LOCKHEED MARTIN

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ENVIRONMENTAL
RESTORATION
PROGRAM

Daytime Multispectral Scanner Aerial Surveys of the Oak Ridge Reservation, 1992–1994:

Overview of Data Processing and Analysis by the Environmental Restoration Remote Sensing Program, Fiscal Year 1995

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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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Daytime Multispectral Scanner Aerial Surveys of the Oak Ridge Reservation, 1992-1994:

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John L. Smyre
Michael E. Hodgson
Brent W. Moll
Amy L. King
Yang Cheng

Environmental Restoration Division
and
Computational Physics and Engineering
P.O. Box 2003
Oak Ridge, Tennessee 37831-7298

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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
managing the
Environmental Management Activities at the
Oak Ridge K-25 Site   Paducah Gaseous Diffusion Plant
Oak Ridge Y-12 Plant   Portsmouth Gaseous Diffusion Plant
Oak Ridge National Laboratory
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PREFACE

This technical report discussing data collection, processing, and analyses conducted by the Remote Sensing Program was prepared as textual documentation for aerial multispectral data that were delivered to the Oak Ridge Environmental Information System (OREIS) for inclusion in the OREIS consolidated data system. This work was performed under work breakdown structure 1.4.12.2.3.04.06 (activity sheet 8304) and milestone number 8304-08-08, selected aerial multispectral data to OREIS.

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ACRONYMS

AGL	Above Ground Level
DOE	Department of Energy
EG&G/EM	EG&G Energy Measurements
EM	Electromagnetic
ER	Environmental Restoration
ERWM	Environmental Restoration and Waste Management
GIS	Geographic Information Systems
IFOV	Instantaneous Field of View
K-25	Former Gaseous Diffusion Plant
MSS	Multispectral Scanner
NAD	North American Datum
NDVI	Normalized Difference Vegetation Index
OREIS	Oak Ridge Environmental Information System
ORR	Oak Ridge Reservation
PGDP	Paducah Gaseous Diffusion Plant
PORTS	Portsmouth Gaseous Diffusion Plant
X-10	Oak Ridge National Laboratory
Y-12	Weapons Production Plant

1. OVERVIEW OF THE ENVIRONMENTAL RESTORATION REMOTE SENSING AND SPECIAL SURVEYS PROGRAM

The Environmental Restoration (ER) Remote Sensing and Special Surveys Program was established in 1992 to apply the benefits of remote sensing technologies to Environmental Restoration and Waste Management (ERWM) programs at all of the five United States Department of Energy (DOE) facilities operated and managed by Martin Marietta Energy Systems, Inc. (now Lockheed Martin Energy Systems)—the three Oak Ridge Reservation (ORR) facilities, the Paducah Gaseous Diffusion Plant (PGDP), the Portsmouth Gaseous Diffusion Plant (PORTS)—and adjacent off-site areas. The Remote Sensing Program includes the management of routine and special surveys at these sites, application of state-of-the-art remote sensing and geophysical technologies, and data transformation, integration, and analyses required to make the information valuable to ER. Remotely-sensed data collected of the ORR include natural color and color infrared (IR) aerial photography, 12-band multispectral scanner imagery, predawn thermal IR sensor imagery, magnetic and electromagnetic geophysical surveys, and gamma radiological data.

Information derived from the Remote Sensing Program is valuable for many reasons. It provides data that can be used to locate potential contamination sources and characterize waste sites efficiently; to document land use and waste site activity; to detect and monitor temporal changes associated with contaminant transport and remediation efforts; to establish baselines for comparison with future conditions; to provide a data base for detailed analysis, comparisons, and integration with field measurements and map data; and to fuel geographic database improvements (e.g., facility layout, land cover, topography). The worth of these technologies, particularly in a sustained program, can be demonstrated throughout the remediation life cycle.

2. MULTISPECTRAL SCANNER IMAGERY AERIAL SURVEYS OVERVIEW

2.1 GENERAL PURPOSE AND METHODOLOGY

The multispectral scanner (MSS) imagery technique in the ER program uses a commercial (e.g., Daedalus) or custom-built scanning spectrometer flown in a small jet aircraft (e.g., Cessna Citation). The MSS spectrometer digitally records the solar reflectance and emissions of electromagnetic (EM) radiation from the earth's surface and partitions the results into 12 distinct wavebands ranging from ultraviolet to thermal infrared, including two thermal channels of the same wavelength but different sensor gain settings. Aerial thermal IR measurements can be obtained both during the daytime and night to enhance detection of diurnal temperature changes through comparison of the two different thermal patterns. Representative altitudes Above Ground Level (AGL) flown for MSS imagery collected at the ORR are 2000 feet, 3000 feet, and 6000 feet during the day and 2000 feet and 4000 feet during the predawn period.

One of the important uses of daytime multispectral imagery in environmental studies is detection of unnatural vegetative stress induced by soil and/or groundwater contamination of the root zone.

Vegetation under stress may exhibit different light absorption and reflectance properties compared to the same species in non-stressed conditions. By comparing the spectral reflectance patterns for similar vegetative cover on different sites, the relative health of the vegetation may be determined (Figure 1). The daytime MSS may also be analyzed to produce landcover/land use data bases. After geographic rectification, comparisons can be made with similar data from previous time periods to detect temporal changes and identify surface anomalies.

Another use of MSS, particularly predawn thermal, is the study of surface and near-surface thermal features. Among applications in the environmental area are (1) the use of temperature variations in water bodies as indicators of internal mixing and of external inputs such as tributaries, springs, and heated effluent; (2) delineation of stream courses and identification of seeps and springs from surface temperature differences; (3) study of the relation of seeps and springs to seasonal changes and precipitation events (when multi-date imagery is available); and (4) determination of thermal properties of materials from comparison of daytime and predawn imagery. If thermal data are acquired periodically, changes in the groundwater behavior of water seeps or in corroding physical plant structures (e.g., building rooftops or underground pipes) may be determined (Figure 2). The thermal IR imagery, its analysis, and its benefits are discussed more fully in another report (See Smyre, et al, 1995d).

Visible and digital analysis of the multispectral imagery should be performed with a full knowledge of the sensor and platform characteristics as well as the geography and meteorology of the study area at the time of image collection. Unlike aerial photography, human interpretation of multispectral imagery requires greater expertise and skill to draw valid conclusions. Some of the multispectral bands, such as near and mid-infrared or thermal infrared wavelengths, are not sensed by humans; thus, we have little precedence for interpretations. Furthermore, the remotely sensed imagery contain a variety of atmospheric, terrain, and sensor/platform induced anomalies.

2.2 MULTISPECTRAL SCANNER DATA COLLECTION: SENSOR / PLATFORM

The fundamental characteristics of the AADS-1268 multispectral scanner are listed in Table 1. Four detector packages with eleven discrete elements are contained in the scanner. The Daedalus DS-1268 scans only in one direction and collects data for one scan line at a time. This scan line represents information orthogonal to the direction of the aircraft's flight path. There are 716 pixels collected along each scan line. After the geometric corrections are applied in the post-processing, there will be 888 pixels per scan line. Normal operation of the scanner is 50 to 100 scans per second, depending on the aircraft forward speed and the flying height. Before a mission is conducted, the sensor is flown over a homogenous target (e.g., over Lake Mead), and the contractor conducts signal-to-noise analyses. If the noise is too high, corrections are made to the sensor before final data collection.

Spectral characteristics of the DS-1268 scanner are summarized in Table 2. Channels 1 through 8 are sensed by a single silicon detector array. Separate detectors are used for the two middle infrared channels. A thermal infrared detector, cooled by liquid nitrogen, is used for channels 11 and 12.

MSS imagery of the ORR, Daedalus bands 1 through 12, has been acquired at altitudes above ground level (AGL) of 2000 feet, 3000 feet, and 6000 feet. Each MSS band records radiation intensity as an 8-bit digital brightness value (BV) for each picture element (pixel). The data thus represent relative intensity values from 0 to 255 for each pixel. After geographic rectification, comparisons can be made with similar data from previous time periods to detect temporal changes and identify surface anomalies.

Table 1
Daedalus AADS 1268 Multispectral Scanning System

Number Channels	12
Operating Wavelengths	.42um to 12.5um
Scan Rate	12.5, 25, 50, 100 scans/s (selectable)
Instantaneous Field of View (IFOV)	2.5_{mr}
Total Field of View	85.92 degrees
Temperature Radiometric Resolution	0.1 centigrade
Roll Correction	±15 degrees
Reference Sources	Infrared: two thermal blackbodies
Video Words per scan line	716
Digitizer Gains	0.5, 1, 2, 4, or 8 (selectable)

At the ORR, multispectral scanner imagery is normally acquired during daylight hours in association with general aerial surveys in which daytime natural color and infrared photography are also acquired. However, predawn thermal infrared (IR) imagery is acquired during the predawn hours to enhance the thermal contrast of water bodies. The two daytime multispectral surveys conducted to date have been flown prior to significant vegetative leafout because ground and terrain details are more easily visible before the deciduous trees bud their spring leaves. Surface hydrology is also more readily apparent in thermal MSS imagery collected during this period.

The MSS imagery collected in both sets of overflight missions by EG&G Energy Measurements, Inc. (EG&G/EM) for the ER Remote Sensing Program in 1992 and 1994 utilized the Daedalus AADS-1268 multispectral scanner. This is a 12-band scanning system (see Table 2) in which channels 1 through 8 cover the wavelength range 0.42 to 0.97 micrometers (violet/blue through near infrared), channels 9 and 10 capture a portion of the middle infrared (1.59-1.79 and 2.10-2.40 micrometers, respectively), and channels 11 and 12 capture the thermal infrared wavelengths from 8.28 through 10.67 micrometers. The thermal bands 11 and 12 are recorded by a thermal infrared detector, cooled by liquid nitrogen, and represent the same wavelength spread, but channel 12 is recorded at a different gain setting and may be too saturated for use in quantitative analysis.

2.3 ORR DAYTIME MSS AERIAL SURVEYS

Two daytime MSS aerial surveys of the Oak Ridge Reservation were conducted under auspices of the ER Remote Sensing Program in 1992 and in 1994 by EG&G/EM, Las Vegas, NV. MSS imagery was collected at 3000 and 6000 feet AGL in 1992 and at 2000 and 6000 feet AGL in 1994. These surveys are described more fully in the following paragraphs.

Table 2
Spectral Sensitivity of the Daedalus AADS 1268 Multispectral Scanning System

Channel Number	Wavelength (um)	Nominal Color
1	0.42 - 0.44	Violet/Blue
2	0.46 - 0.51	Blue/Green
3	0.52 - 0.59	Green/Yellow
4	0.59 - 0.62	Orange
5	0.62 - 0.67	Red
6	0.67 - 0.72	Near Infrared
7	0.73 - 0.85	Near Infrared
8	0.84 - 0.97	Near Infrared
9	1.59 - 1.79	Middle Infrared
10	2.10 - 2.40	Middle Infrared
11	8.28 - 10.67	Thermal Infrared
12	8.28 - 10.67	Thermal Infrared

2.3.1 Oak Ridge Reservation (1992)

An aerial survey was conducted from April 3 to May 10, 1992 over 55 square miles of the entire Oak Ridge Reservation, East Fork Poplar Creek, and surrounding area near Oak Ridge, Tennessee. The survey area included the three plants -- X-10 (Oak Ridge National Laboratory), K-25 (former Gaseous Diffusion Plant), and Y-12 (Weapons Production Plant) -- as well as adjoining areas. Other remote sensing data acquired in conjunction with daytime multispectral imagery during this time period include natural color photography collected at altitudes from 6000 to 40,000 feet AGL; color infrared photography at 3000 and 6000 feet AGL. Predawn thermal infrared imagery was also collected. A helicopter radiological survey (terrestrial and man-made gamma counts) was carried out during the same period of time (Smyre, J. L.; Moll, B. W.; and King, A. L., 1995a).

The MSS imagery was acquired at an altitude of 3000 feet AGL on April 13, 1992 (11 flight lines) and at 6000 feet on the same day (7 flight lines) at an approximate ground speed of 170 knots. The flight lines roughly parallel the valleys and ridges of the reservation (roughly east-west in Administrative Grid map projection coordinates). Daedalus bands 1 through 12 were acquired on each daytime MSS overflight.

2.3.2 Oak Ridge Reservation (1994)

Daytime MSS imagery was collected during an aerial survey that was conducted from March 17 to March 23, 1994. During this survey, natural color photography and color infrared photography were also collected. Predawn MSS imagery was collected during the same time period at altitudes of 2000 feet and 6000 feet AGL.

The daytime MSS imagery (all 12 bands) collected during this later remote sensing survey was flown at 2000 feet AGL on two different dates: March 19, 1994 (11 flight lines) and March 22, 1994 (13 flight lines); and at 6000 feet AGL on March 22 (8 flight lines). Aircraft speed was approximately 170 to 190 knots. Flight lines were oriented along the TN State Plane east-west coordinate axis; thus, flight lines did not parallel the ridges and valleys of the reservation, but rather crossed them at an angle. Collection was conducted in this manner to accommodate comparison with the new base maps being created by the ER Basemap Project.

3. DATA PROCESSING AND QUALITY ASSURANCE (GIS AND COMPUTER MODELING, CPED)

Daytime multispectral and predawn thermal infrared imagery from an aerial survey mission was delivered by the contractor as a single file per Daedalus AADS-1268 wavelength band. The 1992 data were delivered in ERDAS format .lan files. The 1994 data were delivered as headerless single-band files. The data for a given band are organized such that the 888 pixels for the first scan line captured by the sensor are the first row of the image, the second scan line is represented by the second row of the image, and so on. Thus, the image from a flight path flown in an easterly direction has the westernmost pixels at the top of the image and the easternmost pixels at the bottom of the image, which must be rotated 90 degrees to conform to normal viewing orientations. If a multispectral image composite is desired, the images from bands 1 through 12 must be combined into a single image file.

The first part of this section describes corrections to the data applied by the contractor, EG&G/EM. Subsequent parts describe the digital datasets acquired by the Remote Sensing Program and the digital image processing manipulations performed in ORNL by the ER Remote Sensing Program to make these data more usable by computer software such as Geographic Information Systems (GIS).

3.1 CONTRACTOR DATA CORRECTIONS (BY EG&G/EM)

3.1.1 1992 Multispectral Imagery

EG&G/EM corrected the daytime MSS data of April 13, 1992 for S-band and V/H distortions. The data were also radiometrically calibrated using internal blackbody. The contractor noted (in regard to the 3000-foot AGL collection) that "there is a noticeable darkening trend near the edges of Runs 11, 13, 15, 17, and 19. This is due to the difference between the sun angle and the flight heading at the time of data acquisition. This difference is within the limits specified in 'A Field Guide for Scanner and Photographic Missions', EGG-1183-1818" (Brewster, 1992c). In reference to the 6000-foot AGL collection, the contractor observed that "there is also some saturation in a couple of visible channels in urban areas, but this should not affect vegetation and stress analysis" (Brewster, 1992b).

3.1.2 1994 Multispectral Imagery

These data were corrected for systematic distortions caused by aircraft position, and the thermal channels were radiometrically corrected. As in the case of 1992 imagery, the second thermal channel (12) is the same data as the first thermal channel (11) recorded at a different gain setting. EG&G/EM

observed that "runs 27 and 29 at 2000 feet AGL on March 22, 1994 have extensive roll corrections due to a great deal [of] aircraft maneuvering to stay on line" (Howard, 1994b).

3.2 DIGITAL DAYTIME MULTISPECTRAL DATA TAPES DELIVERED BY CONTRACTOR (EG&G/EM)

3.2.1 1992 Imagery

a. Preliminary daytime MSS and predawn thermal data of Parcel A , April 13, 1992. (reference: MRSD-92-214)

The Parcel-A MSS imagery included bands 1 through 12 from portions of flight lines 29 and 31 covering Parcel A. The imagery was acquired at an altitude of 6000 feet AGL on April 13, 1992 at approximately 10:08 and 10:18 a.m., respectively. The two flight lines parallel the valleys and ridges of the reservation (roughly east-west in Administrative Grid coordinates) - flightlines FL-29A and FL-31A in Figure 3A. Approximate spatial resolution of the digital imagery is 4.3 meters per pixel.

b. MSS imagery of ORR at 6000 feet AGL, April 13, 1992. (reference: MRSD-92-278)

This imagery includes bands 1 through 12 and was acquired between approximately 09:46 and 10:53 in the morning. The 7 flight lines parallel the valleys and ridges of the reservation (roughly east-west in Administrative Grid coordinates) (Figure 3A). Approximate spatial resolution of the digital imagery is 4.3 meters per pixel.

c. MSS imagery of ORR at 3000 feet AGL, April 13, 1992. (reference: MRSD-92-398)

This imagery includes bands 1 through 12 and was acquired between approximately 13:42 and 15:30 in the afternoon. As in the earlier overflights, the 11 flight lines parallel the valleys and ridges of the reservation (roughly east-west in Administrative Grid coordinates) (Figure 3B). Approximate spatial resolution of the digital imagery is 2.1 meters per pixel.

3.2.2 1994 Imagery

a. MSS imagery of ORR at 2000 feet AGL, March 19, 1994. (reference: SIGIS-94-130)

The daytime MSS imagery of the ORR (bands 1 through 12) was collected in 11 flight lines between 09:31 a.m. and 11:06 a.m. Flight lines were oriented along the TN State Plane east-west coordinate axis; thus, flight lines did not parallel the ridges and valleys of the reservation, but rather crossed them at an angle (Figure 3C). Nominal spatial resolution of the digital data is approximately 1.5 meters per pixel.

b. MSS imagery of ORR at 2000 feet AGL, March 22, 1994. (reference: SIGIS-94-138)

The MSS imagery of the ORR (bands 1 through 12) was collected in 3 special flights (over Elza Gate and CSX Railroad in east Oak Ridge) from 11:27 to 11:38 a.m. and in 10 additional flight lines between 14:17 and 15:48 in the afternoon. Flight lines were again oriented along the TN State Plane east-west coordinate system (Figure 3D). Nominal spatial resolution of the digital data is again approximately 1.5 meters per pixel.

c. MSS imagery of ORR at 6000 feet AGL, March 22, 1994. (reference: SIGIS-94-141)

Daedalus AADS-1268 daytime imagery was collected in 8 flightlines from 09:34 a.m. until approximately 10:51 a.m. Flightlines at 6000 feet AGL were oriented along true east-west (Figure 3E). Nominal spatial resolution is approximately 4.3 meters per pixel.

3.3 SUMMARY OF DATA TRANSFORMATION AND ANALYSIS PROCEDURES

The following paragraphs describe computer and image processing manipulations necessary to transform and analyze digital data derived from daytime MSS.

3.3.1 Rotation and MSS Band Integration

Once the contents of data tapes have been loaded, data are converted into the image format to be used in image processing software. In most cases, the ER Remote Sensing Program has used the ERDAS 7.5 .lan format for its analysis, although the ERDAS Imagine .img format has also been employed. As noted above, the original imagery is in the form of single band images, which appear as a narrow vertical strip. These images must be rotated 90 degrees to orient the flight path data east-west (either roughly Administrative Grid or Tennessee State Plane coordinates). In all cases, the data from bands 1 through 12 have also been integrated into 12-band ERDAS files.

3.3.2 MSS Data Radiometric Considerations

Variations in spectral reflectance values as a function of viewing angles (topographic and sensor angle) and multi-date composites can be seen in MSS imagery. The difference between south-facing ridge slopes and north-facing ridge slopes, in particular, can be pronounced. The latter can cause problems with landcover classifications. Difficulties in creating multi-date composites may be due to atmospherics or possibly surface moisture, which could be lessened by applying either (1) statistical models or (2) atmospheric models.

Radiometric problems with same-date composites in rugged terrain also occur. Moderate relief results in different viewing angles and viewing distances from adjacent flightlines. (Relief also results in geometric errors from relief displacement and will be discussed later.)

Smaller variations in reflectance within a flightline (due to scan angle) could be removed by empirical modeling using a suitable function. More significant variations from terrain orientation, scan angle, instantaneous field of view (IFOV), and distance to sensor can only be removed using a digital terrain model and an appropriate energy reflectance/emission model, such as Lambertian surface model.

Due to the complexity of modeling all the factors that cause observed variations in reflectance and because of budgetary constraints, little effort has been expended thus far by the ER Remote Sensing Program in addressing these radiometric issues. Further investigation in this area is greatly needed.

3.3.3 Rectification of MSS Imagery to Standard Geographic Map Projections

a. General Raster Imagery Rectification Issues

Geo-rectification is the process of converting a raw digital image such as a natural color photograph into a standard map projection. Since the earth's surface is not flat, points on the earth's irregular (but roughly spheroidal) surface are projected to a flat plane for cartographic purposes. Digital raster imagery must also be transformed into a standard map projection if that imagery is to be combined with other geographic information such as roads, buildings, topographic contours, monitoring wells, etc.

The standard geographic coordinate system most commonly used on the ORR for GIS purposes and for rectification of digital imagery is the Tennessee State Plane coordinate system (North American Datum 1983 (NAD83)). Tennessee State Plane is based on the Lambert Conformal Conic map projection. It has the following advantages: (1) it is aligned with true north, (2) it can be used for spatial data anywhere within Tennessee, and (3) it is recognized widely by cartographers and by GIS software. This is the map projection used in most of the MSS imagery rectifications.

Rectification of a raw image to any coordinate system requires the availability of ground control point information to define the mathematical correspondence between the (X,Y) locations in the coordinate system and (x,y) pixel position within the digital image. Points commonly used for ground control must be easily recognizable in the digital image, and the coordinates of the ground control points in the map projection must be accurately known.

Several sources of ground control have been used in rectification of ORR images. These include:

(1) S16A Arc/Info vector coverages of ORR (1:24,000 scale)
(2) Ortho-photographs from the ER Basemap Project (0.5 meter raster cell size)
(3) Planimetric data from the ER Basemap Project (1:2,400 scale)

The ortho-photography acquired by the ER Basemap Project has been extraordinarily valuable in providing good (X,Y) ground control and high quality digital terrain data.

The common image rectification algorithm used by commercial software for airborne remotely sensed imagery uses an nth-order polynomial to relate the x-y pixel locations with the X-Y map coordinates. A transformation matrix (first order, second order, etc.) is computed using the ground control point information matching (X,Y) coordinates of the ground control points (in the target map projection) with the image (x,y) pixel locations. Use of a higher order transformation may give a better match between the source ground control point locations and the transformed locations of these control points in the output image, but higher order transformations require more ground control points.

An image is geo-rectified to a target map projection by applying the transformation matrix to the source digital raster image. The resampling algorithm assigns a pixel value to each pixel in the output image based on pixel values of the source image. Three re-sampling algorithms are in common use: (1) nearest neighbor in which the output cell value is assigned based on the value of the nearest cell in the source image, (2) bilinear interpolation, and (3) cubic convolution. Bilinear interpolation and cubic convolution assign a cell value based on a distance weighted average of surrounding cells.

b. MSS Imagery Geometric Considerations

MSS and thermal data collected by airborne platforms are notoriously difficult to rectify adequately. The relative instability of the aircraft platform introduces unsystematic geometric variations in the imagery. Such nonsystematic geometric distortions require innovative approaches to the rectification process, such as piecewise rectification. Systematic errors in the scanner/platform combination may be modeled and effectively removed from the imagery, however.

Systematic variations in the IFOV and geometric positioning of the IFOV may be modeled and largely removed through post-processing. At 2000 feet AGL, the ground projected IFOV of the AADS-1268 scanner varies in pixel size 1.5 meters at nadir to 3.3 meters at the scan angle extreme. The forward speed of the aircraft at 180 knots results in a ground sampling distance along track of approximately 0.78 meters. The contractor collecting the imagery largely removes these variations in pixel size off track and along track by post-processing the imagery through a resampling process.

Another systematic distortion in the imagery is caused by the aircraft's forward motion during the acquisition of a scan line. Each scan line in the Daedalus MSS flown in Oak Ridge in 1992 and 1994 was collected at approximately 1/100 second. The aircraft moves forward during this scan acquisition. Also, the scan speed is not linear across the entire scan line. The result of these scanning characteristics is an image with the characteristic sigmoid shape. Post-processing by the contractor minimizes these variations.

Relief displacement from the topographic surface is greatly enhanced by the low altitudes and extreme viewing angles of the daytime MSS imagery of the ORR. Slight changes in local relief can result in dramatic changes in horizontal displacement using airborne MSS and thermal IR imagery of the ORR. Creating a mosaic of MSS imagery from adjacent flightlines exacerbates the problem, since the same spot on the surface is displaced in opposite directions, thereby increasing the overall geometric differences in a composite image. These types of post-processing analyses and corrections have not been applied to the MSS data due to funding limitations.

3.3.4. Landcover Classifications

Landcover classification is a remote sensing/image processing technique that seeks to categorize the earth's surface in terms of natural and man-made features such as water, deciduous forest, marsh, urban development, etc. This classification is usually performed through an analysis of digital imagery, customarily MSS.

a. General Considerations

Digital landcover classifications using multispectral imagery are based on the assumption that pixels within a landcover class share similar spectral and/or spatial responses. The determination of land cover based on spectral characteristics may be performed in a **supervised** or in an **unsupervised** mode, or by some combination of the two. Supervised classifications are commonly performed using seed areas selected by the analyst as being spectrally representative of various land covers of interest. The software then matches the spectral responses of the entire area to be classified to the spectral signatures of the seed areas. Unsupervised classification techniques make use of statistical clustering of the image into geographic areas of similar spectral characteristics. In this case, the analyst attempts to assign each statistical cluster to a land cover in the adopted set of landcover classes. In reality, several iterations, a combination of methods, and editing of the final classification may be employed. Ideally ground truthing should be employed to evaluate the accuracy of the classification and to fine tune the landcover classification.

The band combinations from the Daedalus MSS data used in the classification of landcovers may depend on the landcovers of interest, such as different types of vegetation. In the 12 bands of Daedalus multispectral scanner data, much redundancy in information content is present. One technique for reducing redundancy is **principal components analysis**, which allows the dimensionality of the data to be reduced. Principal components analysis involves rotation of the axes of the spectral space, changing the coordinates of each pixel in spectral space and the data values as well. A linear transformation is performed on the data to create a new image file with the same number of bands as the input. The variance within the original data is distributed such that each band contains non-redundant, independent data. Also, the first principal component contains more of the information (more of the variance) than the other principal components, the second component contains the second most information, and so on. It is not unusual for the first three principal components to contain 95% of the information content of the original 12-band data, and the first five principal components to contain more than 99% of the information content. This allows reduction of data storage and processing time during classification without significant loss of information. Figure 4 is a principal components image of the southern part of Oak Ridge National Laboratory.

A number of other biophysical indicators of landcover, such as vegetation, may be computed directly from the multispectral data. Among these is the **Normalized Difference Vegetation Index (NDVI)**, which can be computed for Daedalus imagery from a difference ratio of the near-infrared and red bands (e.g. Daedalus DS-1268 bands 7 and 5): (7-5)/(7+5). The NDVI indicates the relative vigor of vegetative cover, with higher values indicating greater biomass (Figure 5). Ratio color composites may also be used to depict graphically the health of vegetation and state of the landcover. Another is a **ratio composite** image, obtained from the combination of Daedalus bands (10/7), 7, and 5 assigned to the red, green and blue colors, respectively, of a color composite. The ratio composite image shows growing vegetation as green, inactive vegetation as pink, with water bodies appearing red (Figure 6).

b. Parcel A Landcover Classification

The 12-band Daedalus MSS collected at 6000 feet AGL from April 13, 1992 (a portion of s31.lan) was used as input to principal components analysis using the ERDAS PRINCE program. The five most significant principal components were used in the ERDAS ISODATA ("Iterative Self-Organizing Data Analysis Technique") statistical clustering procedure. ISODATA iteratively uses a minimum spectral distance formula to form a specified number of clusters. The resultant groups were assigned by the image analyst to landcover categories. Significant editing was performed on the classification in certain areas, and the final classification was generalized with a local filter (i.e., the ERDAS SCAN function). The analysis used entirely unrectified imagery.

c. South Oak Ridge National Laboratory Landcover Classification

This classification also employed 6000 foot AGL Daedalus imagery from April 13, 1992. A principal components analysis on the unrectified imagery was performed. The six most significant principal components were used in the ISODATA procedure, and the generated spectral clusters were assigned to tentative landcover classes. Local editing and smoothing were performed to create the final landcover classification (Figure 7).

d. Proposed ED -1 Land Transfer Site

Portions of two Daedalus AADS-1268 flightlines (15 and 17) flown at 6000 feet AGL on March 22, 1994 were used in a landcover analysis. The two flight lines, even though they were flown on the same day, had significant differences in contrast. This meant that radiometric correction, as well as geometric correction, of the MSS data would be necessary to avoid having to spectrally classify the flight lines separately and then match the classifications. To minimize the radiometric differences between the two flightlines, histogram matching of the spectral values of flightline 17 to those of flightline 15 was performed. Figure 8 is a landcover classification of proposed the ED-1 land transfer site.

The radiometric correction was accomplished by the digitizing of a small area of overlap between the two flightlines and by the extraction of a small subset of the MSS data of both flightlines. The histograms of the twelve wavelengths sampled by the scanner in both flightlines were obtained. Evaluation of the difference between flightline 17 and flightline 15 were made at a minimum of three points of the frequency distribution, those being at the mean and at the two tails of the distribution. In some cases, four points were located. The differences were then summed and divided by the number of samples taken. A multiplier constant (ranging from 0.57 to 0.75) was applied to each band of flightline 17 pixel value to match the data to flightline 15 using the ERDAS ALGEBRA program. After slight adjustment of constants, the second processing of the raw flightline 17 data produced an output data set in which histograms matched flightline 15 in a more satisfactory manner.

The raw MSS data were geo-referenced to the Tennessee State Plane (NAD83) coordinate system through the use of preliminary vector data from the ER GIS and Spatial Technologies / Basemap Program. Due to the lack of human development at the site, ground control points were difficult to identify. The final rectification used a second degree polynomial fit to resample the data to a 5.0 meter cell size.

The actual analysis of landcover / land use involved pre-classification and post-classification analysis steps. In the pre-classification phase a principal component transformation was derived from the multispectral data. The result of this analysis was that of all the information in the twelve wavelengths collected by the sensor, 79% can be found in the first principal component, 91.1% in the first two, 96.8% in the first three, and 98.7% in the first four. The remaining eight components contain only 1.3% of the total amount of information in the twelve wavelengths.

Once the pre-classification processing was complete, the data were sorted into a finite number of individual classes, or categories of data, based on the digital sensor value. This multispectral classification was performed both on the original 12-channel sensor dataset and the derived four principal component dataset using unsupervised training classes. The initial signature generation program processed was the STATCL process. In the 12-channel image, nine statistically significant groupings were derived. In the principal component image, eight were derived. These groupings were then used in the classification program MAXCLAS, which actually performed the classification.

In both instances, the results achieved were not acceptable. Using aerial photography for ground truthing, there was significant mis-classification on both images. Different vegetation types were either lumped together into a single class or split into several. There was no delineation between asphalt road surfaces and scrub/shrub. A new approach was needed.

A second attempt made use of an arbitrary number of groupings in a clustering algorithm. Initially, this number was set at 15, but again, in both cases, the number of classes generated seemed too few for the type of vegetation and the ability to discriminate between various types. Twenty clusters finally produced, in the principal component data set, an adequate number of groupings in order to discriminate between the various land uses and vegetative covers. Evaluation of this clustering was performed using the CLASOVR program, in which the classified GIS file can be overlaid on a monochrome image of the data. This grouping of the clusters determined that the study area contained two major land use and six vegetation types. A RECODING of the 20-class GIS file was performed, and the output GIS file was appropriately labeled.

Since the object of this study was to characterize the study area, a polygon file was obtained, and the recoded GIS file was further clipped to create a final raster GIS file that only mapped the area within the proposed ED-1 land transfer area. Acreages were now computed for the GIS classes as follows:

Table 3

Class	Pixel Count	Acres	%	Description
===	======	===	===	=========
0	239015.	1476.587	0.00 %	Offsite/Image Background
1	123.	0.760	0.08 %	Agriculture
2	40858.	252.413	26.86 %	Brush / Stubble
3	88795.	548.558	58.38 %	Mixed Hardwoods
4	15229.	94.082	10.01 %	Pines
5	271.	1.674	0.18 %	Water
6	3061.	18.910	2.01 %	Cleared Areas
7	798.	4.930	0.52 %	Disturbed / Human Endeavors
8	2955.	18.255	1.94 %	Grass

4. DESCRIPTIONS OF DAYTIME MULTISPECTRAL DATASETS

This section describes the daytime multispectral digital datasets prepared by the ER Remote Sensing Program for delivery to the Oak Ridge Environmental Information System (OREIS). The datasets are derived from the four separate MSS collections, two each in April, 1992 at 3000 and 6000 feet elevation and in March, 1994 at altitudes of 2000 and 6000 feet AGL. Figure 3A, 3B, 3C, 3D, and 3E are index maps of the flight paths. These data provide essentially complete coverage of the ORR for each year surveyed. Selected sites on the reservation have been examined in detail, including rectifications, landcover classifications, and annotation. The 78 files in this daytime MSS archive comprise 4.400 gigabytes of data in uncompressed form. An ASCII text documentation file and a downsized preview image were created to accompany each full image. Additional MSS rectifications, analyses, landcover classifications, and annotations can be performed by the ER Remote Sensing Program on a site specific basis upon request.

The data sets are divided into four categories according to type of image product: (1) raw, unrectified MSS imagery (image files contain bands 1 through 12), (2) geo-rectified MSS imagery, (3) derived products such as landcover classifications and normalized difference vegetative index (NDVI) imagery, and (4) annotated MSS imagery. The listed cell size of unrectified images is an approximation only. Refer to the end of the dataset list for geographic area descriptive acronyms.

4.1 RAW, UNCALIBRATED MSS IMAGERY

Name	Altitude (ft. AGL)	Pixel Size	File Size	Geographic Area
April 13, 1992 (3000 feet)				
11rot.lan	3,000	2.1 m	147.9 Mb	Flight Path 11
c13rot.lan	3,000	2.1 m	111.0 Mb	Flight Path 13
c15rot.lan	3,000	2.1 m	102.2 Mb	Flight Path 15
c17rot.lan	3,000	2.1 m	70.3 Mb	Flight Path 17
c19rot.lan	3,000	2.1 m	109.3 Mb	Flight Path 19
c20rot.lan	3,000	2.1 m	37.8 Mb	Flight Path 20
c22rot.lan	3,000	2.1 m	39.5 Mb	Flight Path 22
c24rot.lan	3,000	2.1 m	99.4 Mb	Flight Path 24
c26rot.lan	3,000	2.1 m	97.3 Mb	Flight Path 26
c28rot.lan	3,000	2.1 m	99.3 Mb	Flight Path 28
c29rot.lan	3,000	2.1 m	23.8 Mb	Flight Path 29
April 13, 1992 (6000 feet)				
c25rot.lan	6,000	4.3 m	76.4 Mb	Flight Path 25
c27rot.lan	6,000	4.3 m	75.9 Mb	Flight Path 27
c29rot.lan	6,000	4.3 m	71.8 Mb	Flight Path 29
c31rot.lan	6,000	4.3 m	70.9 Mb	Flight Path 31
c33rot.lan	6,000	4.3 m	72.3 Mb	Flight Path 33
c35rot.lan	6,000	4.3 m	66.8 Mb	Flight Path 35
c37rot.lan	6,000	4.3 m	40.0 Mb	Flight Path 37
s29.lan	6,000	4.3 m	19.3 Mb	Parcel A (north)
s31.lan	6,000	4.3 m	19.5 Mb	Parcel A (south)
March 19, 1994				
c11t1-rotate.lan	2,000	1.5 m	94.9 Mb	Flight Path 11
c13t1-rotate.lan	2,000	1.5 m	75.1 Mb	Flight Path 13
c15t1-rotate.lan	2,000	1.5 m	85.0 Mb	Flight Path 15
c17t1-rotate.lan	2,000	1.5 m	78.5 Mb	Flight Path 17
c19t1-rotate.lan	2,000	1.5 m	61.4 Mb	Flight Path 19
c21t1-rotate.lan	2,000	1.5 m	74.4 Mb	Flight Path 21
c23t1-rotate.lan	2,000	1.5 m	90.2 Mb	Flight Path 23
c25t1-rotate.lan	2,000	1.5 m	91.5 Mb	Flight Path 25
c27t1-rotate.lan	2,000	1.5 m	128.9 Mb	Flight Path 27
c29t1-rotate.lan	2,000	1.5 m	148.8 Mb	Flight Path 29
c33t1-rotate.lan	2,000	1.5 m	122.1 Mb	Flight Path 33
March 22, 1994				
c11t2-rotate.lan	2,000	1.5 m	163.4 Mb	Flight Path 11
c13t2-rotate.lan	2,000	1.5 m	158.4 Mb	Flight Path 13
c15t2-rotate.lan	2,000	1.5 m	132.1 Mb	Flight Path 15
c17t2-rotate.lan	2,000	1.5 m	147.2 Mb	Flight Path 17
c19t2-rotate.lan	2,000	1.5 m	148.8 Mb	Flight Path 19
c21t2-rotate.lan	2,000	1.5 m	134.6 Mb	Flight Path 21
c23t2-rotate.lan	2,000	1.5 m	96.8 Mb	Flight Path 23
c25t2-rotate.lan	2,000	1.5 m	100.4 Mb	Flight Path 25
c27t2-rotate.lan	2,000	1.5 m	59.8 Mb	Flight Path 27

c27t3-rotate.lan	2,000	1.5 m	26.2 Mb	Flight Path 27
c29t2-rotate.lan	2,000	1.5 m	62.2 Mb	Flight Path 29
c29t3-rotate.lan	2,000	1.5 m	29.4 Mb	Flight Path 29
c31t3-rotate.lan	2,000	1.5 m	28.3 Mb	Flight Path 31
c11t3-rotate.lan	6,000	1.5 m	35.2 Mb	Flight Path 11
c13t3-rotate.lan	6,000	1.5 m	47.5 Mb	Flight Path 13
c15t3-rotate.lan	6,000	1.5 m	53.1 Mb	Flight Path 15
c17t3-rotate.lan	6,000	1.5 m	62.8 Mb	Flight Path 17
c19t3-rotate.lan	6,000	1.5 m	59.0 Mb	Flight Path 19
c21t3-rotate.lan	6,000	1.5 m	50.8 Mb	Flight Path 21
c23t3-rotate.lan	6,000	1.5 m	41.0 Mb	Flight Path 23
c25t3-rotate.lan	6,000	1.5 m	41.5 Mb	Flight Path 25

4.2 RECTIFIED MSS IMAGERY

Name	Altitude (ft. AGL)	Pixel Size	File Size	Geographic Area
March 13, 1992				
wag4-mss-stp3.lan	6,000	3.0 m	1.3 Mb	WAG 4
March 22, 1994				
c11-13-stp1-cut.lan	2,000	1.0 m	51.9 Mb	Northwest K-25
c11-subset-stp1.lan	2,000	1.0 m	35.3 Mb	Northwest K-25
c13-subset-stp1.lan	2,000	1.0 m	34.5 Mb	West central K-25
c21-wag5-stp1.lan	2,000	1.0 m	6.2 Mb	WAG 5

4.3 LANDCOVER CLASSIFICATIONS AND DERIVATIVE IMAGERY

Name	Altitude (ft. AGL)	Pixel Size	File Size	Geographic Area
etec-cir-2deg.lan	6,000	5.0 m	1.9 Mb	DOE lease site 9
etec-clus-pc-2deg.gis	6,000	5.0 m	0.3 Mb	DOE lease site 9
etec-lc (Arc/Info coverage)	N/A	N/A	N/A	DOE lease site 9
etec-mss-pc3-2deg.lan	6,000	5.0 m	1.9 Mb	DOE lease site 9
etec-ndvi-2deg.lan	6,000	5.0 m	1.9 Mb	DOE lease site 9
etec-psclr-2deg.lan	6,000	5.0 m	1.9 Mb	DOE lease site 9
ornl-class.gis	6,000	4.3 m	0.9 Mb	South ORNL
ornl-prince.lan	6,000	4.3 m	21.8 Mb	South ORNL
s31a-10div7-7-5.lan	6,000	4.3 m	3.3 Mb	Parcel A / Haw Ridge
s31a-final-class.gis	6,000	4.3 m	0.6 Mb	Parcel A / Haw Ridge
s31a-ndvi-7-5.lan	6,000	4.3 m	3.4 Mb	Parcel A / Haw Ridge
s31a-prince.lan	6,000	4.3 m	16.4 Mb	Parcel A / Haw Ridge
wag4-class-stp3-subset.gis	6,000	3.0 m	0.1 Mb	WAG 4
wag4-prince-stp3-subset.lan	6,000	3.0 m	1.3 Mb	WAG 4

4.4 ANNOTATED MSS IMAGERY

Name	Altitude (ft. AGL)	Pixel Size	File Size	Geographic Area
north-roof-pic.lan	2,000	N/A	3.1 Mb	K-25 roof tops(north)
ornlclass-new-pic.lan	6,000	4.3	6.3 Mb	South ORNL
parcel-a-class.lan	6,000	8.6	3.1 Mb	Parcel A / Haw Ridge
rooftops.lan	2,000	N/A	11.5 Mb	K-25 rooftops
s31a-eastclass-pic.lan	6,000	4.3	3.1 Mb	Parcel A / Haw Ridge (east)
s31a-westclass-pic.lan	6,000	4.3 m	3.1 Mb	Parcel A / Haw Ridge (west)
south-roof-pic.lan	2,000	N/A	3.1 Mb	K-25 rooftops (south)
wag6-ndvi-annot.lan	6,000	N/A	1.2 Mb	WAG 6 and vicinity

Geographic Area Acronyms and Abbreviations:

WAG	Waste Area Grouping

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6. ACKNOWLEDGMENTS

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7. FURTHER INFORMATION AND CONTACTS

The authors of this report are available to answer questions on the ER daytime MSS survey imagery discussed in these pages and to provide further information on the ER Remote Sensing Program. They may be contacted by telephone, mail, or internet at the following addresses:

Mr. John L. Smyre
423-574-2968
P. O. Box 2008
Oak Ridge National Laboratory
Computational Physics and
Engineering Division
Bldg. 4500-N, MS-6274
Oak Ridge, TN 37831-6274
internet: smyrejl@ornl.gov

Dr. Michael E. Hodgson
423-241-5701
P. O. Box 2008
Oak Ridge National Laboratory
Computational Physics and
Engineering Division
Bldg. 4500-N, MS-6274
Oak Ridge, TN 37831-6274
internet: hodgsonme@ornl.gov

Mr. Brent W. Moll
423-574-6335
P. O. Box 2008
Oak Ridge National Laboratory
Computational Physics and
Engineering Division
Bldg. 4500-N, MS-6274
Oak Ridge, TN 37831-6274
internet: mollbw@ornl.gov

Ms. Amy L. King
423-576-1509
P. O. Box 2008
Oak Ridge National Laboratory
Computational Physics and
Engineering Division
Bldg. 4500-N, MS-6274
Oak Ridge, TN 37831-6274
internet: kingal@ornl.gov

Dr. Yang Cheng
423-241-5702
P. O. Box 2008
Oak Ridge National Laboratory
Computational Physics and
Engineering Division
Bldg. 4500-N, MS-6274
Oak Ridge, TN 37831-6274
internet: chengy@ornl.gov

Appendix

FIGURES

Figure Captions

Figure 1. Detailed view of Filled Coal Ash Pond (FCAP). The largely bare ground of the Y-12 landfill at the upper right (shades of blue) contribute clayey silt runoff to the northeast end of FCAP, located at the image center. Coniferous vegetation on Chesnut Ridge is depicted as dark green; jardwoods appear as shades of gray or pink.

Figure 2. Daytime Thermal Imagery (Daedalus AADS-1268 Band 11) of K-25 Plant. Roof tops and asphalt surfaces absorb heat from the sun much more readily than do larger water bodies such as Poplar Creek and Clinch River.

Figure 3A. Index MSS Flight Path Location Map of April 13, 1992 EG&G Overflight at 6000 feet AGL.

Figure 3B. Index MSS Flight Path Location Map of April 13, 1992 EG&G Overflight at 3000 feet AGL.

Figure 3C. Index MSS Flight Path Location Map of March 19, 1994 EG&G Overflight at 2000 feet AGL.

Figure 3D. Index MSS Flight Path Location Map of March 22, 1994 EG&G Overflight at 2000 feet AGL.

Figure 3E. Index MSS Flight Path Location Map of March 22, 1994 EG&G Overflight at 6000 feet AGL.

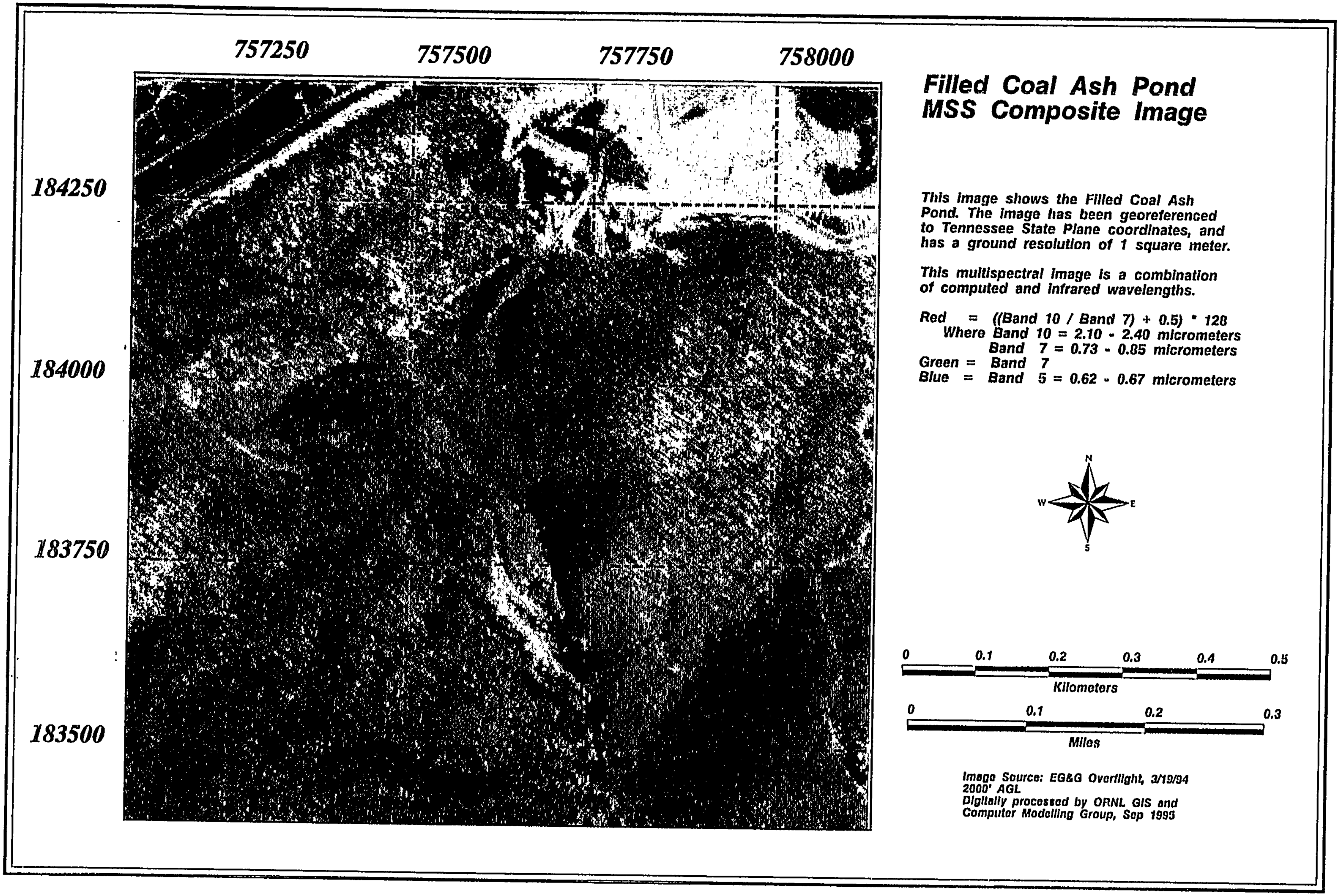
Figure 4. Principal Components Image of South Oak Ridge National Laboratory. The first three principal components are used as red, green, and blue components of a 24-bit color image.

Figure 5. Normalized Difference Vegetation Index Image of the Proposed ED-1 Land Transfer Site.

Figure 6. Ratio Composite Image of South Oak Ridge National Laboratory. Growing vegetation is depicted in green: growing grass as light green, dense pine stands as bright green, more scattered conifers as dark green. Dormant hardwoods appear as a pinkish grey, and water is shown as red.

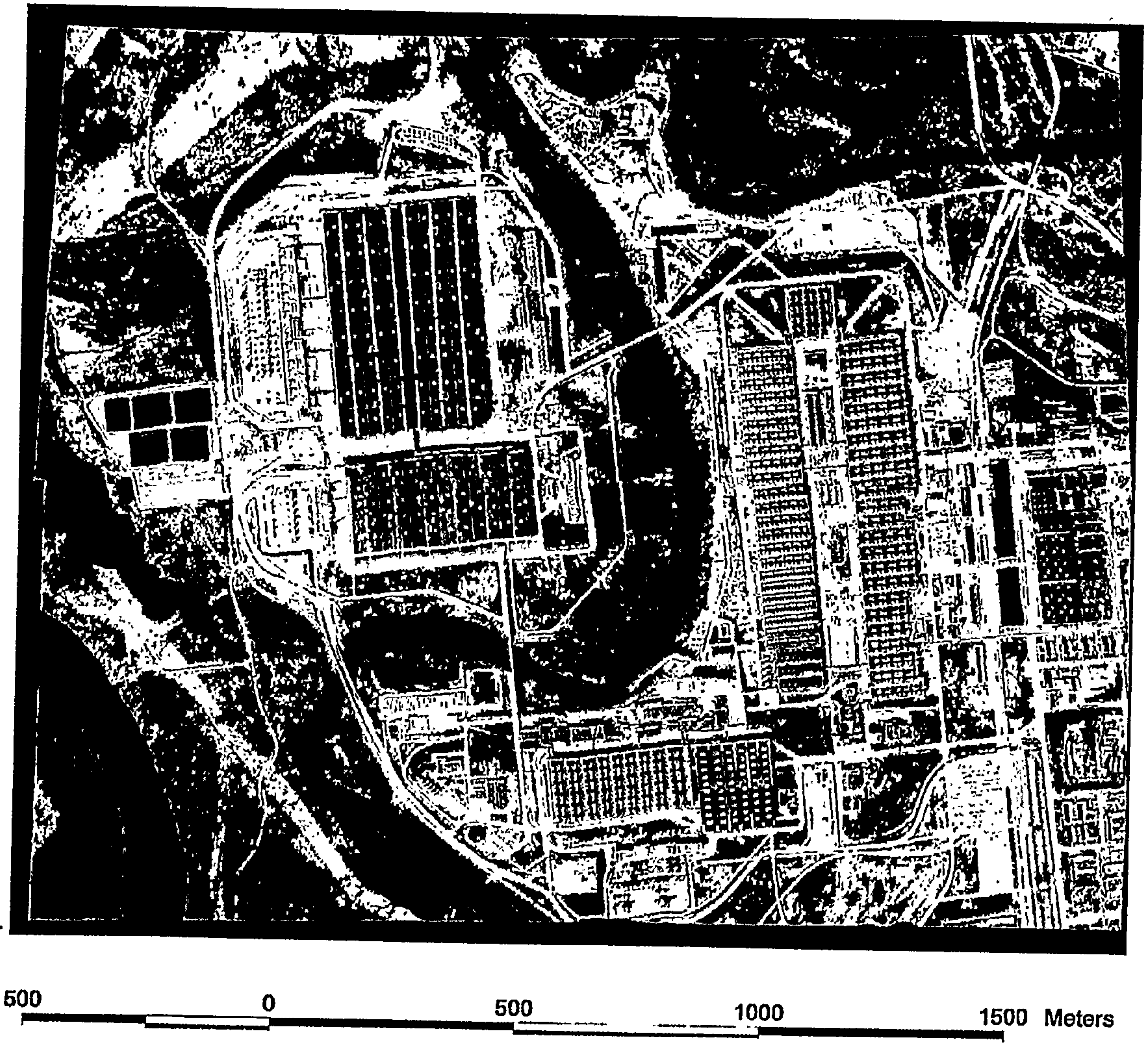
Figure 7. Landcover classification of south Oak Ridge National Laboratory. This classification was derived through principal components analysis and ISODATA clustering of the six principal components. Editing and smoothing were applied to spectral groupings, which were assigned to landcover classes.

Figure 8. Landcover classification of the Proposed ED-1 Land Transfer Site. This classification is derived from 6000 foot AGL 1994 multispectral imagery.



757250
757500
757750
758000
184250
184000
183750
183500
Filled Coal Ash Pond
MSS Composite Image
This image shows the Filled Coal Ash Pond. The image has been georeferenced to Tennessee State Plane coordinates, and has a ground resolution of 1 square meter.
This multispectral image is a combination of computed and infrared wavelengths.
Red = ((Band 10 / Band 7) + 0.5) * 128
Where Band 10 = 2.10 - 2.40 micrometers
Band 7 = 0.73 - 0.85 micrometers
Green = Band 7
Blue = Band 5 = 0.62 - 0.67 micrometers
N
W
E
S
0
0.1
0.2
0.3
0.4
0.5
Kilometers
0
0.1
0.2
0.3
Miles
Image Source: EG&G Overflight, 3/19/94
2000' AGL
Digitally processed by ORNL GIS and Computer Modelling Group, Sep 1995

Figure 1.



Rectified Daytime Thermal IR Mosaic
of Northwest K-25 Plant

2000 Foot Altitude MSS Band 11 Imagery,
March 22, 1994 (flight paths 11 and 13)

Data acquired by EG&G/EM, Las Vegas, NV
for the ER Remote Sensing Program

Processing by
GIS and Computer Modeling Group
Computational Physics and Engineering Division
Oak Ridge National Laboratory

Sensor brightness values coded from cooler temperatures (blue) to warmer temperatures (red)

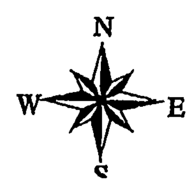


Figure 2.

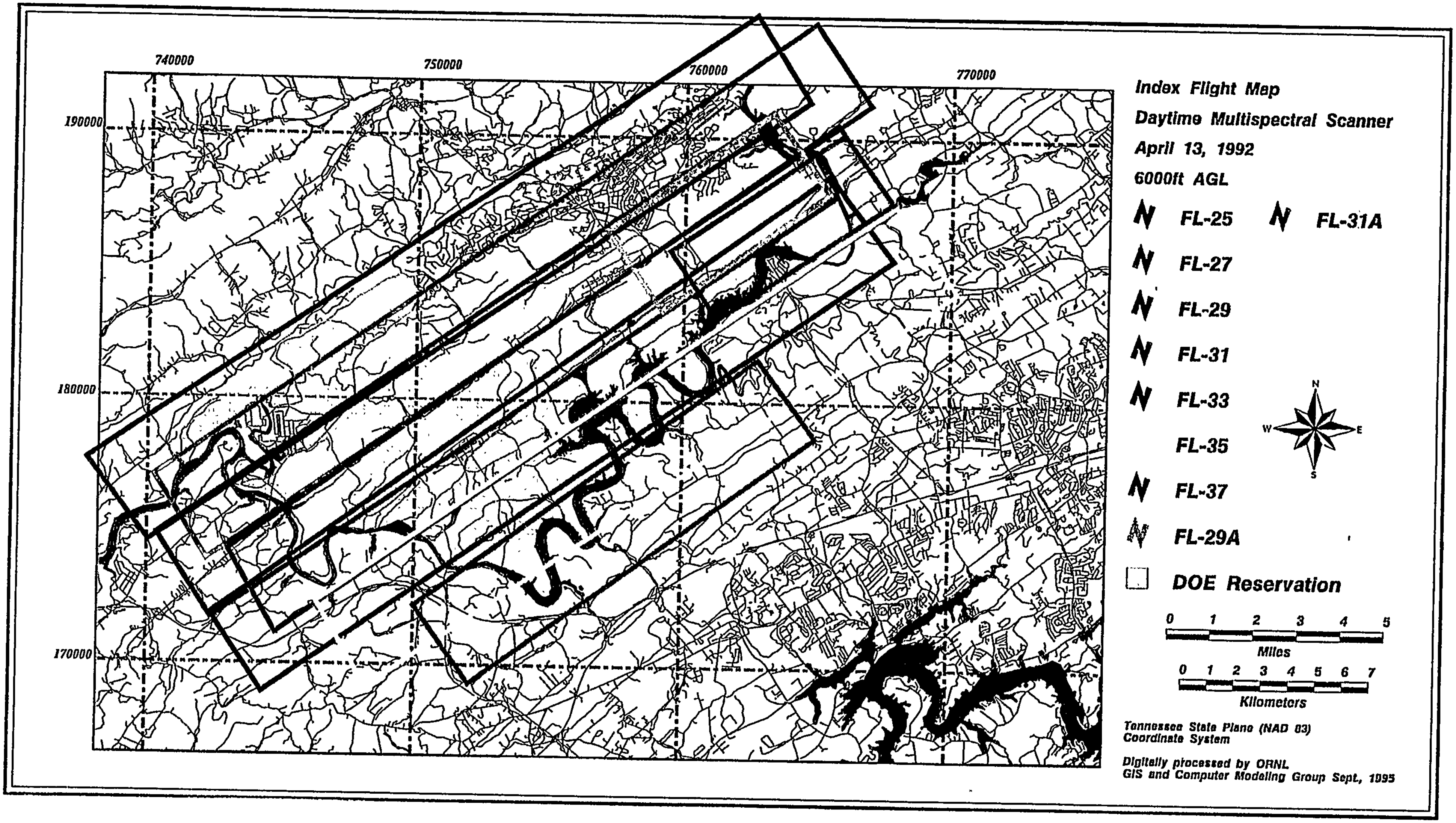
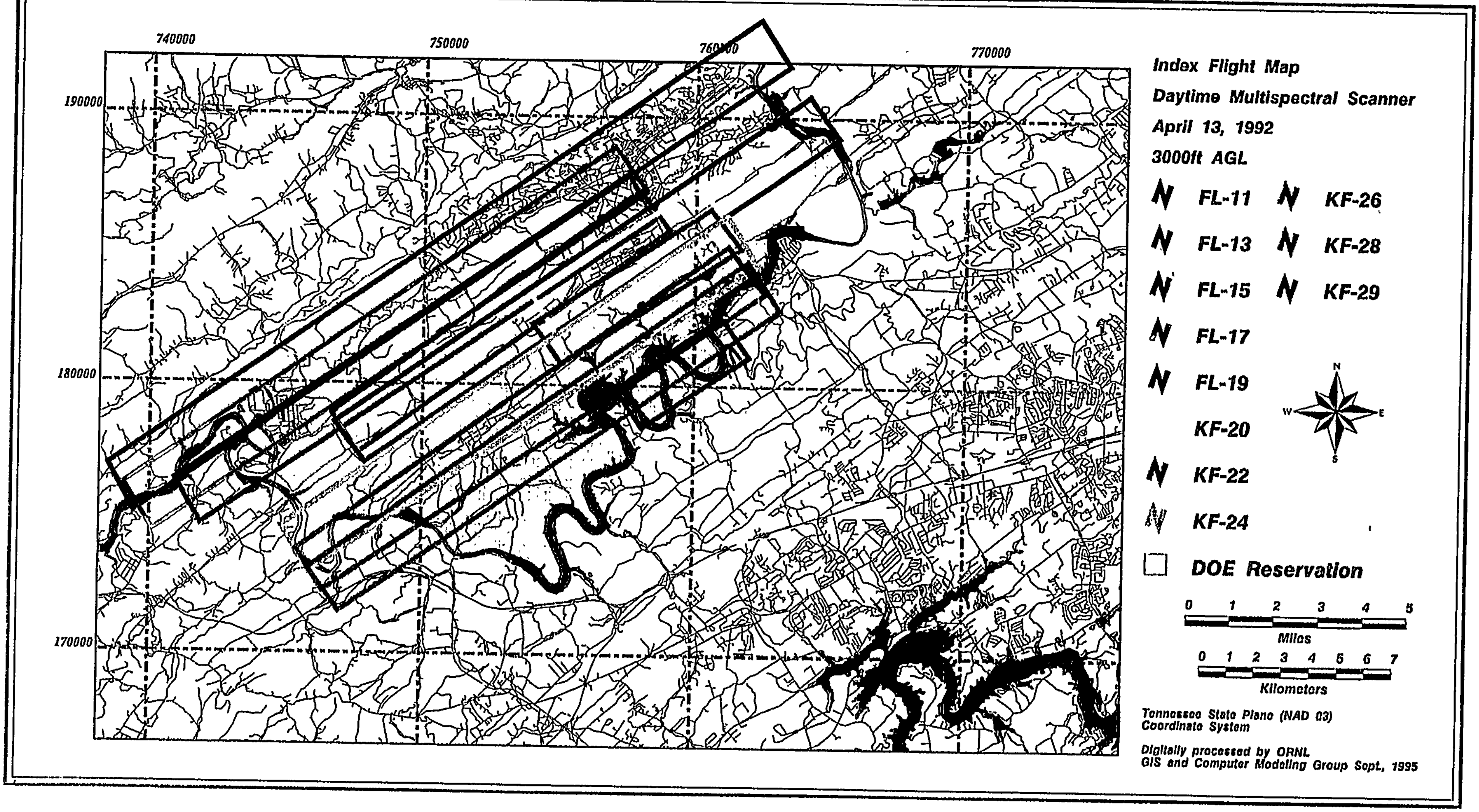
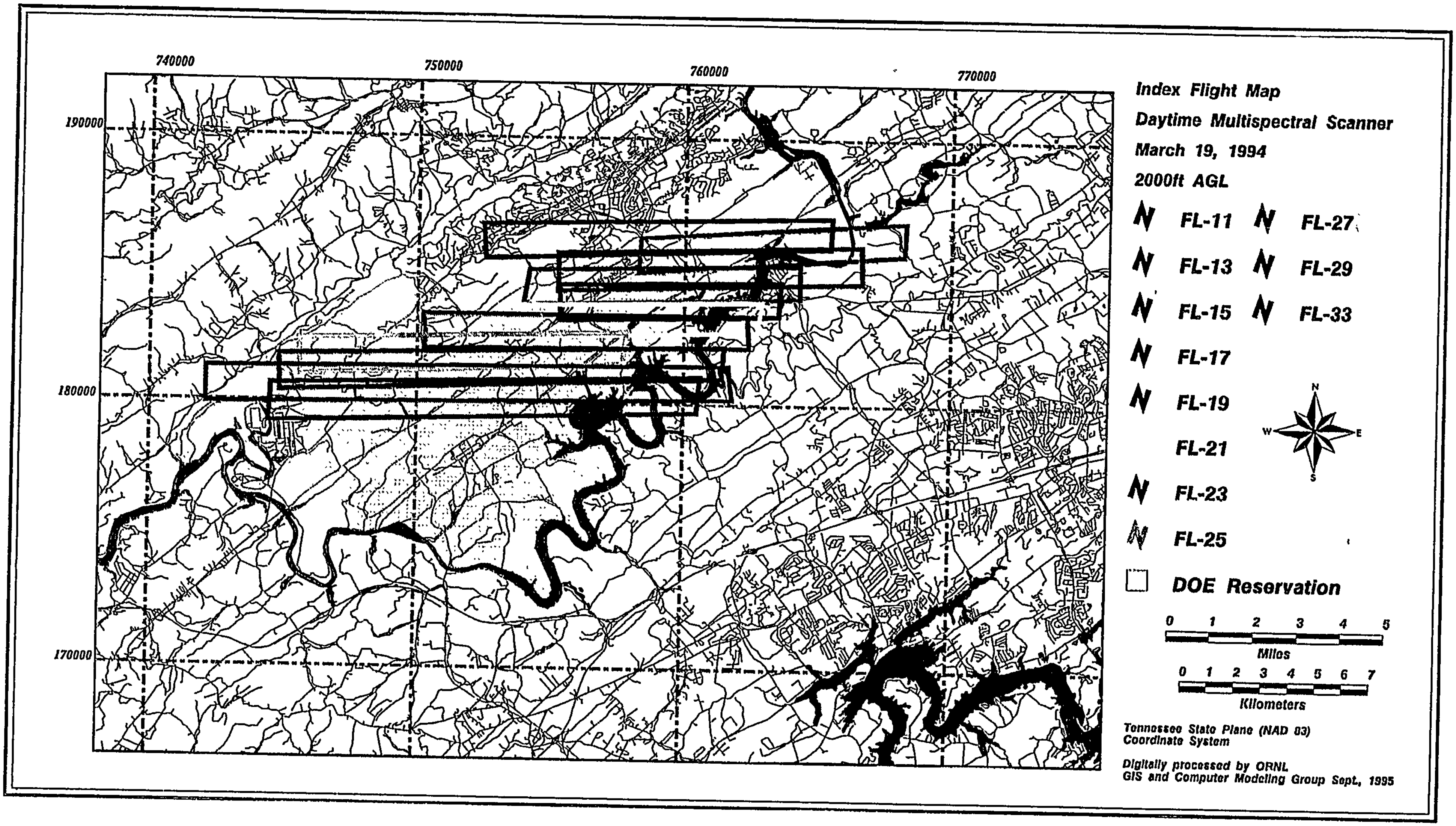

Index Flight Map
Daytime Multispectral Scanner
April 13, 1992
6000ft AGL
FL-25
FL-27
FL-29
FL-31
FL-33
FL-35
FL-37
FL-29A
FL-31A
DOE Reservation
Miles
Kilometers
Tennessee State Plane (NAD 83) Coordinate System
Digitally processed by ORNL GIS and Computer Modeling Group Sept, 1995
740000
750000
760000
770000
190000
180000
170000

Figure 3A.



740000
750000
760000
770000
190000
180000
170000
Index Flight Map
Daytime Multispectral Scanner
April 13, 1992
3000ft AGL
FL-11
FL-13
FL-15
FL-17
FL-19
KF-20
KF-22
KF-24
KF-26
KF-28
KF-29
N
W
E
S
DOE Reservation
0 1 2 3 4 5
Miles
0 1 2 3 4 5 6 7
Kilometers
Tennessee State Plane (NAD 83)
Coordinate System
Digitally processed by ORNL
GIS and Computer Modeling Group Sept, 1995

Figure 3B.



740000
750000
760000
770000
190000
180000
170000
Index Flight Map
Daytime Multispectral Scanner
March 19, 1994
2000ft AGL
FL-11
FL-13
FL-15
FL-17
FL-19
FL-21
FL-23
FL-25
FL-27
FL-29
FL-33
DOE Reservation
N
W
E
S
0 1 2 3 4 5
Miles
0 1 2 3 4 5 6 7
Kilometers
Tennessee State Plane (NAD 83)
Coordinate System
Digitally processed by ORNL
GIS and Computer Modeling Group Sept., 1995

Figure 3C.

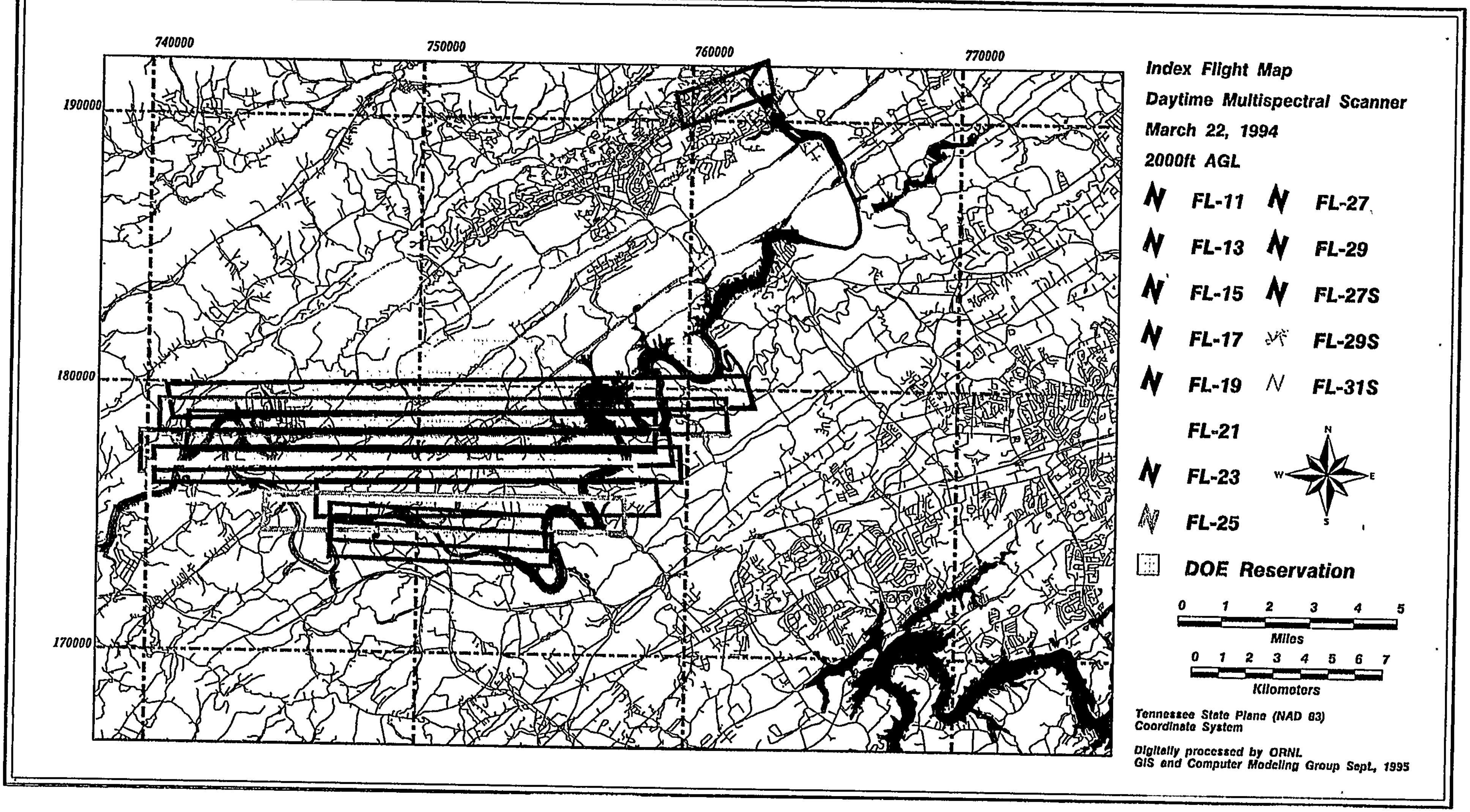
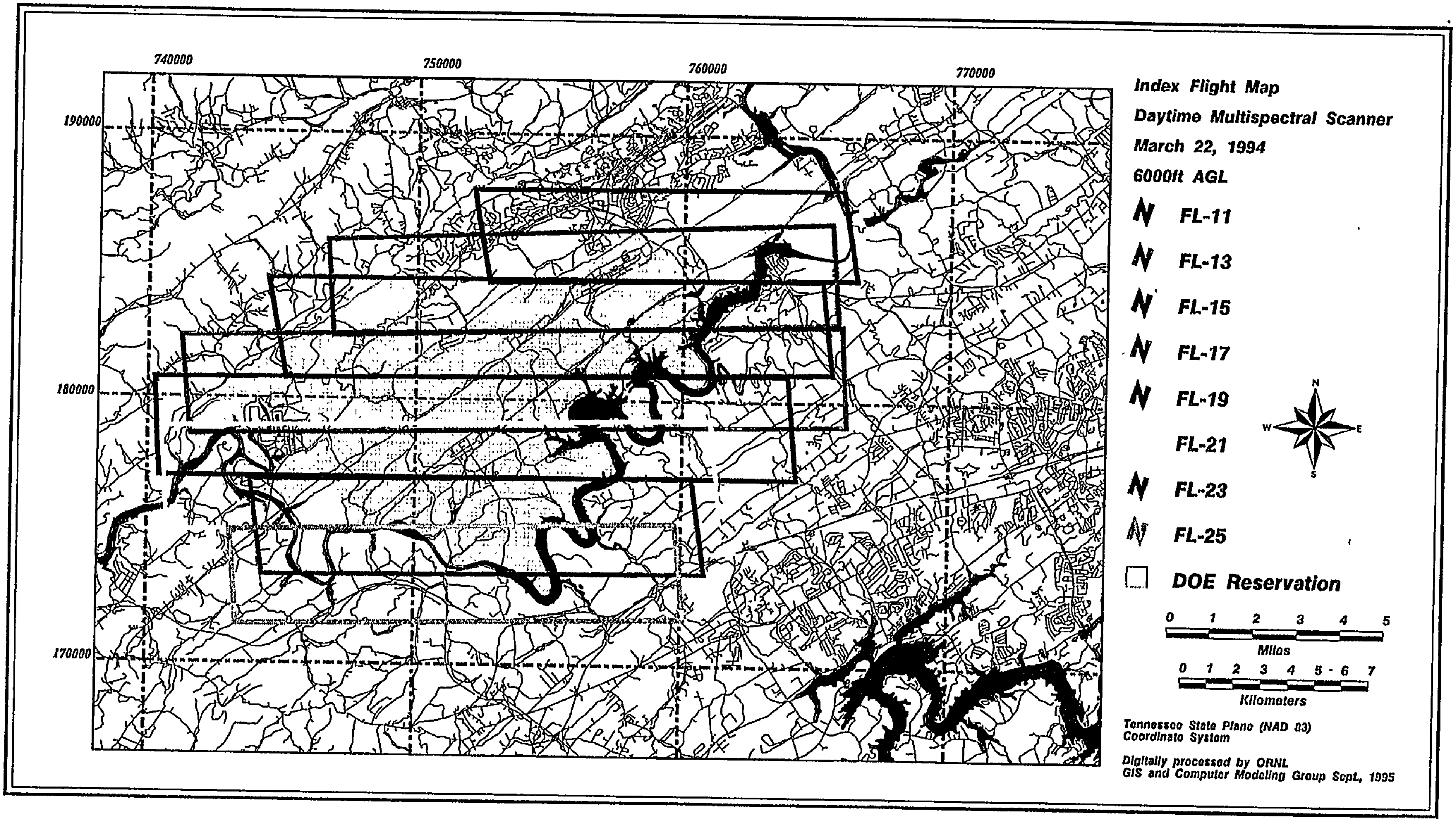

740000
750000
760000
770000
190000
180000
170000
Index Flight Map
Daytime Multispectral Scanner
March 22, 1994
2000ft AGL
FL-11
FL-13
FL-15
FL-17
FL-19
FL-21
FL-23
FL-25
FL-27
FL-29
FL-27S
FL-29S
FL-31S
N
W
E
S
DOE Reservation
0 1 2 3 4 5
Miles
0 1 2 3 4 5 6 7
Kilometers
Tennessee State Plane (NAD 83)
Coordinate System
Digitally processed by ORNL
GIS and Computer Modeling Group Sept., 1995

Figure 3D.


Index Flight Map
Daytime Multispectral Scanner
March 22, 1994
6000ft AGL
FL-11
FL-13
FL-15
FL-17
FL-19
FL-21
FL-23
FL-25
DOE Reservation
740000
750000
760000
770000
190000
180000
170000
N
S
E
W
0 1 2 3 4 5
Miles
0 1 2 3 4 5 6 7
Kilometers
Tennessee State Plane (NAD 83) Coordinate System
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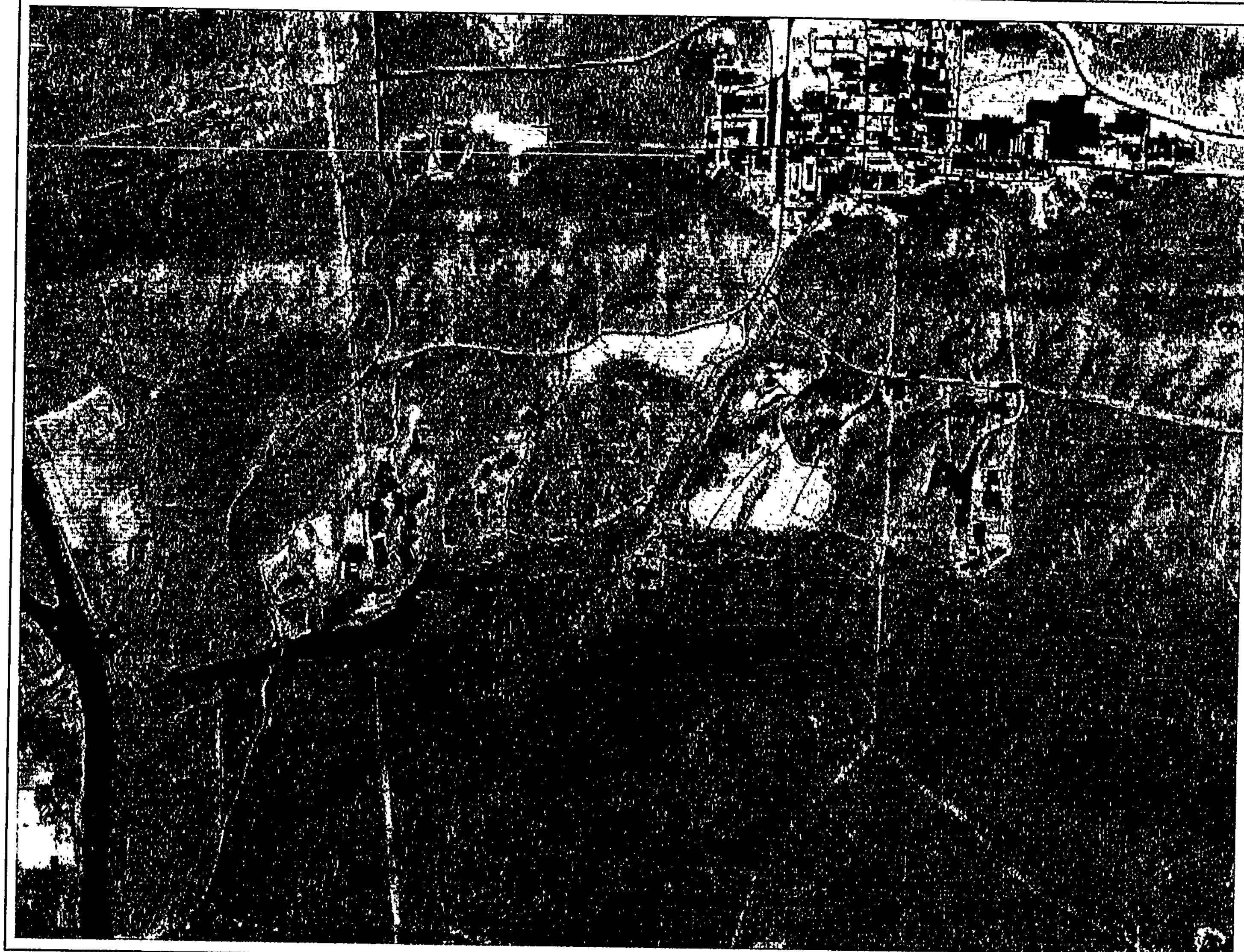

Principal Components Analysis of South Oak Ridge National Laboratory

Derived from MSS Imagery
Flown at 6000 feet altitude
by EG&G/EM, Las Vegas, NV
April 13, 1992

for

the ER Remote
Sensing Program

The three principal components are depicted as false color imagery (R = 1st component, G = 2nd component, B = 3rd component).

Processing by
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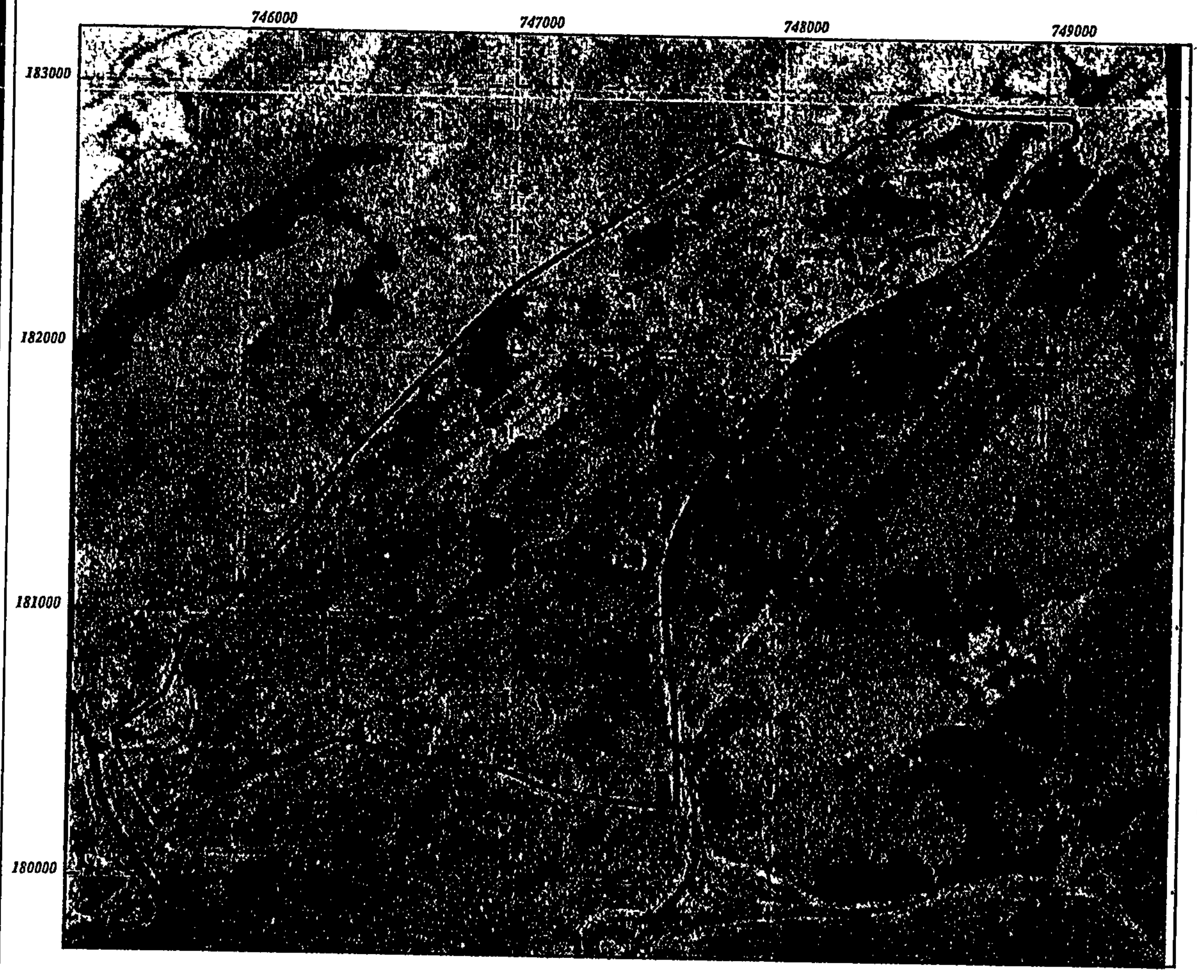
CP & E Division
Oak Ridge National Laboratory
August, 1995



Proposed ED-1 Land Transfer Site

Normalized-Difference Vegetative Index

This map depicts the proposed ED-1 land transfer area. The boundary of the site on this map is overlaid on an aerial image of the site obtained from the Daedalus Aircraft Multispectral Scanner.

Vegetation Index [VI] computation is a method of highlighting areas of high amounts of biomass. The intensity of the biomass is indicated by the high infrared reflectiveness of vegetation. In this image, high biomass is indicated in red tones.

This Normalized-Difference VI image was generated by digitally using the following equation:

Red = (MSS7 - MSS5)/(MSS7 + MSS5)
Green = MSS4
Blue = MSS2

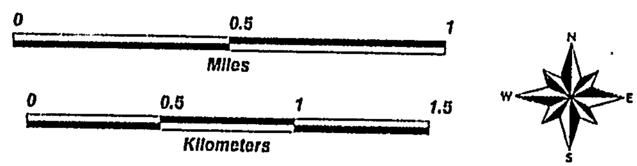
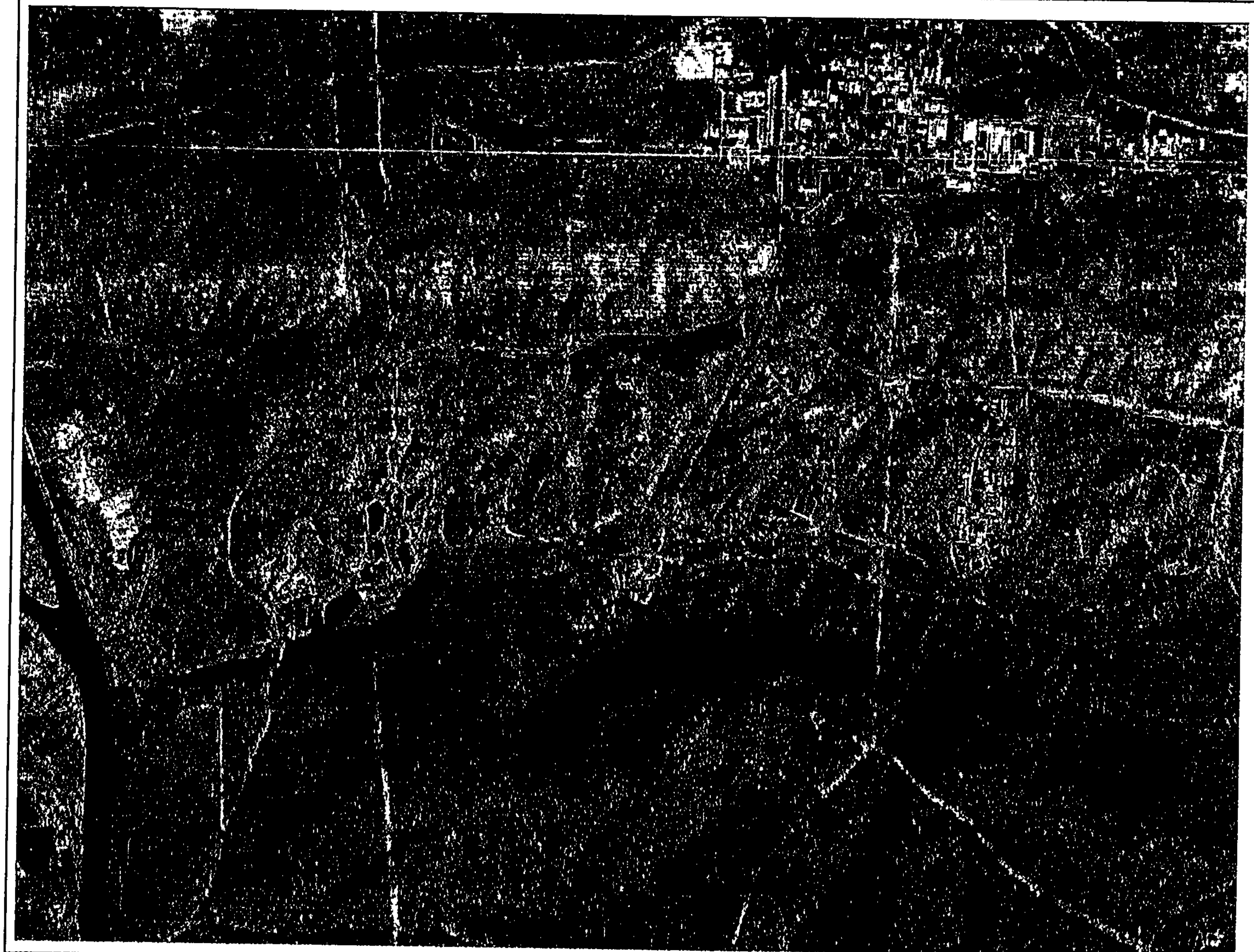


Image Source: Daedalus AADS-1268 6000ft overflight, March 1994, NDVI,MSS4,MSS2 (R,G,B) Digitally processed by ORNL GIS and Computer Modeling Group, July 1995

Figure 5.



Ratio Composite Image of South Oak Ridge National Laboratory

Derived from MSS Imagery
Flown at 6000 feet altitude
by EG&G/EM, Las Vegas, NV
April 13, 1992

for

the ER Remote
Sensing Program

The false color image uses Daedalus bands 10, 7, and 5 to display red, green, and blue components as follows:

(Red = Band 10 / Band 7,
Green = Band 7,
Blue = Band 5).

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Oak Ridge National Laboratory
August, 1995

Figure 6.

Derived from MSS Imagery
Flown at 6000 feet altitude
by EG&G/EM, Las Vegas, NV
April 13, 1992

for

the ER Remote
Sensing Program

A principal components analysis was first performed to reduce redundancy in the 12-band Daedalus AADS-1268 multispectral imagery. An unsupervised ISODATA clustering technique was then employed on the six principal components containing more than 99% of the spectral information. The derived spectral groups were assigned to landcover classes, and the classification was edited interactively and smoothed to create the final classification.

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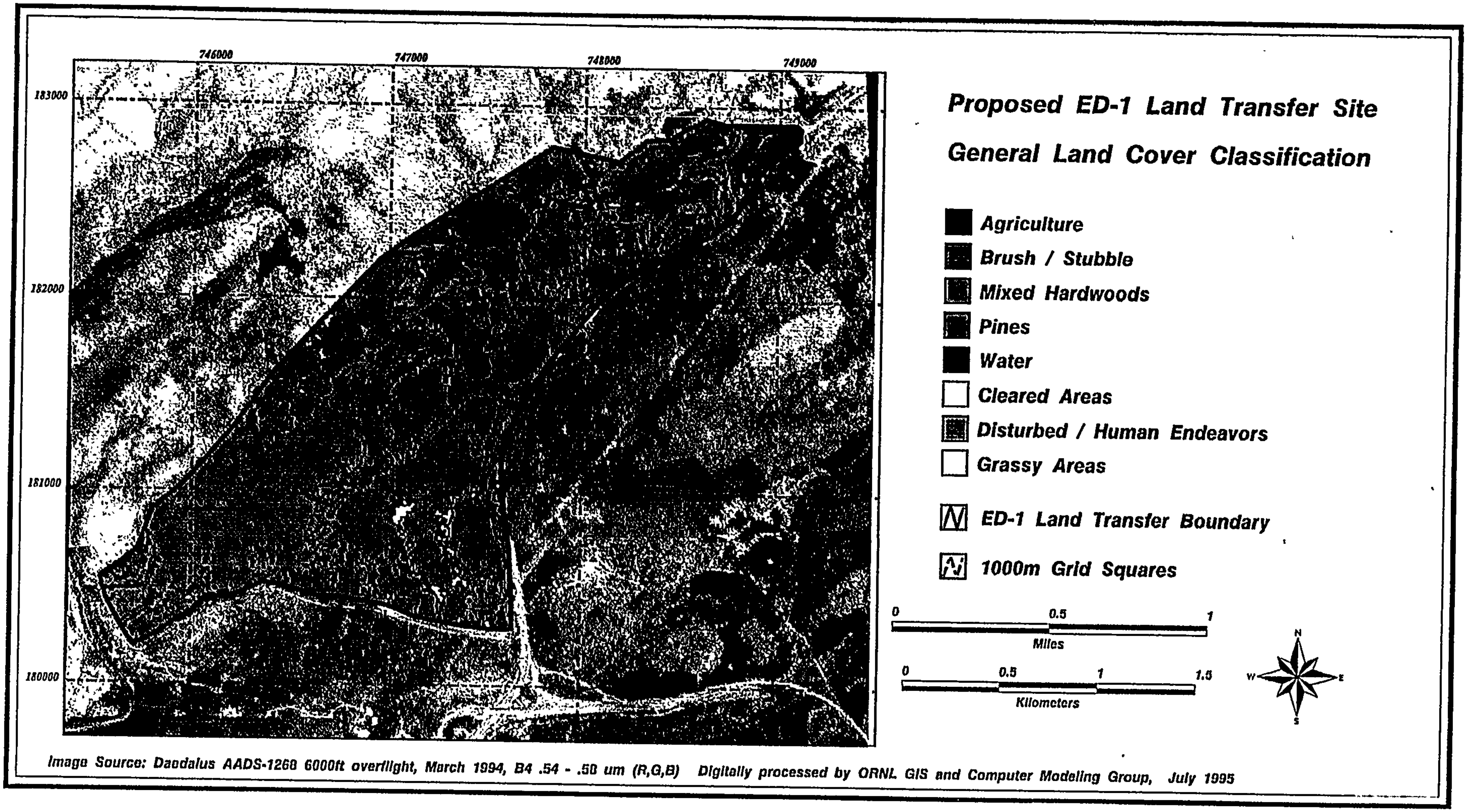
CP & E Division
Oak Ridge National Laboratory
August, 1995

Figure 7.



746000
747000
748000
749000
183000
182000
181000
180000
Proposed ED-1 Land Transfer Site
General Land Cover Classification
Agriculture
Brush / Stubble
Mixed Hardwoods
Pines
Water
Cleared Areas
Disturbed / Human Endeavors
Grassy Areas
ED-1 Land Transfer Boundary
1000m Grid Squares
0
0.5
1
Miles
0
0.5
1
1.5
Kilometers
N
S
E
W
Image Source: Daedalus AADS-1268 6000ft overflight, March 1994, B4 .54 - .58 um (R,G,B) Digitally processed by ORNL GIS and Computer Modeling Group, July 1995

Figure 8.

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