUT) EDIT
                     ('PUNCH', ICLASS, NNT(ICLASS),
                     (TT(J) DO J = 1 TO NBANDSTAT) )
                     (COL(1), A, COL(1), COL(11), F(10), X(10), F(10),
                     9 (COL(11), 8 F(10,5) ) );
                    IF BPUNCH THEN PUT FILE(PUNCH) EDIT(
                     ICLASS, NNT(ICLASS),
                     (TT(J) DO J = 1 TO NBANDSTAT) )
                     (COL(1), F(10), X(10), F(10),
                     9 (COL(1), 8 F(10,5) ) );
                    DO J = 1 TO NBANDSTAT;
                        IF BPRINTOUT THEN PUT FILE(PRINTOUT) EDIT(
                         (CCC(J,K) DO K = 1 TO NBANDSTAT) )
                         (COL(11), 8 F(10,5) );
                        IF BPUNCH THEN PUT FILE(PUNCH) EDIT(
                         (CCC(J,K) DO K = 1 TO NBANDSTAT) )
                         (COL(1), 8 F(10,5) );
                        END; /* J */
                    END; /* BSTATOUT */
                END; /* NT>=5 */
            END; /* ICLASS, BSTAT */

BSTOP:
        PUT FILE(SYSPRINT) EDIT( (15) '-', 'COUNT', (15) '-')
         (PAGE, A, COL(10), A, COL(1), A);
        IF BMERGE THEN PUT FILE(SYSPRINT) EDIT(
         'INPUT1', NRECIN1, 'INPUT2', NRECIN2)
         (COL(1), A, COL(10), F(5,0) );
        ELSE PUT FILE(SYSPRINT) EDIT('INPUT', NRECIN1)
         (COL(1), A, COL(10), F(5,0) );
        PUT FILE(SYSPRINT) EDIT(
```

```
            'ROW', NROW, 'OUTPUT', NRECOUT, (15) '-')
            (COL(1), A, COL(10), F(5,0) );
           IF BIN THEN DO;
               IF BMERGE THEN CLOSE FILE(INPUT1), FILE(INPUT2);
               ELSE CLOSE FILE(INPUT1);
               CALL NOTE(0, 'FILES CLOSED');
               IF BOUT THEN CLOSE FILE(OUTPUT);
               IF BPUNCH THEN CLOSE FILE(PUNCH);
               END;
           ELSE CALL NOTE(1, 'NO INPUT DUE TO OPTION OR ERROR');

           PUT SKIP(2) EDIT(' STOP -', NERR, ' ERRORS.',
            NWARN, ' WARNINGS.') (A, F(5,0) );
           END; /* DELIN */
```

APPENDIX B

JOB CONTROL CARD LISTINGS FOR COMPUTER PROGRAMS

GRID JCL

```
/*MESSAGE FORM A001 = FORM 9001 WITH 8 LINES/INCH (CT88)
/*OUTPUT LIST D=LOCAL,F=A001
/*JOBPARM K=0
//   EXEC PLIXCG
//PLI.SYSIN DD *
" PLACE SOURCE DECK FOR GRID HERE  "
//GO.SYSPRINT DD SYSOUT=(A,,LIST)
//GO.SYSIN DD *
  560     5
//
```

GRID JCL DOCUMENTATION

Line 9 is a data card. The data on the card indicates the size of the grid to be printed. The total number of lines for the grid is punched in columns 1 through 5. The number of columns for the grid in units of 100 is punched in columns 6 through 10.

GODDARD JCL

```
/*MESSAGE * PLEASE MOUNT TAPE T120    *  NO  RING * THANK YOU
//GODDRD EXEC PGM=GODDRD,
// REGION=200K
//* TAPE1 IS THE INPUT TAPE. TAPE2, 3, 4 WILL BE FIXED UP FROM TAPE1
//*  ESTAPE IS THE OUTPUT TAPE
//STEPLIB DD DISP=SHR,DSN=OSU.ACT11236.LIB1
// DD DISP=SHR,DSN=SYS3.LINKLIB
//SYSPRINT DD SYSOUT=A
//TAPE1 DD DISP=(OLD,PASS),
// UNIT=TAPE,VOL=SER=T120,LABEL=1,DSN=JEFF.ARS.S1706.F16332
//TAPE2 DD DISP=(OLD,PASS),
// UNIT=AFF=TAPE1,VOL=REF=*.TAPE1,DSN=*.TAPE1,LABEL=2
//TAPE3 DD DISP=(OLD,PASS),
// UNIT=AFF=TAPE1,VOL=REF=*.TAPE1,DSN=*.TAPE1,LABEL=3
//TAPE4 DD DISP=(OLD,PASS),
// UNIT=AFF=TAPE1,VOL=REF=*.TAPE1,DSN=*.TAPE1,LABEL=4
//ESTAPE DD DISP=(NEW,KEEP),
// DCB=(RECFM=U,BLKSIZE=3200),
// SPACE=(3200,(1500,1500),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.GODDARD
//
//
```

GODDARD JCL DOCUMENTATION

The numbers and dataset names in parenthesis are variable.

Lines 9 and 10 describe the input tape (T120) and dataset (JEF.ARS. S1706.F16332) used for the program. The input tape and dataset is the original Landsat data on the CCT's as received from EROS at Sioux Falls, South Dakota.

Lines 17 through 20 describe the output dataset (JEF.S1706.GODDARD) and identify the disk (PACK13) used to store the dataset.

FRAME JCL

```
//FRAME EXEC PGM=FRAME,
// REGION=100K
//*
//*
//* SCRAT IS A SCRATCH FILE LARGE ENOUGH TO HOLD THE OHOLD THE OUTPUT
//* ERTSX IS THE INPUT FILE
//* FRAMEX IS THE OUTPUT FILE
//* DATRX IS THE DATA CARD FILE
//*  IN FOUR FIELDS OF 5, PLACE THE NUMBER OF THE FIRST LINE, NUMBER
//*  OF LINES, FIRST COLUMN NO., NUMBER OF COLUMNS, IN THAT ORDER.
//*  EACH SHOULD BE AN INTEGER, AND RIGHT JUSTIFIED IN ITS FIELD.
//*
//*
//*  NOTE: THIS FRAME PROGRAM WILL NOT CORRECTLY PROCESS IN ONE COMPUTER
//*        RUN A SUBSCENE WHICH OVERLAPS ANY ONE OF THE COLUMNS 810,
//*        1620, OR 2430. THESE COLUMNS ARE THE LEFTMOST COLUMN FOR
//*        FILES 2,3, AND 4 RESPECTIVELY  OF RAW DATA. TO CORRECTLY
//*        EXTRACT A SUBSCENE WHICH OVERLAPS COLUMNS 810, 1620, AND 2430
//*        THE FRAME PROGRAM MUST BE RUN SEPARATELY FOR EACH FILE
//*        ( 1, 2, 3, OR 4) WHICH CONTAINS A PART OF THE SUBSCENE.
//*        COLUMNS FOR FILE 1 (1-810), FILE 2 (811-1620), FILE 3 (1621-
//*        2430), FILE 4 (2431-3240).
//*  EXAMPLE: A SUBSCENE BOUNDARIES ARE: START AT LINE 200 FOR 400 LINES
//*        (200-600), START AT COLUMN 500 FOR 1000 COLUMNS ( 500-1000).
//*        THIS SUBSCENE OVERLAPS COLUMN 810 (BOUNDARY BETWEEN FILES 1
//*        AND 2). THE FRAME PROGRAM WOULD HAVE TO BE RUN FOR THAT
//*        PORTION OF THE SUBSCENE CONTAINED IN FILE 1 ( COLUMNS 500-
           810) ONLY, AND THEN AGAIN FOR THAT PART CONTAINED IN FILE 2
//*        ( COLUMNS 811-1500). A GREYSCALE WOULD BE PRINTED FOR EACH
//*        FRAME PROGRAM RUN AND THE PRINTOUTS SPLICED TOGETHER FOR A
//*        COMPLETE GREYSCALE OF THE ENTIRE SUBSCENE.
//*
//*
//STEPLIB DD DISP=SHR,DSN=OSU.ACT11236.LIB1
// DD DISP=SHR,DSN=SYS3.LINKLIB
//SYSPRINT DD SYSOUT=A
//SCRAT DD DISP=(NEW,PASS),
// DCB=(RECFM=U,BLKSIZE=3240),
// UNIT=3330-1,VOL=SER=PACK13,
// SPACE=(TRK,(100,100)),
// DSN=&&SCRAT
//ERTSX DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.GODDARD
//FRAMEX DD DISP=(NEW,KEEP),
// DCB=(RECFM=U,BLKSIZE=3200),
// SPACE=(3200,(885,885),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.FRAME1
//DATRX DD *
 IN FRMT (4)F(5,0) ENTER 1ST LINE NO., NO. OF LINES, 1ST COLUMN NO.,NO.
     1 1040 2431   300
//
//
```

FRAME JCL DOCUMENTATION

Numbers and dataset names in parenthesis are variable.

Lines 42 and 43 describe the input dataset (JEF.S1706.GODDARD) and identify the disk (PACK13) on which the dataset is stored. The input dataset is the output dataset of the GODDARD program.

Lines 44 through 47 describe the output dataset (JEF.S1706.FRAME1) and identify the disk (PACK13) used to store the dataset.

Line 50 is a data card used to identify the coordinates of that portion of the original scene to be isolated by the FRAME program. The description of the data on the card is the following:

Column	Data Description
1 to 5	Number of first line of subscene
6 to 10	Total number of lines in subscene
11 to 15	Number of first column of subscene
15 to 20	Total number of columns in subscene

GREYSCALE JCL

```
/*MESSAGE FORM A001 = 9001 WITH 8 LINES/INCH (CT88) THANK YOU
/*OUTPUT LIST D=LOCAL,F=A001
//*                                                                   100A=F K
//GREY EXEC PGM=GREY,REGION=85K
//* ERTSX IS THE INPUT FILE TO BE PRINTED
//* INXX IS THE DATA CARD FILE
//*  ENTER BOTTOM (DARKEST=0 ) DARKEST VALUES FOR EACH BAND ON THE
//*  THIRD DATA CARD.
//*  THEN ENTER TOP (BRIGHTEST=127 FOR BANDS 1,2,3 AND 63 FOR BAND 4 )
//*  VALUES ON FOURTH CARD.  EXAMPLE.
//*   12   14   08   05      THESE WOULD BE THE DARKEST VALUES
//*   50   45   86   58      THESE WOULD BE THE BRIGHTEST VALUES.
//*  BRIGHTNESS VALUES ARE OBTAINED FROM HISTOGRAM COMPUTED BY THE
//*  FRAME PROGRAM.
//*  ON FIFTH DATA CARD ENTER THE BANDS DESIRED, IN THE ORDER THAT
//*  YOU WANT THEM PRINTED.  EXAMPLES:
//*    1    2    3    4      THIS PRINTS ALL FOUR BANDS IN THAT ORDER
//*    0    2    0    4      THIS PRINTS THE 2ND AND 4TH BANDS.
//*    1    0    0    0      THIS PRINTS THE FIRST BAND ONLY.
//*  ALL DATA IS ENTERED IN FIELDS OF 5 COLUMNS, WITH NO DECIMAL POINT
//*  AND IS RIGHT JUSTIFIED.
//*  THE FIRST TWO DATA CARDS ARE SKIPED BY THE PROGRAM AND CAN CONTAIN
//*  ANYTHING, INCLUDING ALL BLANKS, BUT THEY MUST BE THERE IN FRONT
//*  OF THE ACTUAL DATA CARDS ( CARDS 3 THROUGH 5 ).
/*JOBPARM K=0  NO PAGING
//STEPLIB DD DISP=SHR,DSN=OSU.ACT11236.LIB1
// DD DISP=SHR,DSN=SYS3.LINKLIB
//SYSPRINT DD SYSOUT=(A,,LIST)
//ERTSX DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.FRAME1
//INXX DD *
CARD1-2 -- COMMENTS, CARD 3 -- DARKEST (SMALLEST) VALUES.
CARD 4 -- BRIGHTEST (LARGEST) VALUES TO BE PRINTED, CARD 5 SELECT BANDS.
    1   26    1    1
    9   54    9    9
    0    2    0    0
//
```

GREYSCALE JCL DOCUMENTATION

Number and datset names in parenthesis are variable.

Lines 29 and 30 describe the input dataset (JEF.S1706.FRAME1) and identify the disk (PACK13) on which the dataset is stored.

Lines 32 and 33 are the first and second of five data cards. No data is listed on these two cards. The cards may be left blank, but they must be included with the data cards.

Lines 34 and 35 are data cards which indicate the brightness values used by the program. The data on each of the cards is described as the following:

Card	Column	Data Description
34	1 to 5	Smallest brightness value for band one
	6 to 10	Smallest brightness value for band two
	11 to 15	Smallest brightness value for band three
	16 to 20	Smallest brightness value for band four
35	1 to 5	Largest brightness value for band one
	6 to 10	Largest brightness value for band two
	11 to 15	Largest brightness value for band three
	16 to 20	Largest brightness value for band four

Line 36 is the fifth and last data card. It indicates the bands for which a greyscale is to be printed. The number of the band desired is punched in the appropriate column. The indicated column is left blank if the band is not needed. The data on the card is described as the following:

Column	Data Description
5	The number 1 for a greyscale of band one
10	The number 2 for a greyscale of band two
15	The number 3 for a greyscale of band three
20	The number 4 for a greyscale of band four

All other columns on card 36 are left blank. Greyscales for more than one band are printed individually in order from left to right as punched on the card. The dark and light brightness values are obtained from an evaluation of the histogram produced by the FRAME program. A greyscale may be printed for any dataset except the GODDARD dataset and original data as received from EROS.

DELIN-merge JCL

```
/*OUTPUT LIST N=1
/*OUTPUT MAP   D=HOLD
//DELINO   EXEC PGM=LOADER,
// REGION=400K
//SYSLIB DD DISP=SHR,DSN=SYS1.PLIBASE
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,
// DSN=U11236A.AQUIFER1.OFLO.OBJECT(DELIN3M1)
//SYSPRINT DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=629)
//PRINT1 DD SYSOUT=(A,,LIST)
//PRINT2 DD SYSOUT=(A,,LIST)
//PRINT3 DD SYSOUT=(A,,LIST)
//MAPOUT1 DD SYSOUT=(A,,MAP)
//MAPOUT2 DD SYSOUT=(A,,MAP)
//MAPOUT3 DD SYSOUT=(A,,MAP)
//PUNCH DD SYSOUT=B
PRINTHEAD
HEADIN1
HEADIN2
HEADOUT
INPUT         3200            4
MERGE         3200                    0
COPY          3200
//INPUT1 DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.FRAME1
//INPUT2 DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.FRAME2
//OUTPUT DD DISP=(NEW,KEEP),
// DCB=(RECFM=U,BLKSIZE=3200),
// SPACE=(3200,(885,885),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.FRAME12
//
```

DELIN-merge JCL DOCUMENTATION

The numbers and dataset names in parenthesis are variable.

Lines 24 through 27 describe the two input datasets (JEF.S1706.FRAME1 and JEF.S1706.FRAME2) and identify the disk (PACK13) on which they are stored. The input datasets are the output datasets of separate runs of the FRAME program.

Lines 28 through 31 describe the output dataset (JEF.S1706.FRAME12) and identify the disk (PACK13) used to store the dataset.

SMOOTH JCL

```
//SMOOTH EXEC PGM=SMOOTH,     REDUCE BANDING
// REGION=200K
//* XIN IS THE INPUT FILE
//* XOUT IS THE OUTPUT FILE
//* NO SYSIN OR DATA CARDS ARE NEEDED
//STEPLIB DD DISP=SHR,DSN=OSU.ACT11236.LIB1
// DD DISP=SHR,DSN=SYS3.LINKLIB
//SYSPRINT DD SYSOUT=A
//XIN DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.MERGE14.NOT.SMOOTH
//XOUT DD DISP=(NEW,KEEP),
// DCB=(RECFM=U,BLKSIZE=3200),
// SPACE=(3200,(2000,2000),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.MERGE14.SMOOTH
//
```

SMOOTH JCL DOCUMENTATION

Numbers and dataset names in parenthesis are variable.

Lines 9 and 10 describe the input dataset (JEF.S1706.MERGE14.NOT. SMOOTH) and identify the disk (PACK13) on which it is stored. The input dataset is the output dataset of the DELIN-merge program. The input dataset can be any dataset except the GODDARD dataset and original data as received from EROS.

Lines 11 through 14 describe the output dataset (JEF.S1706.MERGE14. SMOOTH) and identify the disk (PACK13) on which it is stored.

DELIN-subscene JCL

```
/*OUTPUT MAP   N=1
/*OUTPUT LIST N=1
//DELINO   EXEC PGM=LOADER,
// REGION=400K
/*JOBPARM K=0
//SYSLIB DD DISP=SHR,DSN=SYS1.PLIBASE
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,
// DSN=U11236A.AQUIFER1.OFLO.OBJECT(DELIN3M1)
//SYSPRINT DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=629)
//PRINT1 DD SYSOUT=(A,,LIST)
//PRINT2 DD SYSOUT=(A,,LIST)
//PRINT3 DD SYSOUT=(A,,LIST)
//MAPOUT1 DD SYSOUT=(A,,MAP)
//MAPOUT2 DD SYSOUT=(A,,MAP)
//MAPOUT3 DD SYSOUT=(A,,MAP)
//MAPOUT4 DD SYSOUT=(A,,MAP)
//INPUT DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.MERGE14.SMOOTH
//OUTPUT DD DISP=(NEW,KEEP),
// DCB=(RECFM=U,BLKSIZE=3200),
// SPACE=(3200,(570,570),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.TONKAWA
INPUT         3200          4
PRINTHEAD
HEADIN1
HEADOUT
COPY          3200
WINDOW           1   550 1600   500
//
```

DELIN-subscene JCL DOCUMENTATION

Numbers and dataset names in parenthesis are variable.

Lines 18 and 19 describe the input dataset (JEF.S1706.MERGE14.SMOOTH) and identify the disk (PACK13) on which the dataset is stored. The input dataset can be any dataset except the GODDARD dataset and original data as received from EROS.

Lines 20 through 23 describe the output dataset (JEF.S1706.TONKAWA) and identify the disk (PACK13) on which the dataset is stored.

Line 29 defines the boundaries of the subscene to be copied from the input dataset. The data is described as follows:

Column	Data Description
11 to 15	Number of first line to be copied from input
16 to 20	Total number of lines to be copied
21 to 25	Number of first column to be copied from input
26 to 30	Total number of columns to be copied

REGISTER JCL

```
//REGSTR EXEC PGM=LOADER,
// REGION=200K
//* VECTOR IS A FILE TO STORE THE INPUT POINT DATA (CAN BE TEMP)
//* VEC IS THE COEFFICIENT FILE USED BY TRNSFM
//* DATA CARDS ARE READ ON SYSIN (NO DD CARD NEEDED)
//*
//SYSLIB DD DISP=SHR,DSN=SYS1.PLIBASE
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,
// UNIT=3330-1,VOL=SER=PACK13,DSN=LANDSAT.CARD(REGSTR)
//SYSPRINT DD SYSOUT=A
//VECTOR DD DISP=(NEW,PASS),
// DCB=(RECFM=FB,LRECL=32,BLKSIZE=3200),
// SPACE=(TRK,(5,5),RLSE),
// UNIT=SYSDA,DSN=&&VECTOR
//VEC DD DISP=(NEW,KEEP),
// DCB=(RECFM=FB,LRECL=176,BLKSIZE=4224),
// SPACE=(TRK,(5,5),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.GEOREF.VEC.COEF
YES 17
366.9      1819.4     77.2       185        2,6
344.6      1976.5     77.5       343        2,12
605.5      2042.2     351.1      317.3      15,11
643.5      1777.2     350.2      53.7       15,1
386.7      1826.6     98.3       185        3,6
364.5      1983.6     98.5       343        3,12
625.4      2049.1     372.2      317.6      16,11
639.6      1803.6     350.2      80         15,2
501.0      1755.6     203        79.9       8,2
348.2      1951.1     77.7       316.3      2,11
602.0      2068.2     351.2      343.6      15,12
624.5      1909.8     350.8      185.7      15,6
504.6      1729.2     203        53.5       8,1
368.2      1957.6     98.7       316.6      3,11
621.6      2075.4     372.2      343.8      16,12
644.3      1916.6     371.9      185.7      16,6
344        1832.2     55.5       204.5
2 4 3  4
NO 1 3 4  4
//
```

REGISTER JCL DOCUMENTATION

Numbers and dataset names in parenthesis are variable.

Lines 16 through 19 describe the output dataset (JEF.GEORF.VEC.COEF) and identify the disk on which the dataset is stored. The output dataset contains the geometric correction constants to be used by the TRANSFORMATION program.

Line 20 is a data card. Punch "YES" in columns 1 through 3. Punch the number of points to processed by the program in columns 5 and 6.

Lines 21 through 37 are data cards. On these cards are punched the old coordinates of the reference points as obtained from the greyscale print of ungeometrically corrected subscene and the corresponding coordinates of the same reference points on a topographic map. The data on the cards is described as the following:

Column	Data Description
1 to 9	Greyscale line number of reference point
10 to 19	Greyscale column number of reference point
20 to 29	Topographic map line number of corresponding reference point used for columns 1 to 19
30 to 39	Tograhpic map column number of corresponding reference point used for columns 1 to 19
40 ...	Remaining columns on data card may be used for comments

Line 38 is a data card. Punch the same numbers in columns 1, 3, 5, and 8.

Line 39 is a data card. Punch "NO" in columns 1 and 2. Punch the same numbers in columns 4, 6, 8, and 11.

TRANSFORMATION JCL

```
//TRANSFM EXEC PGM=TRANSFM,
// REGION=200K
//* HOLD IS A TEMPORARY FILE TO HOLD THE INPUT (DIRECT ACCESS)
//* COEF IS THE COEFFICIENT FILE FROM PROGRAM REGSTR
//* ERTS IS THE INPUT SCENE FILE (USUALLY OUTPUT FROM SMOOTH)
//* ERTS2 IS THE OUTPUT SUBSCENE (GEOREFFED)
//* DATX IS THE CONTROL CARD FILE
//STEPLIB DD DISP=SHR,DSN=OSU.ACT11236.LIB1
// DD DISP=SHR,DSN=SYS3.LINKLIB
//SYSPRINT DD SYSOUT=A
//HOLD DD DISP=(NEW,PASS),                  TEMPORARY FILE
// DCB=(RECFM=FB,LRECL=6400,BLKSIZE=12800),
// SPACE=(TRK,(530,530),RLSE),
// UNIT=SYSDA,DSN=&&HOLD
//COEF DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.GEOREF.VEC.COEF
//ERTS DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.TONKAWA
//ERTS2 DD DISP=(NEW,KEEP),
// DCB=(RECFM=U,BLKSIZE=3200),
// SPACE=(TRK,(580,580),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.TONKAWA.GEOREF
//DATX DD *                                 DATA CARDS (ROWS, COLS)
 ENTER FIRST ROW, LAST ROW, FIRST COL, LAST COL
     1  560     1  500
//
```

TRANSFORMATION JCL DOCUMENTATION

Numbers and dataset names are variable.

Lines 15 and 16 describe one of two input datasets (JEF.GEOREF.VEC.COEF) used for input and identify the disk (PACK13) on which the dataset is stored. This dataset is the output dataset of the REGISTER program and contains the geometric correction constants which are used by the TRANSFORMATION program.

Lines 17 and 18 describe the second input dataset (JEF.S1706.TONKAWA) and identify the disk (PACK13) on which the dataset is stored. This dataset is the output dataset of the DELIN-subscene program. However, any dataset created by FRAME or any subsequent program may be used except datasets in the original or GODDARD format.

Lines 19 through 22 describe the output dataset (JEF.S1706.TONKAWA.GEOREF) and identify the disk on which the dataset is stored.

Line 25 is a data card. The data on this card defines the size of the geometrically corrected subscene. The data is described as follows:

Column	Data Description
1 to 5	First line number of corrected subscene
6 to 10	Total number of lines for corrected subscene
11 to 15	First column number of corrected subscene
16 to 20	Total number of columns for corrected subscene

Note: The corrected subscene does not retain the original line and column numbers of the ungeometrically corrected subscene used for input. If the size defined in line 25 for the geometrically corrected subscene is larger than the size of the uncorrected subscene, the excess area of the corrected subscene will be filled with some repeated portion of the corrected subscene. The repeated portion can be easily detected on a greyscale print of the corrected subscene.

DELIN-classification-first phase JCL

```
/*OUTPUT MAP   N=1
/*OUTPUT LIST N=1
//DELINO   EXEC PGM=LOADER,
// REGION=400K
/*JOBPARM K=0
//SYSLIB DD DISP=SHR,DSN=SYS1.PLIBASE
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,
// DSN=U11236A.AQUIFER1.OFLO.OBJECT(DELIN3M1)
//SYSPRINT DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=629)
//PRINT1 DD SYSOUT=(A,,LIST)
//PRINT2 DD SYSOUT=(A,,LIST)
//PRINT3 DD SYSOUT=(A,,LIST)
//MAPOUT1 DD SYSOUT=(A,,MAP)
//MAPOUT2 DD SYSOUT=(A,,MAP)
//MAPOUT3 DD SYSOUT=(A,,MAP)
//MAPOUT4 DD SYSOUT=(A,,MAP)
//INPUT DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.TONKAWA.GEOREF
//OUTPUT DD DISP=(NEW,KEEP),
// DCB=(RECFM=U,BLKSIZE=3200),
// SPACE=(3200,(1500,1500),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.TONKAWA.TRAIN.SOIL
//PUNCH DD DISP=(NEW,KEEP),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=2480),
// SPACE=(TRK,(1,1)),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.STAT.S1706.SOIL
STATOUT
STAT             4     1     2     3     4
PRINTSTAT
HEADIN1
HEADOUT
INPUT        3200              4
ADD
COPY         3200
NOLIST
WINDOW           50   460    50   400
MAP               0     0     0    17
             R$ 123456789ABCDEFGH
PATTERN
// DD DISP=SHR,
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.SOIL.TRAINING.SET.DATA
//
```

DELIN-classification-first phase

JCL DOCUMENTATION

Numbers and dataset names in parenthesis are variable.

Lines 18 and 19 describe one of the two input datasets (JEF.S1706. TONKAWA.GEOREF) and identify the disk (PACK13) on which the datset is stored. This input dataset is the output dataset of the TRANSFORMATION program.

Lines 20 through 23 describe one of the output datasets (JEF.S1706. TONKAWA.TRAIN.SOIL) and identify the disk (PACK13) on which it is stored.

Lines 24 through 27 describe the second output dataset (JEF.STAT.S1706. SOIL) and identify the disk (PACK13) on which the dataset is stored. This dataset contains the statistics calculated by the program.

Line 29 is an option card. This card indicates the number of bands of digital data which are to be used to calculate the statistics and identifies which bands are to be used. The data is described as follows:

Column	Data Description
15	Number of bands used
20	Punch number 1 if band one is to be used, if not, leave blank
25	Punch number 2 if band two is to be used, if not, leave blank
30	Punch number 3 if band three is to be used, if not, leave blank
35	Punch number 4 if band four is to be used, if not, leave blank

Line 37 is an option card. This card defines the size and boundaries of the subscene to be processed. The data is described as follows:

Column	Data Description
11 to 15	First line of subscene
16 to 20	Total number of lines in subscene
21 to 25	First column of subscene
26 to 30	Total number of columns in subscene

Line 38 is an option card. This card indicates the total number of classes used for the program. The number of classes are punched in columns 26 through 30. The remainder of the card is punched as shown.

Line 39 is an option card. This card indicates the symbols used for printing a map of the classes. The choice of the symbols is optional and is left to the programer. The data is described as follows:

Column	Data Description
8	Symbol for error on map
9	Symbol for map boundary
10	Symbol for areas not used as training sets
11 to 40	Symbols used to denote classes

Lines 41 and 42 describe the second input dataset (JEF.S1706.SOIL. TRAINING.SET.DATA) and identify the disk (PACK13) on which the dataset is stored. This dataset contains the training set data appropriate for the program.

DELIN-classification-second phase JCL

```
/*OUTPUT MAP   N=1
/*OUTPUT LIST N=1
//DELINO   EXEC PGM=LOADER,
// REGION=400K
/*JOBPARM K=0
//SYSLIB DD DISP=SHR,DSN=SYS1.PLIBASE
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,
// DSN=U11236A.AQUIFER1.OFLO.OBJECT(DELIN3M1)
//SYSPRINT DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=629)
//PRINT1 DD SYSOUT=(A,,LIST)
//PRINT2 DD SYSOUT=(A,,LIST)
//PRINT3 DD SYSOUT=(A,,LIST)
//MAPOUT1 DD SYSOUT=(A,,MAP)
//MAPOUT2 DD SYSOUT=(A,,MAP)
//MAPOUT3 DD SYSOUT=(A,,MAP)
//MAPOUT4 DD SYSOUT=(A,,MAP)
//INPUT DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.TONKAWA.TRAIN.SOIL
//OUTPUT DD DISP=(NEW,KEEP),
// DCB=(RECFM=U,BLKSIZE=3200),,
// SPACE=(3200,(1500,1500),RLSE),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.S1706.TONKAWA.CLASS.SOIL
//STATIN DD DISP=(OLD,PASS),
// UNIT=3330-1,VOL=SER=PACK13,DSN=JEF.STAT.S1706.SOIL
STAT            4    1    2    3    4
PRINTSTAT
HEADIN1
HEADOUT
INPUT        3200          5
COPY         3200
DISCRIM        14
NOLIST
WINDOW         50   460   50   400
MAP             0     0    0    17
             R$ 123456789ABCDEFGH
//
//
```

DELIN-classification-second phase

JCL DOCUMENTATION

Numbers and dataset names in parenthesis are variable.

Lines 18 and 19 describe one of two input datasets (JEF.S1706.TONKAWA.TRAIN.SOIL) and identify the disk (PACK13) on which the dataset is stored. This input dataset in one of the output datasets of DELIN-classification-first phase.

Lines 20 through 23 describe the output dataset (JEF.S1706.TONKAWA.CLASS.SOIL) and identify the disk (PACK13) on which the dataset is stored.

Lines 24 and 25 describe the second input dataset (JEF.STAT.S1706.SOIL) and identify the disk (PACK13) on which the dataset is stored. This input dataset is one of the output datasets of DELIN-classification-first phase.

Line 26 is an option card. This card is a duplicate of line 29 of DELIN-classification-first phase.

Line 32 is an option card. This card indicates the number of classes to be discriminated. The number is punched in columns 11 through 15.

Line 34 is an option card and is a duplicate of line 37 of DELIN-classification-first phase.

Line 35 is an option card and is a duplicate of line 38 of DELIN-classification-first phase.

Line 36 is an option card. The data description for this card is the same as that for line 39 of DELIN-classification-first phase.

APPENDIX C

RESULTS OF THE CLASSIFICATION TREATMENTS

TABLE XIII

RESULTS OF THE JUNE-SOIL-ALL BAND (4,5,6, AND 7) CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,698	4,023	NA**	4,050	3,459	764	5,614	5,840	1,087	6,986	2,738	3,700	5,510	3,854	10,527	11,541	NA**	NA**
Within Training Sets																		
1*	2,309	438		52	330	16	33	83	3	128	42	37	87	121	543	396		
2	NA**																	
3	98	2		54	2	0	1	1	1	6	4	6	11	1	5	4		
4	656	95		0	370	24	2	2	4	20	3	25	13	20	54	24		
5	66	0		0	1	55	0	3	0	0	3	0	0	0	4	0		
6	398	5		0	2	0	251	103	0	4	4	1	2	3	8	15		
7	812	4		9	2	0	198	468	0	26	23	5	3	7	34	33		
8	29	0		1	0	0	0	0	21	1	0	6	0	0	0	0		
9	93	5		17	1	0	2	6	2	25	5	2	4	6	10	8		
A	116	3		6	0	0	0	20	0	3	52	5	14	2	4	7		
B	21	1		1	0	0	0	0	1	1	0	15	0	1	1	0		
C	1,668	81		264	51	34	1	6	21	190	141	78	666	30	59	46		
D	1,512	85		44	44	2	14	179	62	160	51	109	17	86	335	324		
E	824	60		22	43	6	7	97	17	75	28	51	21	42	246	109		
F	173	8		3	3	0	31	20	0	10	5	5	3	7	29	49		
G	NA**																	
H	NA**																	

*See Tables I and III for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XIV

RESULTS OF THE JUNE-IR-ALL BAND (4,5,6, AND 7) CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,708	NA**	7,582	4,108	2,621	783	6,860	6,787	1,088	8,151	3,088	3,724	5,549	6,426	12,941	NA**	NA**	NA**
Within Training Sets																		
1*	NA**																	
2	448		184	11	53	3	8	19	0	33	5	3	12	24	93			
3	98		0	54	2	0	1	1	1	7	4	6	13	2	7			
4	656		167	0	323	24	3	5	4	20	3	25	16	24	42			
5	66		0	0	1	55	0	3	0	0	3	0	0	0	4			
6	398		6	0	1	0	257	105	0	4	4	1	2	5	13			
7	812		14	9	2	0	203	472	0	30	23	5	3	13	38			
8	29		0	1	0	0	0	0	21	1	0	6	0	0	0			
9	93		14	15	0	0	2	6	2	28	5	2	2	7	10			
A	116		3	6	0	0	2	21	0	3	52	5	14	3	7			
B	21		2	1	0	0	0	0	1	0	0	15	0	1	1			
C	1,663		115	265	50	35	4	8	21	190	143	78	657	36	61			
D	1,512		211	43	22	2	38	200	62	180	56	110	19	170	399			
E	824		150	20	26	7	14	101	17	73	30	51	17	69	249			
F	NA**																	
G	NA**																	
H	NA**																	

*See Tables I and III for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification.

TABLE XV

RESULTS OF THE MARCH-SOIL-ALL BAND (4,5,6, AND 7) CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,702	1,062	NA**	3,950	4,257	278	4,044	3,325	2,842	2,575	3,277	3,129	850	8,774	5,743	11,236	4,260	10,100
Within Training Sets																		
1*	2,292	93		35	136	8	19	47	70	31	88	141	4	493	184	525	90	328
2	NA**																	
3	95	0		32	0	0	3	10	0	8	9	2	2	1	1	8	6	13
4	651	5		0	532	3	1	1	4	0	2	6	1	44	29	12	3	8
5	61	0		0	0	54	0	0	0	0	3	4	0	0	0	0	0	0
6	397	2		1	0	0	291	58	2	4	14	1	1	0	0	14	9	0
7	804	2		23	4	0	399	184	9	22	14	2	15	12	17	42	47	12
8	46	0		2	0	0	1	0	7	1	5	6	1	1	0	9	7	6
9	236	0		32	0	1	9	17	20	49	19	1	3	3	0	17	54	11
A	348	1		7	0	10	13	1	6	2	195	37	2	7	5	20	9	34
B	110	1		1	0	2	0	0	2	0	31	16	0	11	3	19	0	23
C	1,952	27		366	7	1	121	180	79	272	103	47	127	40	35	115	258	174
D	1,385	11		16	113	0	0	1	37	6	9	54	19	392	205	190	24	308
E	961	8		4	68	0	0	2	28	3	10	82	3	167	220	184	7	175
F	172	1		3	8	0	4	12	7	1	14	8	0	21	14	49	9	21
G	63	0		4	0	0	4	2	6	3	4	0	0	1	0	7	32	0
H	18	0		0	0	0	0	0	0	0	0	1	1	1	0	1	0	14

*See Tables II and IV for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does apply to this classification treatment.

TABLE XVI

RESULTS OF THE MARCH-IR-ALL BAND (4,5,6, AND 7) CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,702	NA**	966	547	4,250	266	4,068	3,963	6,316	4,015	4,254	4,099	1,898	10,890	8,156	NA**	4,820	11,194
Within Training Sets																		
1*	NA**																	
2	442		15	1	29	3	4	3	33	9	33	47	1	128	54		17	65
3	95		0	5	0	0	3	8	6	20	14	2	13	2	1		6	15
4	651		5	5	530	1	1	1	4	0	2	8	1	48	34		3	8
5	61		0	0	0	54	0	0	0	0	3	4	0	0	0		0	0
6	397		1	0	0	0	291	59	10	4	15	1	1	3	1		11	0
7	804		0	1	4	0	402	198	35	29	19	3	16	14	19		49	15
8	46		0	0	0	0	1	2	11	1	5	6	1	4	1		8	6
9	236		1	6	0	1	9	19	30	60	20	2	10	4	1		59	14
A	348		2	0	0	10	13	1	12	2	205	39	5	7	6		9	37
B	110		1	0	0	2	0	0	3	0	33	22	2	17	5		0	25
C	1,976		30	8	7	1	122	208	149	442	127	51	247	52	45		299	188
D	1,382		11	0	113	0	0	5	67	6	12	74	33	450	255		25	331
E	961		8	1	71	0	0	2	56	3	16	100	3	214	278		7	202
F	NA**																	
G	63		0	0	0	0	4	3	11	3	5	0	1	2	1		33	0
H	18		0	0	0	0	0	0	0	0	0	1	1	1	1		0	14

*See Tables II and IV for Identification of Ground Cover Classes and Training Sets

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XVII

RESULTS OF THE JUNE-IR-BANDS FOUR AND FIVE CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	68,262	NA**	3,386	4,358	5,047	418	6,747	6,373	4,835	10,629	2,079	4,010	4,616	1,224	14,540	NA**	NA**	NA**
Within Training Sets																		
1*	NA**																	
2	449		52	5	130	0	11	10	31	44	5	10	14	10	127			
3	98		1	53	3	0	1	0	0	12	2	11	10	0	5			
4	656		70	2	418	0	2	5	15	18	0	10	23	6	87			
5	66		1	0	1	5	32	8	11	1	2	0	1	0	4			
6	398		1	0	4	14	284	59	11	7	5	0	1	2	10			
7	812		3	4	1	8	321	334	19	45	32	10	1	2	32			
8	29		0	1	1	1	1	0	20	0	0	4	0	0	1			
9	93		6	9	0	1	7	2	6	25	3	11	2	2	19			
A	116		3	6	0	0	0	23	1	11	36	5	28	0	3			
B	21		2	3	4	0	0	0	2	0	0	7	2	0	1			
C	1,663		82	256	86	0	5	38	10	146	146	258	538	4	94			
D	1,510		83	28	113	2	40	156	128	330	30	80	36	35	449			
E	824		62	12	82	1	26	76	45	158	8	35	29	22	268			
F	NA**																	
G	NA**																	
H	NA**																	

*See Tables I and III for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XVIII

RESULTS OF THE MARCH-IR-BANDS FOUR AND FIVE CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class 1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,702	NA**	1,225	396	5,418	544	5,694	49	3,977	7,641	5,743	802	0	12,410	2,243	NA**	7,952	15,608
Within Training Set																		
1*	NA**																	
2	442		23	7	33	2	6	0	38	36	11	1	0	136	2		63	84
3	95		1	2	0	1	9	0	4	20	30	0	0	3	0		9	16
4	651		17	0	479	0	0	0	5	2	1	0	0	78	44		7	18
5	61		0	0	0	32	17	3	2	3	0	0	0	0	0		4	0
6	397		0	2	0	42	281	6	3	28	18	0	0	0	0		16	1
7	804		2	2	10	83	421	21	11	98	70	1	0	10	14		43	18
8	46		1	1	0	0	2	0	4	6	5	0	0	6	0		12	9
9	236		1	0	0	4	51	0	15	45	29	0	0	3	0		75	13
A	348		15	4	0	1	94	8	11	41	92	6	0	10	1		19	46
B	110		2	2	1	0	22	0	3	0	14	4	0	25	0		3	34
C	1,976		65	3	15	13	306	1	104	472	344	36	0	77	39		253	248
D	1,382		19	2	187	0	0	0	46	26	23	19	0	465	64		37	494
E	961		19	1	113	0	0	0	55	10	18	39	0	266	98		40	302
F	NA**																	
G	63		1	0	0	1	9	0	4	13	5	0	0	5	0		24	1
H	18		0	0	0	0	0	0	1	0	1	0	0	1	2		0	13

*See Tables II and IV for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XIX

RESULTS OF THE JUNE-SOIL-BAND FOUR CLASSIFICATION TREATMENT

		Number of Pixels Assigned to Each Ground Cover Class																
Number of Pixels	Total Pixels	1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	68,263	0	NA**	0	5,208	3	3,594	7,310	14,517	0	393	14,202	2,443	12,607	7,986	0	NA**	NA**
Within Training Area																		
1*	2,328	0		0	266	0	6	78	427	0	43	587	111	466	344	0		
2	NA**																	
3	98	0		0	11	0	0	3	8	0	2	32	3	21	18	0		
4	656	0		0	167	0	0	3	17	0	11	258	79	34	87	0		
5	66	0		0	0	1	24	19	15	0	2	0	1	0	4	0		
6	398	0		0	2	0	239	113	30	0	1	4	2	5	2	0		
7	812	0		0	1	0	278	381	86	0	0	34	0	19	13	0		
8	29	0		0	3	0	0	8	11	0	0	1	0	3	3	0		
9	93	0		0	2	0	3	6	15	0	0	26	0	22	19	0		
A	116	0		0	17	0	3	41	10	0	7	10	17	7	4	0		
B	21	0		0	4	0	0	0	0	0	0	12	0	3	2	0		
C	1,668	0		0	370	0	8	59	80	0	45	552	340	114	100	0		
D	1,510	0		0	57	0	3	75	425	0	1	332	18	404	195	0		
E	824	0		0	48	0	2	46	186	0	0	226	6	197	113	0		
F	173	0		0	9	0	23	19	47	0	0	20	1	35	19	0		
G	NA**																	
H	NA**																	

*See Tables I and III for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XX

RESULTS OF THE MARCH-SOIL-BAND FOUR CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,702	212	NA**	0	6,625	417	9,010	0	0	10,345	0	0	0	8,399	106	0	11,071	23,517
Within Training Sets																		
1*	2,292	22		0	195	5	60	0	0	201	0	0	0	407	7	0	330	1,065
2	NA**																	
3	95	0		0	0	0	35	0	0	30	0	0	0	2	0	0	11	17
4	651	3		0	509	0	0	0	0	4	0	0	0	87	2	0	10	36
5	61	0		0	0	19	29	0	0	6	0	0	0	0	0	0	4	3
6	397	0		0	0	60	272	0	0	44	0	0	0	0	0	0	14	7
7	804	0		0	19	115	475	0	0	123	0	0	0	12	1	0	37	22
8	46	0		0	0	2	5	0	0	9	0	0	0	0	0	0	9	21
9	236	0		0	0	4	60	0	0	65	0	0	0	1	0	0	85	21
A	348	0		0	1	24	161	0	0	53	0	0	0	4	0	0	56	49
B	110	1		0	3	2	27	0	0	5	0	0	0	6	0	0	22	44
C	1,952	2		0	61	4	521	0	0	641	0	0	0	54	0	0	370	299
D	1,385	0		0	202	0	1	0	0	29	0	0	0	354	6	0	105	688
E	961	0		0	205	0	0	0	0	14	0	0	0	187	1	0	100	454
F	172	0		0	10	0	19	0	0	33	0	0	0	21	1	0	33	55
G	63	0		0	0	0	11	0	0	19	0	0	0	0	0	0	15	18
H	18	0		0	2	0	0	0	0	0	0	0	0	0	0	0	3	13

*See Tables II and IV for the Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XXI

RESULTS OF THE JUNE-IR-BAND FIVE CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	68,262	NA**	0	9,261	14,344	3	5,355	14,932	0	0	300	0	3,691	1,945	18,431	NA**	NA**	NA**
Within Training Sets																		
1*	NA**																	
2	449		0	82	146	0	4	64	0	0	0	0	6	11	136			
3	98		0	47	17	0	0	1	0	0	0	0	19	0	14			
4	656		0	98	259	0	0	30	0	0	0	0	22	8	239			
5	66		0	0	0	0	42	13	0	0	0	0	3	2	6			
6	398		0	3	3	1	301	70	0	0	1	0	1	2	16			
7	812		0	16	35	0	338	340	0	0	0	0	1	15	67			
8	29		0	1	0	0	16	8	0	0	0	0	3	1	0			
9	93		0	20	35	0	8	10	0	0	0	0	0	1	19			
A	116		0	17	11	0	0	23	0	0	10	0	23	6	26			
B	21		0	5	2	0	0	3	0	0	0	0	6	0	5			
C	1,663		0	625	306	0	2	56	0	0	60	0	480	5	129			
D	1,510		0	61	363	0	8	388	0	0	3	0	43	60	584			
E	824		0	73	207	0	5	177	0	0	0	0	9	22	331			
F	NA**		0															
G	NA**		0															
H	NA**		0															

*See Tables I and III for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover class or Training Set which does not apply to this classification treatment.

TABLE XXII

RESULTS OF THE MARCH-IR-BAND FIVE CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,702	NA**	11,212	0	8,098	265	6,284	0	4,329	6,697	0	195	0	0	0	NA**	10,827	21,795
Within Training Sets																		
1*	NA**																	
2	442		123	0	17	0	9	0	37	18	0	1	0	0	0		77	160
3	95		12	0	1	0	11	0	2	25	0	0	0	0	0		29	15
4	651		21	0	355	0	0	0	3	2	0	4	0	0	0		7	259
5	61		2	0	0	37	16	0	1	2	0	0	0	0	0		3	0
6	397		5	0	0	42	294	0	2	31	0	0	0	0	0		23	0
7	804		16	0	20	95	446	0	9	111	0	0	0	0	0		84	23
8	46		10	0	0	0	4	0	6	5	0	0	0	0	0		14	8
9	236		13	0	0	0	58	0	25	38	0	0	0	0	0		95	7
A	348		31	0	13	11	98	0	20	83	0	0	0	0	0		39	53
B	110		29	0	0	0	25	0	4	5	0	4	0	0	0		2	41
C	1,976		193	0	107	0	332	0	134	399	0	11	0	0	0		537	263
D	1,382		218	0	261	0	0	0	29	0	0	6	0	0	0		58	810
E	961		216	0	294	0	0	0	35	4	0	5	0	0	0		35	372
F	NA**																	
G	63		12	0	0	0	10	0	6	13	0	0	0	0	0		22	0
H	18		1	0	2	0	0	0	0	0	0	0	0	0	0		0	15

*See Tables II and IV for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XXIII

RESULTS OF THE JUNE-SOIL-BAND SEVEN CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	68,263	0	NA**	6,891	0	1,679	0	15,401	1,227	0	0	10,856	812	0	0	31,397	NA**	NA**
Within Training Sets																		
1*	2,328	0		118	0	21	0	563	24	0	0	195	16	0	0	1,391		
2	NA**																	
3	98	0		36	0	1	0	29	0	0	0	6	2	0	0	24		
4	656	0		64	0	36	0	115	6	0	0	133	2	0	0	300		
5	66	0		4	0	54	0	4	1	0	0	2	1	0	0	0		
6	398	0		28	0	0	0	104	0	0	0	70	1	0	0	195		
7	812	0		194	0	0	0	337	0	0	0	30	5	0	0	246		
8	29	0		0	0	0	0	0	24	0	0	1	0	0	0	4		
9	93	0		10	0	0	0	30	6	0	0	13	0	0	0	34		
A	116	0		19	0	12	0	21	4	0	0	25	0	0	0	35		
B	21	0		0	0	0	0	1	5	0	0	7	0	0	0	8		
C	1,668	0		334	0	121	0	400	48	0	0	263	36	0	0	466		
D	1,510	0		66	0	1	0	421	66	0	0	249	0	0	0	707		
E	824	0		102	0	0	0	234	29	0	0	96	0	0	0	363		
F	173	0		4	0	0	0	28	1	0	0	13	0	0	0	127		
G	NA**																	
H	NA**																	

*See Tables I and III for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XXIV

RESULTS OF THE JUNE-IR-BAND SEVEN CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,698	NA**	23,659	6,919	0	1,683	9,905	13,779	1,210	0	0	11,822	721	0	0	NA**	NA**	NA**
Within Training Sets																		
1*	NA**																	
2	448		216	30	0	3	68	99	0	0	0	32	0	0	0			
3	98		19	36	0	1	5	29	0	0	0	6	2	0	0			
4	656		204	65	0	35	104	102	6	0	0	138	2	0	0			
5	66		0	5	0	54	0	4	1	0	0	2	0	0	0			
6	398		124	28	0	0	79	96	0	0	0	70	1	0	0			
7	812		210	194	0	0	61	313	0	0	0	30	4	0	0			
8	29		2	0	0	0	2	0	24	0	0	1	0	0	0			
9	93		27	10	0	0	8	28	6	0	0	14	0	0	0			
A	116		24	19	0	12	13	19	4	0	0	25	0	0	0			
B	21		6	0	0	0	3	0	5	0	0	7	0	0	0			
C	1,663		318	336	0	121	171	368	48	0	0	268	33	0	0			
D	1,512		591	66	0	1	161	376	66	0	0	251	0	0	0			
E	824		315	100	0	0	79	203	29	0	0	98	0	0	0			
F	NA**																	
G	NA**																	
H	NA**																	

*See Tables I and III for Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XXV

RESULTS OF THE MARCH-SOIL-BAND SEVEN CLASSIFICATION TREATMENT

		Number of Pixels Assigned to Each Ground Cover Class																
Number of Pixels	Total Pixels	1*	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H
Within Study Area	69,702	0	NA**	0	18,091	275	9,747	3,223	0	0	420	360	290	12,672	0	16,852	0	7,772
Within Training Sets																		
1*	2,292	0		0	710	6	201	99	0	0	4	12	9	434	0	648	0	169
2	NA**																	
3	95	0		0	21	0	14	9	0	0	0	3	1	9	0	26	0	12
4	651	0		0	249	0	25	9	0	0	1	0	0	188	0	100	0	79
5	61	0		0	0	51	3	1	0	0	5	0	0	0	0	1	0	0
6	397	0		0	6	2	304	37	0	0	17	0	0	2	0	29	0	0
7	804	0		0	33	1	476	73	0	0	25	0	0	14	0	156	0	26
8	46	0		0	12	1	9	3	0	0	2	0	0	6	0	10	0	3
9	236	0		0	71	8	42	6	0	0	6	0	1	28	0	54	0	20
A	348	0		0	29	28	123	7	0	0	74	0	0	32	0	44	0	11
B	110	0		0	29	8	5	2	0	0	19	3	1	6	0	37	0	0
C	1,952	0		0	336	6	330	129	0	0	14	27	30	314	0	437	0	329
D	1,385	0		0	489	0	5	12	0	0	0	9	8	456	0	190	0	216
E	961	0		0	296	0	17	14	0	0	0	3	10	241	0	181	0	199
F	172	0		0	41	0	27	12	0	0	0	0	0	20	0	66	0	6
G	63	0		0	7	0	16	1	0	0	1	0	0	3	0	23	0	12
H	18	0		0	7	0	0	0	0	0	0	0	0	6	0	1	0	4

*See Tables II and IV for Identification of Ground Cover Classes and Training Sets.

** Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

TABLE XXVI

RESULTS OF THE MARCH-IR-BAND SEVEN CLASSIFICATION TREATMENT

Number of Pixels	Total Pixels	Number of Pixels Assigned to Each Ground Cover Class																
		1*	2	3	4	5	6	7	8	9	A	B	C	C	E	F	G	H
Within Study Area	69,702	NA**	14,009	0	18,700	275	9,747	5,457	0	0	420	387	249	12,672	0	NA**	0	7,786
Within Training Sets																		
1*	NA**																	
2	442		132	0	148	2	52	34	0	0	1	0	0	51	0		0	22
3	95		22	0	21	0	15	11	0	0	0	3	1	9	0		0	13
4	651		88	0	254	0	25	16	0	0	1	0	0	188	0		0	79
5	61		0	0	0	51	3	2	0	0	5	0	0	0	0		0	0
6	397		23	0	7	2	304	42	0	0	17	0	0	2	0		0	0
7	804		114	0	35	1	476	113	0	0	25	0	0	14	0		0	26
8	46		8	0	13	1	9	4	0	0	2	0	0	6	0		0	3
9	236		51	0	72	8	42	8	0	0	6	0	1	28	0		0	20
A	348		36	0	29	28	123	15	0	0	74	0	0	32	0		0	11
B	110		31	0	31	8	5	6	0	0	19	3	1	6	0		0	0
C	1,976		349	0	357	6	331	218	0	0	14	29	26	315	0		0	331
D	1,382		170	0	493	0	5	25	0	0	0	9	6	456	0		0	218
E	961		149	0	301	0	17	41	0	0	0	3	8	241	0		0	201
F	NA**			0														
G	63		19	0	7	0	16	5	0	0	1	0	0	3	0		0	12
H	18		1	0	7	0	0	0	0	0	0	0	0	6	0		0	4

*See Tables II and IV for the Identification of Ground Cover Classes and Training Sets.

**Denotes Ground Cover Class or Training Set which does not apply to this classification treatment.

VITA

William Jeffrey Fleming

Candidate for the Degree of

Master of Science

Thesis: IDENTIFICATION OF GYPSUM USING NEAR-INFRARED PHOTOGRAPHY AND DIGITAL LANDSAT IMAGERY

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Professional Experience: High School Earth Science and Biology teacher, Moore High School, Moore, Oklahoma, 1973-1974; Logging Engineer, Petroleum Well Logging, Oklahoma City, Oklahoma, 1974-1976; Graduate Research assistant, Department of Geology, Oklahoma State University, 1978-1979.

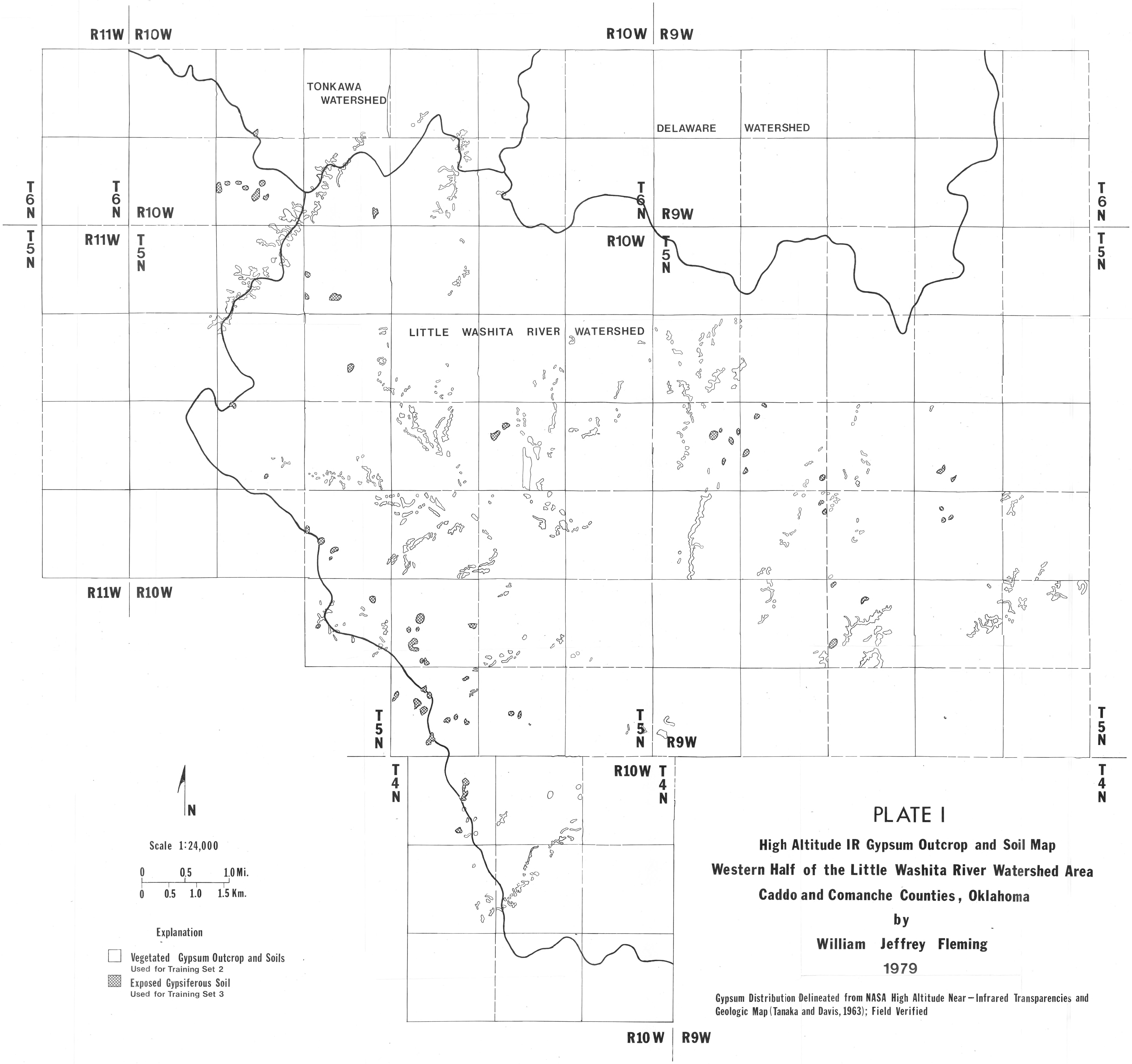


PLATE I

High Altitude IR Gypsum Outcrop and Soil Map

Western Half of the Little Washita River Watershed Area

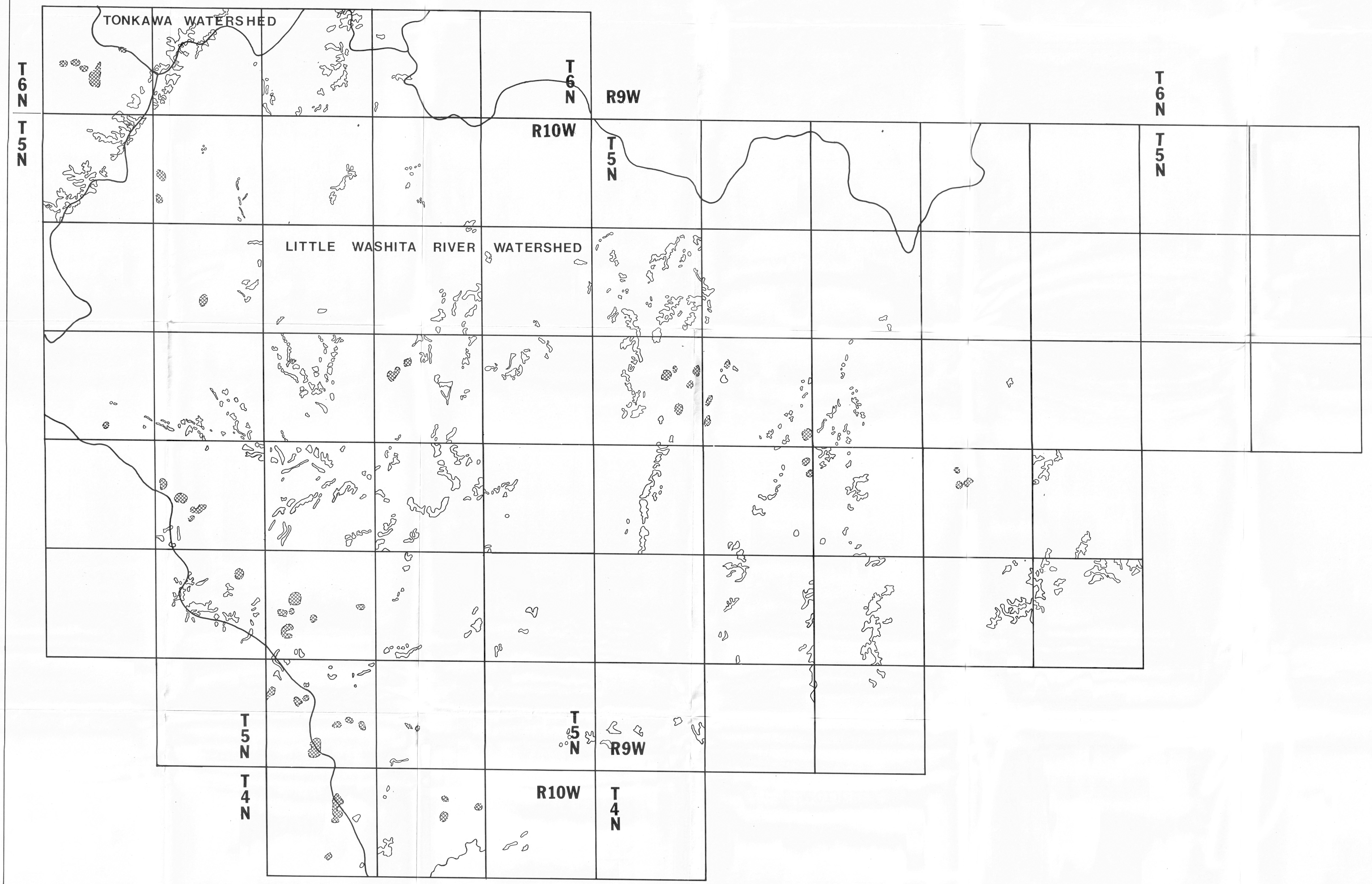
Caddo and Comanche Counties, Oklahoma

by

William Jeffrey Fleming

1979

Gypsum Distribution Delineated from NASA High Altitude Near–Infrared Transparencies and Geologic Map (Tanaka and Davis, 1963); Field Verified



N

Scale 1:24,000

0 0.5 1.0 Mi.

0 0.5 1.0 1.5 Km.

Explanation

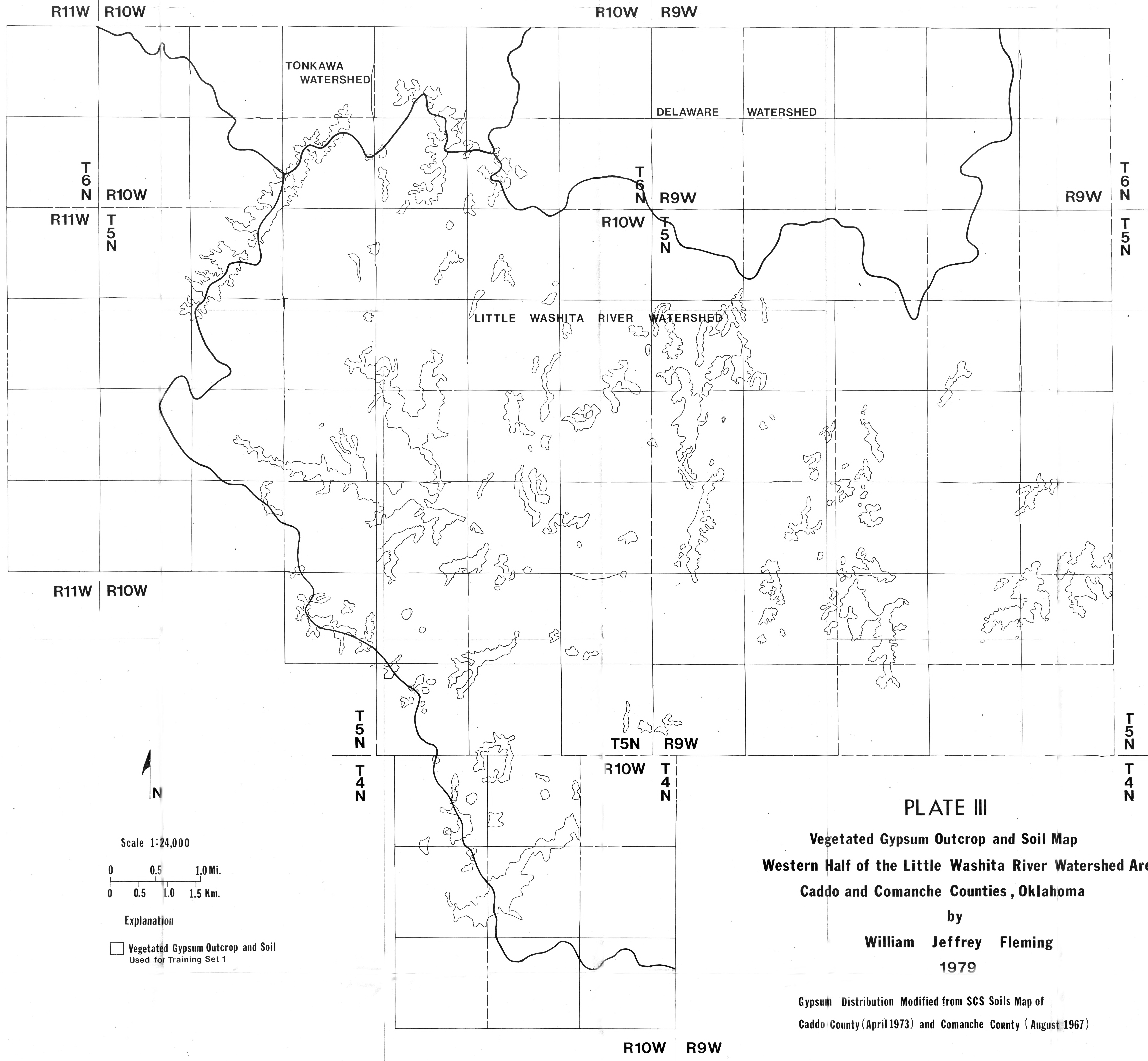
Vegetated Gypsum Outcrops and Soils

Exposed Gypsiferous Soils

PLATE II

Low Altitude IR Gypsum Outcrop and Soil Map
Western Half of the Little Washita River Watershed Area
Caddo and Comanche Counties, Oklahoma
by
William Jeffrey Fleming
1979

Gypsum Distribution Delineated from Low Altitude Color Near-Infrared Photographic Mosaic; Field Verified



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0 0.5 1.0 1.5 Km.

Explanation

Vegetated Gypsum Outcrop and Soil Used for Training Set 1

PLATE III

Vegetated Gypsum Outcrop and Soil Map

Western Half of the Little Washita River Watershed Area

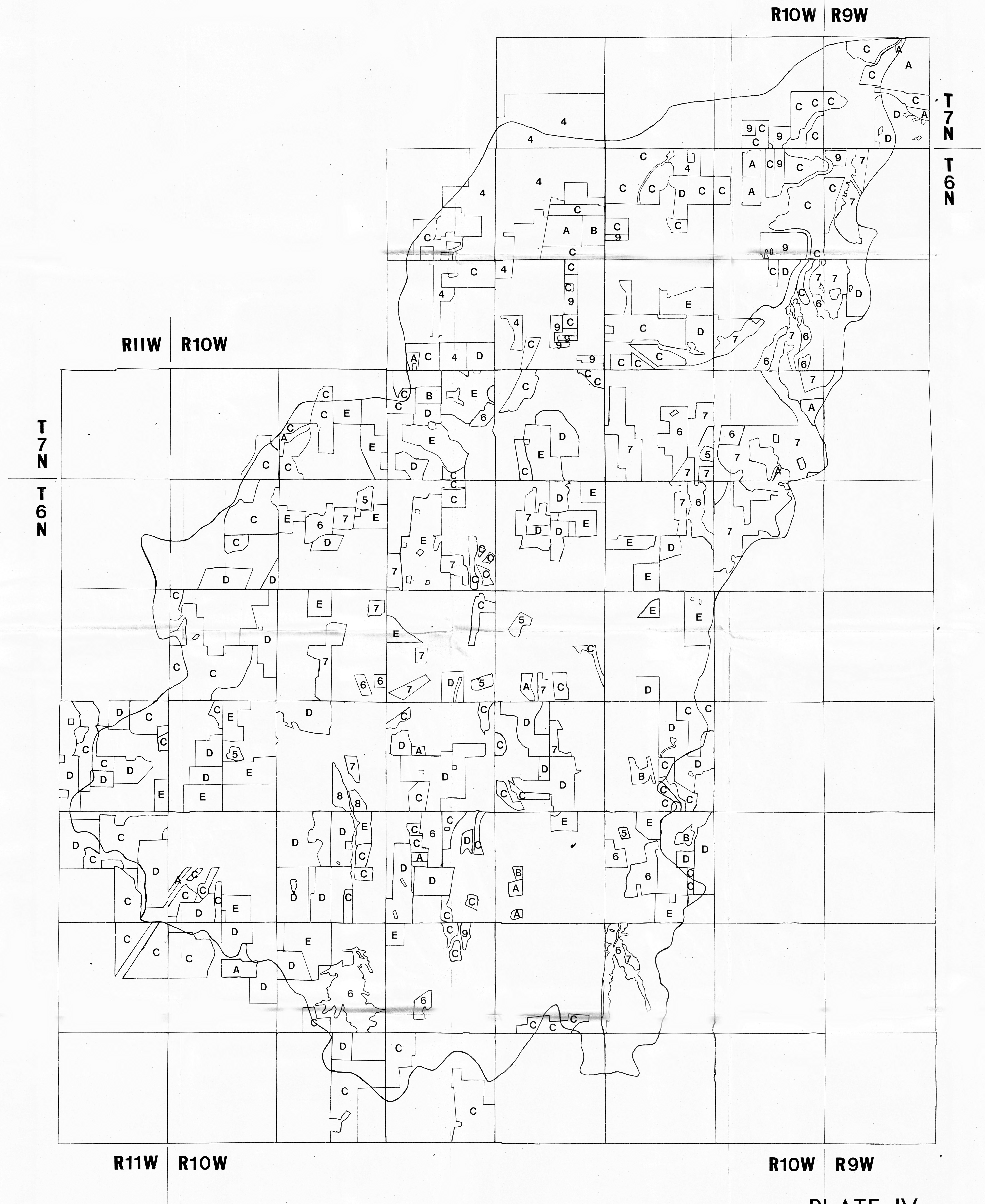
Caddo and Comanche Counties, Oklahoma

by

William Jeffrey Fleming

1979

Gypsum Distribution Modified from SCS Soils Map of Caddo County (April 1973) and Comanche County (August 1967)



Explanation
Ground Cover Classes

- 1, 2, 3 See Plates I and III
- 4 Town
- 5 Water
- 6 Dense Woodland
- 7 Moderately Dense Woodland
- 8 Sudan
- 9 Alfalfa
- A Cotton
- B May Maize
- C June Maize and Bare Ground
- D Improved Pasture
- E Unimproved Pasture
- F See Plate VI

N

Scale 1:24,000

0 0.5 1.0 Mi.
0 0.5 1.0 1.5 Km.

PLATE IV

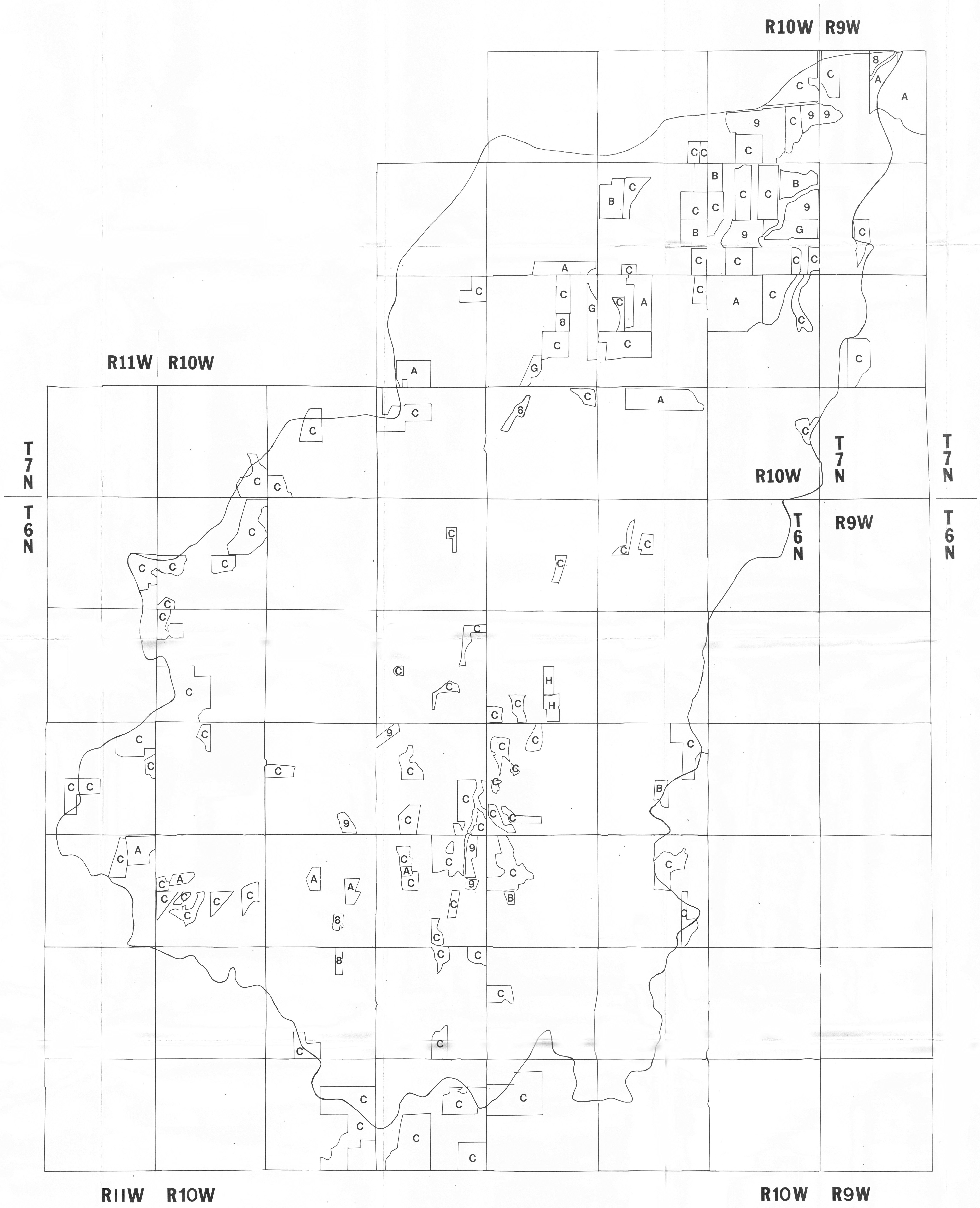
June 29, 1974 Ground Truth Map

Tonkawa Watershed Area, Caddo County, Oklahoma

by

William Jeffrey Fleming

1979



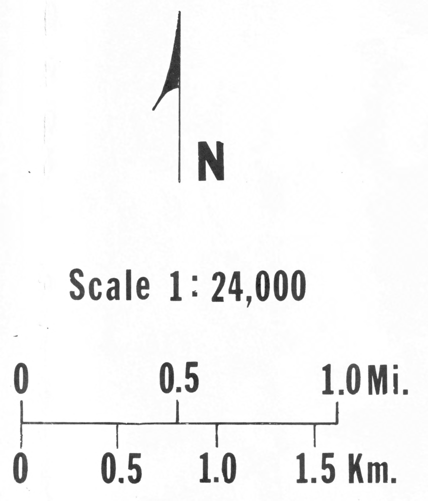


PLATE V

March 9, 1978 Ground Truth Map

Tonkawa Watershed Area, Caddo County, Oklahoma

by

William Jeffrey Fleming

1979

Explanation
Ground Cover Classes

- 1 → 7 See Plates I, III, IV
- 8 Sudan
- 9 Alfalfa
- A Cotton
- B Maize
- C Wheat
- D, E See Plate IV
- F See Plate VI
- G Barley
- H Oats

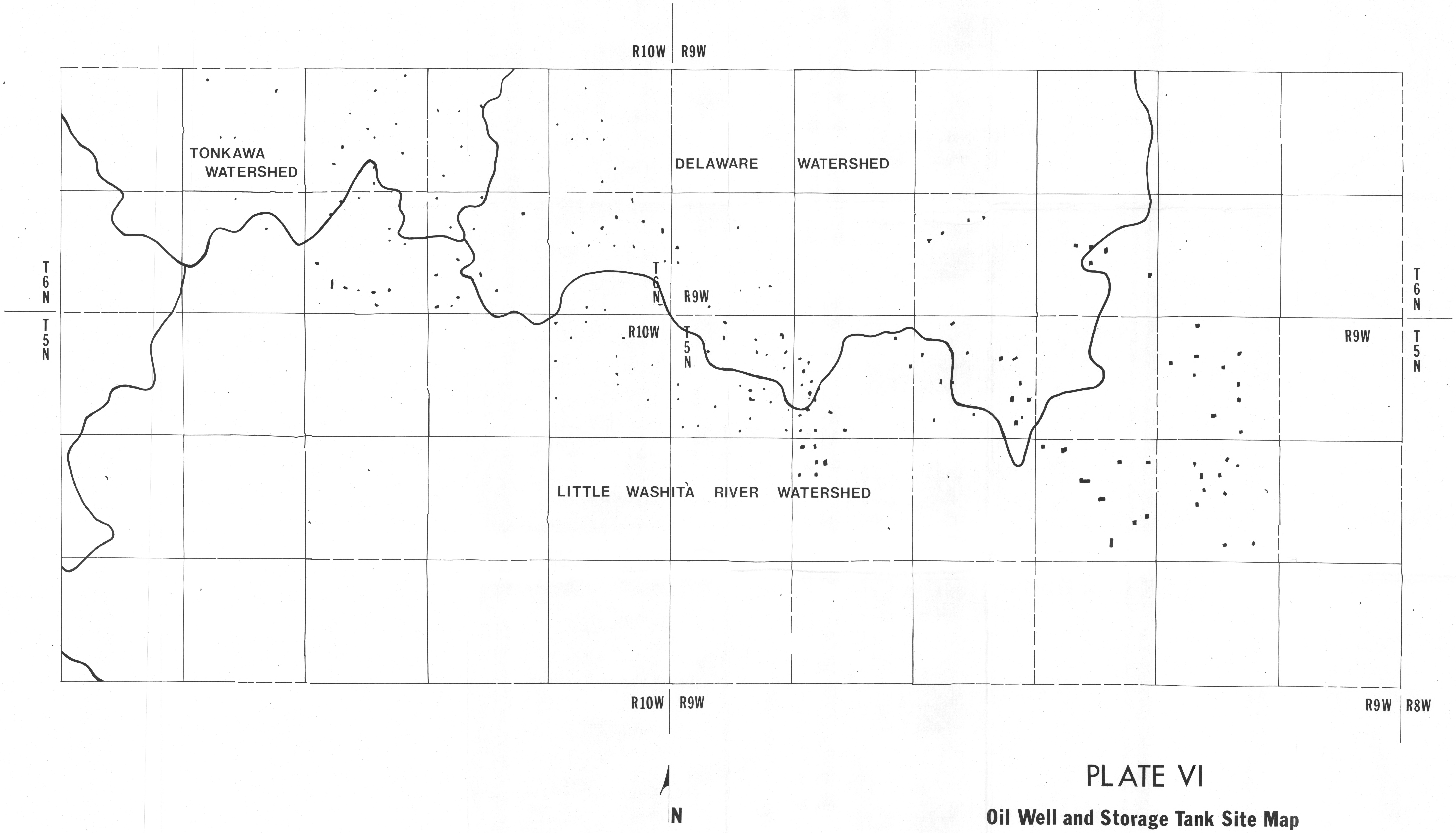


PLATE VI

Oil Well and Storage Tank Site Map

Western half of the Little Washita River Watershed Area

Caddo County, Oklahoma

by

William Jeffrey Fleming

1979

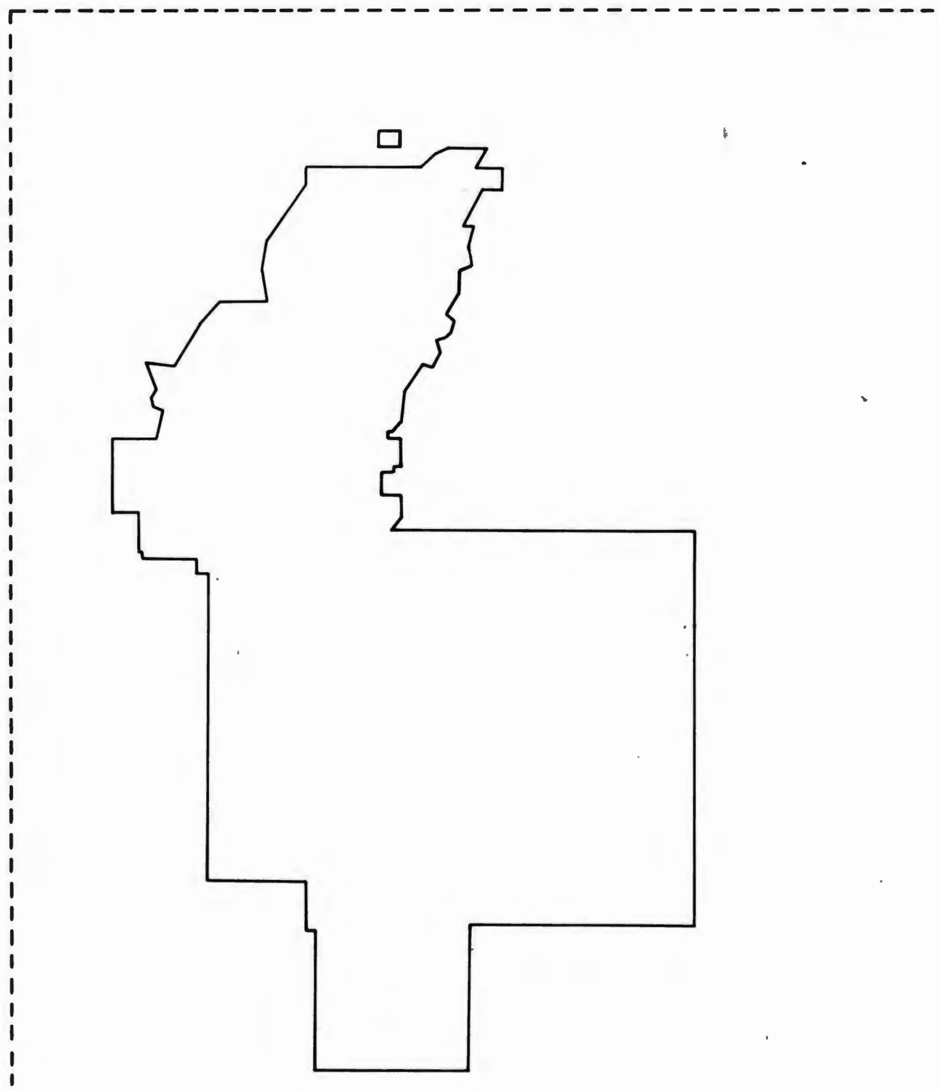
Explanation

■ Oil Well and Storage Tank Site
Used for Training Set F

Scale 1:24,000

0 0.5 1.0 Mi.

0 0.5 1.0 1.5 Km.



OUTLINE OF THE STUDY AREA FOR FIGURES 5 and 6

PLATE VII