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Conference on Energy Resource Management

Proceedings

Vol. II - Applications

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Proceedings of a working group meeting held at Baltimore, Maryland September 9-12, 1982

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National Conference on Energy Resource Management

Vol. II – Applications

Theme: Integration of Remotely Sensed Data with Geographic Information Systems for Application in Energy Resource Management

Proceedings of a working group meeting
Sponsored by Energy Planning Division
A Division of the American Planning Association
National Aeronautics and Space Administration
Nuclear Regulatory Commission
and U.S. Region of the Remote Sensing Society
September 9-12, 1982

'82
ENERGY RESOURCE
MANAGEMENT 1982

NASA
National Aeronautics
and Space Administration

Scientific and Technical
Information Branch

ENERGY RESOURCE MANAGEMENT

PROCEEDINGS OF THE NATIONAL CONFERENCE ON ENERGY RESOURCE MANAGEMENT
Integration of Remotely Sensed Data with Geographic Information Systems for Application in Energy Resource Management

VOLUME I: TECHNIQUES, PROCEDURES AND DATA BASES

VOLUME II: APPLICATIONS

Edited by James O. Brumfield and Yale M. Schiffman

All papers submitted for the presentation at the National Conference on Energy Resource Management for the subsequent publication in these Proceedings have been reviewed, first on the basis of the abstracts and then on the basis of the final manuscripts. The authors copies were submitted camera ready and are presented essentially as we received them. Several full length papers were not received in time for inclusion thus we have taken the liberty of including the abstract. You may wish to contact the authors of those abstracts directly for further information. Inclusion of the paper in the Proceedings in no way constitutes an endorsement by the American Planning Association's Energy Planning Division nor by the sponsors of this conference of the authors' views and opinions.

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TENTATIVE SCHEDULE OF FUTURE MEETINGS

August 23 - 27, 1983	Hyatt Regency, San Francisco, CA
January/February, 1984	Rio de Janiero, Brazil
September, 1984	Boston, MA
April/May, 1985	London, England (in conjunction with International Remote Sensing Society Annual Meeting)
September, 1985	San Francisco, CA

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Pre-Conference Workshops

Four pre-conference workshops were offered on the afternoon of September 9, 1982. These workshops were designed to broaden the understanding of participants in the areas of remote sensing, geographic information systems, energy resource management and energy facility siting. They lasted approximately 2 hours.

I. ENERGY RESOURCE MANAGEMENT
Yale M. Schiffman, Schiffman Energy Services

This workshop provided a broad overview of energy resource management and explored the range of data needs for implementation of this type of a program in residential/commercial, industrial and utility sectors.

II. REMOTE SENSING
Dr. Nicholas M. Short, NASA/Goddard Space Flight Center

This workshop provided an introduction and overview of remote sensing; its history, and what it is today. The electromagnetic spectrum, spectral signatures, and basic energy relationships were discussed. Photographic and non-photographic remote sensing systems were also explored along with several image analysis options.

III. GEOGRAPHIC INFORMATION SYSTEMS
Chuck Killpack, IRIS International, Inc.
William J. Campbell, NASA/Goddard Space Flight Center

This workshop explored the concepts underlying Geographic Information Systems. GIS data bases were discussed. Emphasis was placed on guidelines for establishing a practical GIS system for energy resource management.

IV. ENERGY FACILITY SITING
Rod Heller, Wirth Associates

Current practices by the industry on approaches to site screening, evaluation and selection were discussed. The types of data needed, traditional sources and limitations of different systems were also explored.

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VOLUME II - APPLICATIONS

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PREFACE

These proceedings contain a selection of papers presented at the National Conference on Energy Resource Management which was held at the Baltimore Hilton Hotel, Baltimore, Maryland, September 9-12, 1982. The papers cover a wide variety of subject areas related to the conference theme, "Integration of Remotely Sensored Data With Geographic Information Systems for Application in Energy Resource Management," and describe the current trends and advances in the application of these systems to a number of energy concerns.

The APA Energy Planning Division co-sponsored the National Conference on Energy Resource Management with the National Aeronautics and Space Administration, the Nuclear Regulatory Commission, and the U.S. Region of the Remote Sensing Society. The conference brought together for the first time a number of professionals in such diverse fields as remote sensing, geographic information systems, information systems, urban and regional planning, fish and wildlife management, geography, cartography, systems analysis and resource extraction to name a few. The audience also had an international flavor with representatives from India, South America, Africa, Europe, Canada, Asia, and the United States. In all, nearly two hundred professionals met to exchange information and ideas regarding the information needs to manage energy and natural resources that are used as feedstock, materials or special resources in support of energy development. Seventeen exhibitors displayed some of the latest hardware, software and services for use in resource management.

On September 9, several preconference tutorials were given to provide a more detailed understanding of remote sensing, geographic information systems, energy resource management, and facility siting. September 10 was the opening session of the conference which v s chaired by Yale M. Schiffman, President of the Energy Planning Division. Sharing the responsibilities for running the meeting was Dr. James Brumfield, Director of the Marshall University Remote Sensing Program and Mr. William J. Campbell, Project Manager ERRSAC, NASA Goddard, Space Flight Center. Dr. John MacElroy, Assistant Administrator for Satellites, NOAA, U.S. Department of Commerce was the keynote speaker. Dr. MacElroy took this opportunity to make the first public announcement of NOAA's plans to commercialize the Landsat Satellite Program and also mentioned that similar plans are being evaluated for the nation's weather satellites. The closing session of the conference held Sunday, September 12, was chaired by Dr. Phil Cressy, Head of ERRSAC/NASA, Dr. Richard Kott, Senior Staff Member--U.S. DOE, Dr. Ray Harris, Honorable General Secretary of the Remote Sensing Society, Mr. Schiffman and Dr. Brumfield.

The meeting closed on a positive note indicating that that there was indeed a need to continue dialog by specialists from this wide array of interests. The emphasis should be on improving the communication between the user community and the software, hardware and analytical support specialists in the field. Thus, this meeting serves as the starting point for a continuing series on the subject, the next which will be held in San Francisco, August 23-27, at the Hyatt Regency at Embacadero and in early 1984 in Rio de Janeiro, Brazil.

The interdisciplinary oriented conference provided a forum for presenting and discussing scientific works in the areas of energy resource management, remote sensing, geographic information systems, other georeferenced data systems, environmental analysis and applied systems research. Nearly 200 scientists, engineers, planners, and other professionals from eight countries contributed to these proceedings which were held over a three-day period, and in which nearly 100 presentations were given, most of which are included in these proceedings. These papers will undergo an additional rigorous review by our editorial committee. The purpose of the additional review is to select a limited number of papers for inclusion in a state of the art, hard covered publication that will be published in 1983.

Since the main theme of the conference was "The Integration of Remotely Sensed Data With Geographic Information Systems for Application in Energy Resource Management," a large number of papers are included in Volume I and II that deal with this topic. The proceedings have been organized along subject lines rather than in order of presentation. The editors felt the information would be more useful to the readers if organized in this fashion. These papers examine, in Volume I, the techniques and procedures that have been used to integrate remotely sensed data with geographic information systems, while in Volume II the papers explore the topic from an applications focus. Many papers also explore the integration of remotely sensed data with other georeferenced data systems. The proceedings clearly reflect the trends to integrate remotely sensed data with a number of different georeferenced data systems and illustrate an emerging interest among a number of different specialties in energy resource management for use of these integrated data systems in environmental assessment, facility siting, and facility planning.

There also appears to be a strong interest in developing countries for the acquisition and utilization of low to moderate cost hardware and software for resource management. It is the opinion of the editors that this conference brought together a mix of professionals -- the providers of hardware and software and the users -- that needed to communicate with one another. The conference provided the proper setting for an exchange of information to take place, which will serve to improve the understanding of each other's needs in this emerging field.

We believe that what was started at the NASA-Ames Research Center in 1981 and expanded threefold in Baltimore by NASA-Goddard Space Flight Center's ERRSAC group will tremendously expand the domain and research activities of the specialists involved in resource management in the years to come.

As mentioned earlier, the conference proceedings are divided into two volumes. Volume I covers techniques, procedures and data bases while Volume II focuses on applications. Volume I is presented in two parts. Part 1 examines the techniques and procedures for extraction or reduction of data. Several papers compare techniques and procedures and data sources. Part 2 examines the process of integrating remotely sensed and other georeferenced data bases into geographic information systems for use in modeling and resource management applications. This is accomplished primarily by examining case studies and demonstration projects. Volume II is presented in five parts and is applications oriented. Part 1 examines the application of these systems to energy and environmental resource management. Part 2 describes the systems use in energy facility siting, while Part 3 examines its use in reclamation and surface mining. We also felt that this Volume would provide an appropriate framework for the examination of these systems use in various countries throughout the world. Several technique and procedure papers within an international context are also presented in Part 4. There were several

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symposia and user forums presented throughout the conference and these are presented in Part 5. At the end of each Volume we have included the abstracts of the related poster sessions.

The wide spectrum of topics covered in these proceedings indicate that systems research techniques and procedures related to remotely sensed data and other georeference data bases for integration with geographic information systems are being increasingly applied to a larger number of resource management applications where they are helping us improve our ability to manage a finite set of the earth's resources in an environmentally sound manner.

In conclusion, the greatest contributions of these proceedings are that they help us create greater awareness of the issues among the designers and users of geographic information systems and georeferenced data bases. We hope that this will motivate each of us to devote more effort to this field and expand our interests even further in future meetings.

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ACKNOWLEDGEMENTS

I would like to express my thanks to all of the participants of the National Conference on Energy Resource Management for making this a successful conference and for submitting papers of excellent quality. I would also like to express my thanks to the members of the conference and paper review committees whose efforts contributed measurably to the success of the Conference.

My special thanks goes to Jim Brumfield of MURSAC, Bill Campbell of ERRSAC, Jimmie Weber of NASA--Headquarters, Rob Tanenhaus of IMI, and Germaine LaRouche of NRC, who were responsible for planning major segments of the Conference agenda. Bill, in particular, was responsible for planting the seeds from which this meeting grew. Many thanks to Dr. John McElroy who gave us the moral and fiscal support we needed at the early stages of conference planning. Thanks again to Jim Brumfield and Bill Campbell for their help in chairing the meeting. My special thanks also goes to Drs. Phil Cressy of ERRSAC, Dick Kott, and Ray Harris who helped us tie the various conference subthemes together in a coherent manner at our wrap-up session.

Many thanks to Chuck Killpack of IRIS International, Nicholas Short of NASA, and Rod Heller of Wirth Associates for their efforts in planning and conducting the pre-conference workshops.

A special thanks to the following chairpersons for their efforts in organizing a fine series of technical discussions: Jim Wray of USGS and George Jones of

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Princess Coal--Use of Remotely Sensed Data and Geographic Information Systems for Energy Resource Management; William Campbell of ERRSAC and Ronald Ballard of NRC--Remote Sensing and Geographic Information Systems for Environmental Information Needs; Charles Cushwa of the Fish and Wildlife Service, Germain LaRouche of NRC, and Calvin DuBrock of the Pennsylvania Game Commission--Use of Remote Sensing for Environmental Analaysis; Major Brian Lenz of the U.S. Air Force--Energy Management in the U.S. Air Force; Daniel Cotter and Russell Koffler of NOAA--Landsat Users Forum; Ray Harris, the Honorable General Secretary of the Remote Sensing Society and Joe Berry of Yale University--Use of Remote Sensing and Geographic Information Systems for Integration and Modeling; Brian Turner of ORSER, Scott Cox of NASA and John Estes of the University of California--Remote Sensing: Techniques and Procedures; Germain LaRouche of NRC and Ram Singh of the Department of Treasury--Use of Remote Sensing for Environmental Analysis; Robert Tanenhaus of Implementation Management International and Jimmie Weber of NASA Headquarters--Remote Sensing for Energy Resource Management, an International Perspective; Sue Norman and Dave Mouat of NASA--Energy Resource Management Data Bases; Rod Heller of Wirth Associates--Power Plant Siting; Herb Blodget and Marc Imhoff of NASA--Use of Remote Sensing for Reclamation and Surface Mining; and thanks to those who designed and conducted the poster sessions.

I am grateful for the support of the American Planning Association, U.S. Nuclear Regulatory Commission, NASA Goddard Space Flight Center--ERRSAC, and the U.S. Region of the Remote Sensing Society.

On behalf of the American Planning Association's Energy Planning Division, I would like to gratefully acknowledge the financial support of NASA Goddard

Space Flight Center--ERRSAC for the front end costs of this conference and the resources they are committing to the publication of these proceedings.

I would also like to thank the following exhibitors for the confidence they expressed in our conference and for their financial support: Earth Satellite Corporation of Chevy Chase, MD; U.S. National Oceanic and Atmospheric Administration of Washington, DC; Schiffman Energy Services, Inc. of Springfield, VA; U.S. Geological Survey of Reston, VA; Greenhorne and O'Mara, Inc. of Riverdale, MD; IRIS International, Inc. of Landover, MD; Computer Science Corporation of Silver Spring, MD; and Rogers, Golden and Halpern of Philadelphia, PA.

My gratitude to Diane Kugelmann of the NASA Goddard Space Flight Center, ERRSAC who shepherded the various conference mailings and related data through the system so that we could maintain schedule.

Our thanks to the Baltimore Convention Bureau, and Trina Mello and Gary Flowers of the Baltimore Hilton for their fine efforts on our behalf.

My deepest gratitude goes to Monique Gormont of the Energy Planning Division who devoted many hours to all the small details and who handled the conference logistics, luncheons, audio visual aids, printing and directed the secretarial staff, and it is largely to her credit that all went so smoothly at the Conference. Thanks also to Pam Moore of APA who pitched in the last weeks to help us with the final details of the Conference.

Yale M. Schiffman
Conference Chairperson
President of APA Energy Planning Division
Executive Director of the Center for Earth Resource Management Applications

November, 1982

Part 1

USE OF REMOTELY SENSED DATA AND GIS

FOR ENERGY AND ENVIRONMENTAL RESOURCE MANAGEMENT

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COMPARISON OF LAND COVER INFORMATION FROM LANDSAT MSS AND AIRBORNE TMS FOR HYDROLOGICAL APPLICATIONS: PRELIMINARY RESULTS

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ABSTRACT

Land cover information for the Clinton River Basin (Michigan) derived from Landsat Multispectral Scanner (MSS) data was compared with that from airborne Thematic Mapper Simulator (TMS) to investigate the probable capabilities of the Thematic Mapper (TM) launched aboard Landsat-4 in July 1982. This paper reports the preliminary findings for one 7.5 minute topographic map, Mt. Clemens West. Significant improvements in land cover classification accuracy were obtained using TMS data as compared with MSS data. Overall mapping accuracy increased from 49 to 61 percent with an improvement from 71 to 84 percent in the residential category. A combination of four bands with one band in each major region of the spectrum (visible, near IR, middle IR and thermal IR) provided as good a discrimination of land cover as all seven TM bands. Based on the improved land cover classification accuracy of TM, TM data has the potential to provide more useful and effective input to US Army Corps of Engineers flood forecasting and flood damage prediction/assessment models.

1.0 INTRODUCTION

In a cooperative program with the US Army Corps of Engineers, NASA is evaluating the capabilities of Landsat-4 Thematic Mapper (TM) data for environmental and hydrologic applications. The spectral and spatial characteristics of the TM considerably exceed those of the Multispectral Scanner (MSS) carried by all Landsat satellites (Table 1), but the complexity and cost of analyzing TM data may make MSS data an attractive alternative for certain applications. Both NASA and the Corps are interested in assessing the relative effectiveness of TM, MSS and conventional data for land cover classification, particularly in urban/suburban areas, and for developing parameters (e.g., imperviousness) for input to hydrologic (flood forecasting) and economic (flood damage) models (Davis, 1979). In addition, it would be particularly desirable to establish a set of optimal TM band combinations for land cover classification and related data analysis which could reduce processing time and cost while preserving accuracy and reliability.

Several sites already under study by the Corps were selected for this program. This paper will report preliminary results for one of these sites, the Clinton River Basin in Michigan. Moreover, the data examined here were gathered by the Thematic Mapper Simulator (TMS), an airborne sensor designed to simulate TM spatial and spectral resolution prior to launch.

2.0 SITE DESCRIPTION

The Clinton River Basin flows into Lake St. Clair, draining an area of approximately 760 square miles in southeastern Michigan just north of Detroit. A detailed description of its topography, geology and climate may be found in Revised Plan of Study, Clinton River Basin (Corps, 1980).

The basin has experienced an increasing number of floods in recent years accompanied by rapid growth and development, particularly within the floodplain. For these reasons, the Corps has developed and revised a plan for flood control measures. The Detroit District has established a data base and comprehensive watershed model using spatial analysis methods (SAM) developed by the Corps Hydrologic Engineering Center (Davis, 1980) as a basin-wide management tool to satisfy a wide range of planning needs.

3.0 APPROACH (METHODOLOGY)

Detailed land cover classifications were performed on TMS and MSS data of the Clinton River Basin using supervised classification techniques. Differences in interclass separability and classification accuracy were compared for various TMS band combinations. Preliminary processing, including classification and accuracy assessment, was completed for one USGS topographic map, Mt. Clemens West. Results from seven additional 7.5 minute USGS maps of diverse land cover will be evaluated in the future. MSS and TMS land cover information for the basin derived from these classifications will then be provided to the Corps for use in flood forecasting and damage calculation models to evaluate differences in model performance, particularly in terms of accuracy and sensitivity.

3.1 Data Acquisition (Collection)

Relatively cloud-free, high quality Landsat MSS data from early summer (June 28, 1981) were obtained for the study site. TMS data were acquired by NASA on August 19, 1981, in a single 60-mile-long flight line stretching from the mouth of the Clinton River at Lake St. Clair through the town of Pontiac to Ortonville. These data at a spatial resolution of 31 meters were cloud-free and of good to excellent quality

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in most bands. Color infrared aerial photography was flown simultaneously with the TMS aboard the NASA Earth Resources Laboratory's Lear Jet for use in visual interpretation.

Twenty-seven USGS 7.5 minute (1:24,000 scale) topographic maps covering the Clinton River Basin were obtained. Using 1978 aerial photography, the Southeast Michigan Council of Governments (SEMCOG) prepared conventional land cover maps on mylar overlays at a scale of 1:24,000 for the Corps Detroit District. Selected maps were digitized and converted to raster images for use in verification and accuracy assessment of TMS and MSS classifications.

3.2 Preprocessing and Spatial Registration

3.2.1 Preprocessing

The Landsat MSS data were reformatted to remove earth-rotational skew and synthetic pixels. Then the data were computer enhanced to facilitate the selection of ground control points and training areas.

NASA's Goddard Institute for Space Studies (GISS) radiometrically corrected the TMS data for changes in illumination across the scan line and resampled along each scan line to correct for the aircraft scanner's variable viewing angle. The 31-meter TMS thermal band was degraded to 124 meters by simple averaging to simulate the spatial resolution of the Landsat-4 TM thermal band. No weights were used in the averaging process, as would be required to simulate the sensor point spread function resulting from the optical properties of the scanner system (Sadowski and Sarno, 1976). A simple averaging, as in this process, significantly increases the signal-to-noise ratio above that which would be expected from the actual sensor. No attempt was made to simulate the thermal sensor signal-to-noise ratio that would characterize lower spatial resolution data or the distortion introduced by the forward and reverse scanning of the TM. This image was then expanded back to 31-meter pixels, where each block of 16 pixels had the same value, and merged with the other six bands of 31-meter spectral data.

The other TMS bands had much lower dynamic ranges than are expected from the actual TM bands (NASA, 1982). Table 2 presents the means and variances of all bands. Since variance can be related to the signal-to-noise ratio, TMS bands 1, 5 and 6 had the lowest relative noise as confirmed by visual examination. TM data is expected to provide a full radiometric range of 256 levels compared with as few as 54 levels from TMS (Band 6).

3.2.2 Spatial Registration

The TMS and Landsat MSS data covering the Mt. Clemens West area were spatially registered to the digital ground verification maps using ground control points. Sixty control points common to both data sets and uniformly distributed throughout the study area were recorded and marked on the USGS 7.5 minute topographic map. The Universal Transverse Mercator

(UTM) coordinates were digitized from the map using a Talos digitizing table with the Electromagnetic Systems Laboratory's Geographic Entry System (ESL/GES). To produce an image data base representative of the UTM projection, the digitized coordinates were rescaled to image coordinates representing 30-meter square pixels for TMS data and 60-meter square pixels for MSS data, with an origin at 334000E and 4722000N; that is, the location of line and sample coordinate (0, 0) in the output image. Two third-order polynominal equations were used to model (in a least squares fit) the relationship between image coordinates and the transformed UTM coordinates. Control points with large residuals were iteratively deleted until the final residuals ranged from 0 to $\pm$ 1.6 pixels. The MSS and TMS data were then resampled using nearest neighbor interpolation to 30 and 60 meter resolution.

When the registration of the MSS and TMS data to the digital ground truth was checked on a display device, portions of the TMS data were found to be more than a pixel off, indicating that the third order polynominal used was not adequate to produce precise registration of the entire flight line. Since satellite platforms are more stable, actual TM data should not present as much of a misregistration problem.

3.3 Supervised Classifications

Forty training sites were initially located in the TMS data using ground survey data provided by the Corps Detroit District Office and simultaneous color infrared aerial photography acquired by NASA. Statistics were generated for each site and saved in a special statistics file which could be easily edited. These sites represented the following land use categories used by the Detroit District:

- o Low-, medium-, and high-density residential
- o Institutional, industrial, and commercial
- o Active cropland
- o Woodland
- o Extractive and barren
- o Brushland
- o Grassland
- o Wooded wetland
- o Open wetland
- o Water

A maximum likelihood algorithm was used to classify the whole TMS data set based on statistics from 40 training sites. This classification image was thresholded using a chi-square confidence of 99 percent to form a second classification image. Both classification images, the thresholded and unthresholded, were displayed on an interactive display device. Transformed divergence analysis was used to identify statistically similar sites (Swain and Davis, 1978). Ten colors were assigned to the classes to represent the land use categories listed above. By flagging the same class in each image plane and flickering between the two classified images, it was possible to determine which classes needed to be thresholded or further refined. Major errors of omission and commission were found in the grassland, agricultural, and brushland categories. Moreover, much of the TMS scene remained unclassified at the 99 percent confidence level. Additional training sites were located in the image to minimize these errors, bringing the total number of training sites to 67. Once the entire TMS scene was classified, the same statistics were used to classify the registered TMS data for the Mt. Clemens West area using the maximum likelihood algorithm. The resultant classified image was thresholded using a chi-square confidence of 99 percent to form a second classified image.

The same 67 training site statistics were also used to classify several data sets using other TMS band combinations. The first was composed of TMS Bands 2, 3 and 4, making it spectrally similar to MSS but with greater spectral and radiometric resolution. Transformed divergence, which measures the statistical separability between each class pair for all band combinations, was applied to the first 40 training sites to select optimal TMS band combinations from the 127 possible permutations. An optimal band selection would reduce processing time while hopefully preserving most of the information content in the scene. The transformed divergence test identified Bands 3, 4 and 7 and 3, 4, 5 and 7 as th optimum 3 and 4 band combinations, respectively. These three TMS a sets, composed of Bands 2, 3 and 4; 3, 4 and 7; and 3, 4, 5 and 7 were classified using 67 training site statistics and a maximum likelihood algorithm. Companion images thresholded at a chi-square confidence of 99 percent were also produced.

Both the thresholded and unthresholded classifications were cross-tabulated with the digital ground truth. Using a simple plurality decision rule, each training site signature was relabeled based upon the most predominant land cover present. Using this method, discrepancies were quickly found between the category determined by the plurality rule and the land cover within the original training site. The majority of confusion was between grass d (both natural and planned, such as idleland, golf courses and parks) . agricultural areas. Using the plurality decision rule, the 67 classes developed from the training site statistics in both thresholded and unthresholded classifications were assigned to one of ten categories: water, cropland, woodland, wooded wetland, open wetland, brush, grassland, commercial/industrial, residential, and extractive.

The MSS image was classified in a similar manner using 73 different training classes. Because of the difference in resolution between MSS and TMS data, TMS training sites were generally too small (i.e., had too few pixels) to use in classifying the MSS data. Both thresholded and unthresholded classifications were produced.

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3.4 Accuracy Assessment

For the preliminary accuracy assessment, the ten land cover categories were aggregated into six because no open wetland and very little brushland or wooded wetland were present in the Mt. Clemens West area. Brushland, wooded wetland and woodland were therefore combined into a single woodland category. Since the extractive/barren category included many construction sites in 1978 which by 1981 represented other land cover types, this category was removed from analysis.

One USGS quadrangle, Mt. Clemens West, was selected for the preliminary accuracy assessment. Although primarily residential, this area contained many other small heterogeneous land cover parcels, including industrial plants, commercial buildings along major roadways, small ponds, golf courses, narrow woodlands along streams, and a few agricultural fields. A pixel-by-pixel comparison was performed between the digitized ground truth map of Mt. Clemens West and each corresponding Landsat MSS and TMS classification map.

4.0 RESULTS AND DISCUSSION

The resulting comparison between the Landsat MSS land cover classification and the digitized ground truth data prepared by SEMCOG is shown in Table 3. Tables 4 through 6 compare classification results for the following TMS band combinations: all Bands; 2, 3 and 4; 3, 4 and 7; and 3, 4, 5 and 7, respectively. Table 8 summarizes the information for percent correctly classified by land cover category, band combination and sensor.

The rather low overall classification accuracies of both TMS and MSS can be attributed to the heterogeneity of this largely suburban area and the rigorous accuracy assessment applied. Although these figures could be improved through the use of multitemporal data, contextual classification, or other more advanced digital techniques, this might obscure the results of greatest interest; a comparison of per point land cover classification capabilities between MSS and TMS.

Classification of the 3-band TMS data with spectral bands comparable to the MSS shows a slight improvement in accuracy over the MSS, 55 percent versus 49 percent. Moreover, the best 3-band combination (Bands 3, 4 and 7), as identified by transformed divergence analysis, provided similar results.

The 4-band and 7-band TMS classifications show considerable overall improvement in accuracy over the MSS, 61 percent for TMS versus 49 percent correctly classified for MSS. The most notable improvements are in grassland, commercial and residential areas. The lower water classification accuracy of TMS can be attributed to the fact that the MSS classification accuracy was determined for the whole quadrangle, whereas the TMS data only covered the northern 65 percent of the quadrangle. This northern portion contains very small water bodies including ponds, rivers and a canal. The MSS data included a portion of Lake St. Clair which was not covered by TMS. Furthermore, the misregistration of the TMS data with the ground truth was most noticeable in that portion of the map containing the small water bodies.

The observation that using 7 bands instead of 4 bands did not improve the classification accuracy is supported by previous theoretical results of pattern-classifier systems. Swain and Davis (1978) suggest that for a fixed number of training samples there is an optimal number of spectral bands or brightness levels per band. Increasing the number of spectral bands results in a higher and higher dimensional set of statistics to be estimated with a fixed number of samples. Theoretically, increasing the dimensionality requires more training samples to characterize the added variability, but with a fixed sample, classification accuracy can actually decrease. In this case, the most optimal combination of features contained four bands, with each band from a major region of the spectrum: visible, near infrared, middle infrared, and the thermal infrared.

The above observation is further confirmed by examination of the thresholded results presented in Table 9. A chi-square confidence level is recorded for each classified pixel of the output classification in a second image. Using the chi-squared image, pixels at less than the 99 percent confidence level are eliminated from the classification and termed unclassified. As expected with a fixed sample, the number of pixels classified decreased as the number of bands increased. Furthermore, a marked improvement in accuracy is obtained with the increase in the number of bands, although only half of the image is classified at the 99 percent confidence level.

The larger areas of lower confidence (Table 9) when using Bands 3, 4 and 7 may be due in part to the lower spatial resolution of Band 7 (120 meters). This supposition will be examined in detail using 30m thermal data in the future. Taken together, these results indicate that a band subset of 4 bands was optimal for classification purposes, whereas three bands significantly decreased the classification accuracy. The improved TMS spectral resolution therefore significantly increased the classification accuracies for the quadrangle.

5.0 CONCLUSIONS AND IMPLICATIONS

These results are preliminary and any conclusions drawn from them should be tempered with that caution. In particular, these results are based on only one topographic map from a heavily residential/commercial area. The data are from a Thematic Mapper Simulator rather than the actual TM. Finally, the MSS data were obtained in early summer while the TMS was flown in late summer; therefore some of the differences noted could be due to seasonal, atmospheric and sun angle effects rather than sensor differences.

Based on these preliminary results, TMS data produced a more accurate and spatially contiguous classification than MSS for this study site. While the accuracy of the 4-band TMS data set was almost as good as the 7-band, the 3-band TMS data sets were only moderately better than the MSS. These results indicate that the increased spectral resolution contributes to improved classification accuracy. The possibility of reducing the data analysis burden associated with large TM data volumes through effective band selection therefore appears promising.

The combination of bands selected based on the transformed divergence technique provided one band in each of the major regions of the spectrum: visible (Band 3), near IR (Band 4), middle IR (Band 5) and thermal IR (Band 7). This selection agrees reasonably well with results obtained by Dottavio and Williams (1982) using linear discriminant analysis and Latty and Hoffer (1982) using divergence measures for forest types. This would be expected in light of the intercorrelation studies of Staenz et al. (1980). Additional related studies are summarized in Irons (1982).

The implications of the improved classification accuracy of TMS data are important for Corps hydrological and economic modeling. In particular, the higher accuracies for the developed categories (residential and commercial) should improve the predictions of runoff in flood forecasting models and of flood damage for damage calculation models appreciably. The increased spectral sensitivity of TM may also improve calculations of watershed infiltration capacity. Moreover, the promising results with band selection will permit users of the data to benefit from the improved classification capability without having to deal with the entire data volume.

6.0 ACKNOWLEDGMENTS

The authors extend their appreciation to the Detroit Corps District, and in particular to Roger L. Gauthier and Robert L. Gregory, for their valuable suggestions, assistance and contributions to this research work.

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	TM	MSS
Spectral Bands (μm)	0.45-0.52	
	0.52-0.60	0.5-0.6
	0.63-0.69	0.6-0.7
	0.76-0.90	0.7-0.8
	1.55-1.75	0.8-1.1
	2.08-2.35	
	10.40-12.50	
Spatial Resolution (m)	30 120 (thermal)	80
Radiometric Resolution (bits)	8	6

Table 1. TM and MSS Sensor Characteristics

Band	Minimum	Maximum	Mean	Std. Dev.
1	31	255	56	10
2	43	255	81	18
3	2	255	72	25
4	2	234	103	19
5	0	148	49	10
6	0	185	29	9
7	0	255	101	30

Note: The thermal band on the Thematic Mapper is Band 6, not Band 7 as on the Thematic Mapper Simulator.

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Table 2. Summary Statistics for TMS Flight Line of Clinton River, Michigan

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MSS CATEGORIES

Ground Truth Categories	Water	Agriculture	Woodland	Grass	Commercial/ Industrial	Residential	Total	Percent Correct
Water	262	23	22	21	74	28	430	61
Agriculture	4	330	649	331	70	664	1877	20
Woodland	5	140	1321	523	58	670	2717	49
Grass	8	1047	2194	2202	580	3857	10076	22
Commercial/ Industrial	10	1043	267	345	2541	1009	5820	40
Residential	11	2073	1055	1130	831	12433	17633	71
Total	290	4730	5403	4082	4062	18529	30379	49

Table 3. Comparison of Ground Truth Data and MSS Classification for Mt. Clemens West

TMS CATEGORIES (ALL BANDS)

Ground Truth Categories	Water	Agriculture	Woodland	Grass	Commercial/ Industrial	Residential	Total	Percent Correct
Water	204	3	47	84	151	233	607	33.2
Agriculture	19	2,301	433	3,420	144	1,453	7,885	29.3
Woodland	27	1,120	4,033	2,222	230	1,045	9,647	41.9
Grass	117	1,449	2,127	16,370	1,174	11,403	32,651	50.2
Commercial/ Industrial	4	26	16	707	5,548	4,739	11,130	49.8
Residential	42	378	538	4,470	1,408	35,709	42,604	83.8
Total	403	5,277	7,214	27,414	8,715	55,491	104,604	61.4

Table 4. Comparison of Ground Truth Data and TMS (All Bands) Classification for Mt. Clemens West

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TMS CATEGORIES (BANDS 2, 3, 4)

Ground Truth Categories	Water	Agriculture	Woodland	Grass	Commercial/ Industrial	Residential	Total	Percent Correct
Water	229	18	30	197	183	150	807	28.4
Agriculture	8	1,450	339	3,697	104	1,929	7,836	18.6
Woodland	2	334	3,703	3,705	50	1,053	9,647	38.8
Grass	61	1,010	1,721	15,871	820	13,108	32,051	49.0
Commercial/ Industrial	12	187	13	880	5,080	4,003	11,130	45.6
Residential	44	229	529	9,100	1,175	31,539	42,094	74.0
Total	356	3,247	6,330	33,810	7,432	53,303	104,804	55.3

Table 5. Comparison of Ground Truth Data and TMS (Bands 2, 3, 4) Classification for Mt. Clemens West

TMS Categories (Bands 3, 4, 7)

Ground Truth Categories	Water	Agriculture	Woodland	Grass	Commercial/ Industrial	Residential	Total	Percent Correct
Water	260	8	65	115	151	208	807	32.2
Agriculture	33	1,550	470	3,519	145	2,139	7,835	19.8
Woodland	20	204	4,123	3,231	219	1,637	9,647	43.2
Grass	135	1,512	2,032	15,478	1,070	12,364	32,051	47.4
Commercial/ Industrial	14	568	14	1,301	5,233	3,929	11,130	47.0
Residential	39	619	632	11,273	1,377	28,064	42,004	67.3
Total	501	4,558	7,339	34,937	8,193	48,321	104,804	52.8

Ground Truth Categories

Table 6. Comparison of Ground Truth Data and TMS (Bands 3, 4, 7) Classification for Mt. Clemens West

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TMS CATEGORIES (BANDS 3, 4, 5, 7)

Ground Truth Categories	Water	Agriculture	Woodland	Grass	Commercial/ Industrial	Residential	Total	Percent Correct
Water	220	1	54	83	134	163	607	35.9
Agriculture	24	1,885	449	4,157	133	1,237	7,885	23.7
Woodland	42	593	4,080	2,931	225	1,053	9,547	42.7
Grass	153	1,243	2,032	17,331	1,217	10,075	32,051	54.0
Commercial/ Industrial	16	75	14	834	5,677	4,454	11,130	51.0
Residential	55	433	539	5,537	1,557	34,330	42,604	80.5
Total	565	4,243	7,153	31,020	8,833	51,931	104,004	61.3

Table 7. Comparison of Ground Truth Data and TMS (Bands 3, 4, 5, 7) Classification for Mt. Clemens West

PERCENT CORRECT

Sensor	Water	Agriculture	Woodland	Grass	Commercial/ Industrial	Residential	Total	Percent Average by Category
MSS	65	20	49	22	40	71	40	43
TMS (Bands 2, 3, 4)	28	19	39	49	46	74	55	42
TMS (Bands 2, 3, 4)	32	20	43	47	47	67	53	43
TMS (Bands 3, 4, 5, 7)	30	24	43	55	51	80	61	48
TMS (All Bands)	35	29	42	60	59	84	61	43

Table 8. Classification Accuracy Assessment Summary, 100% Classification

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PERCENT CORRECT

Sensor	Water	Agriculture	Woodland	Grass	Commercial/ Industrial	Residential	Total	Percent Classified
MSS	53	20	49	21	40	70	43	99.7
TMS (Bands 2, 3, 4)	18	13	41	47	45	75	58	91
TMS (Bands 3, 4, 7)	32	19	63	50	60	68	58	70
TMS (Bands 3, 4, 5, 7)	45	26	58	60	56	88	69	58
TMS (All Bands)	28	34	62	53	56	90	71	62

Table 9. Classification Accuracy Assessment Summary, 99% Chi-Square Confidence Level

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THE ROLE OF REMOTE SENSING IN ASSESSING FOREST BIOMASS IN APPALACHIAN SOUTH CAROLINA

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ABSTRACT

Information is presented on the use of color infrared aerial photographs and ground sampling methods to quantify standing forest biomass in Appalachian South Carolina. Local tree biomass equations are given and subsequent evaluation of stand density and size classes using remote sensing methods is presented. Methods of terrain analysis, environmental hazard rating and subsequent determination of accessibility of forest biomass are discussed. Computer-based statistical analyses are used to expand individual cover-type specific ground sample data to area-wide cover type inventory figures based on aerial photographic interpretation and area measurement. Forest biomass data are presented for the study area in terms of discriminant size classes, merchantability limits, accessibility (as related to terrain and yield/harvest constraints) and potential environmental impact of harvest.

INTRODUCTION

South Carolina, like many other states, is heavily dependent upon non-renewable fuels obtained outside its economy for a large portion of its energy needs. Many industries are using natural gas or fuel oil to meet their energy needs and these fuels are particularly vulnerable to fluctuations in cost and supply. Thus, alternative, local sources of energy, such as wind, solar, and biomass are becoming increasingly more attractive. This study was undertaken because information available on the amount and availability of wood resources was insufficient to allow confident commercial decisions to be made about converting to wood as a fuel.

Past inventories of the forest resource have been made primarily as an assessment of conventional products such as pulpwood and lumber. Net forest growth of this commercial material is currently double the amount harvested in Appalachian South Carolina (Snyder, 1978). Forest industries have not quantified the non-merchantable material, the tops and limbs of merchantable trees, the trees less than 4 inches diameter breast height (dbh), and the trees too crooked or defective to be of much conventional commercial value. These unquantified materials are often considered to be the potential fuel wood resource.

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The hardwood material in the study area that is traditionally classified as pulpwood has few markets compared to its abundance. Hardwood is the predominant forest cover type in each Appalachian county and much of it is of low quality (Snyder, 1978). Should the future bring an increase in the demand for these naturally reproducing and growing hardwoods, such as for fuel wood, forest managers in this area may be able to reduce the expensive need for removing "junk hardwoods" from potentially productive sites and, thus, stop spending enormous amounts of money in clearing land so that the currently more commercially valuable pines may be planted and managed effectively.

However, before any effort can be made to entice large users of energy in this area of South Carolina to convert to energy systems that utilize wood biomass, the amount and stability of supply/cost of such fuelwood must be clearly established. Such determinations must include the total amount of biomass available, the portion of the total that is readily accessible, and from a logging and ownership standpoint, the amount and location of excess low value conventional products that would be readily available to any potential fuel wood user. This study was designed to provide the types of data that will help encourage the use of wood for industrial fuel in upstate South Carolina.

MATERIALS AND METHODS

1.1. Standing Forest Biomass

Multiphase sampling involving aerial photographs and ground samples was used to quantify the standing forest biomass in the six counties that make up the Appalachian portion of South Carolina (Figure 1). Estimates of the forest biomass within predetermined naturally-occurring species groups or forest cover types were made from measurements of trees on ground sample plots within the different forest types. Aerial photographs, interpreted with the aid of ground samples, were then used to calculate the number of acres in each forest cover type and the total acreage of forests within the study area. Biomass was estimated based on equations derived from individual tree measurements and stand tree size and density estimates for each cover type taken from aerial photographs.

Color infrared aerial photographs were taken by the Clemson University Department of Forestry in the form of thirteen strips located nine miles apart at a scale of 1/12,000 (Figure 1). The photographs were developed as positive transparencies and viewed on light tables. Aerial coverage was taken in early spring of 1980 to allow maximum forest cover type differentiation, based on foliage coloration.

A two-man crew collected ground sample data during a six-month period. Groups or clusters of three samples were taken at 95 locations so as to coincide with the aerial photographic coverage (Figure 1). On each plot, sample trees were selected with an ocular prism method (basal area factor 10 - Grosenbaugh, 1952) and measured or observed for each of the following factors: species, dbh, total height, defects, product class, and canopy position. Trees less than

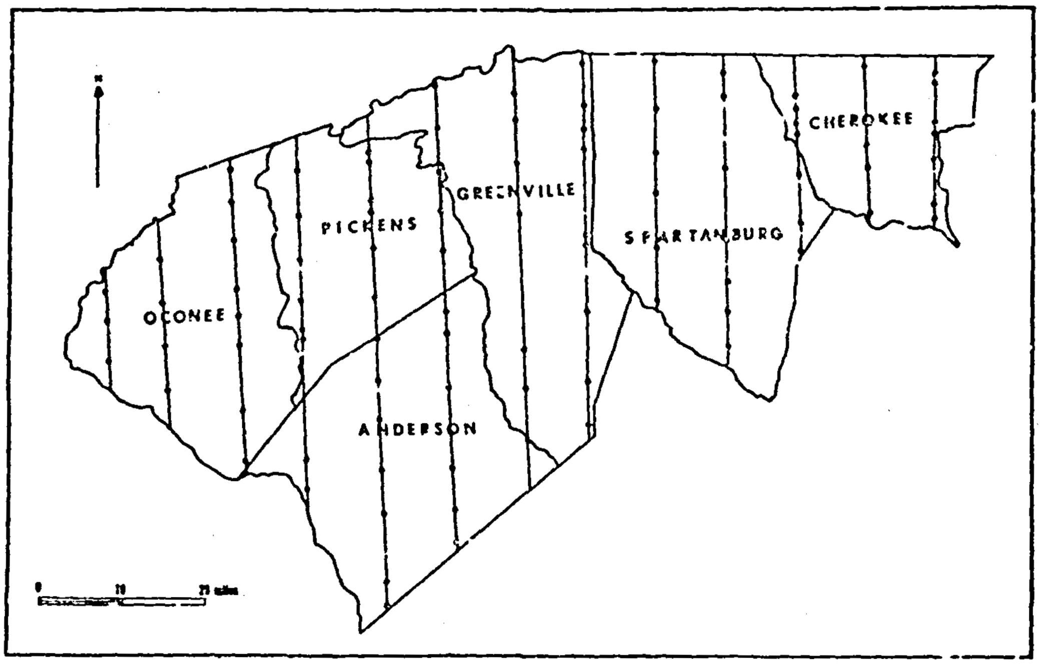

Figure 1. Locations of aerial photographic strips and ground sample groups in the six county study area of Appalachian South Carolina.

3.6 inches dbh were sampled with a 1/100th acre rectangular plot. For every tree on these small plots, species, dbh (in 1 inch classes), and total height were recorded.

In addition to the individual tree data, detailed descriptions of the surrounding site or stand (a group of similar, associated trees) were made at every point. The general area or stand was evaluated for forest cover type, understory vegetative cover, topography, erosion hazard, and accessibility. Site quality was determined by using tree heights, increment core age sampling, and species cross reference site index curves (Hamph, 1965). Site quality was expressed as site index (height at base age 50 yrs.) for commercial southern pines.

On the aerial photographs forest cover types which were usually stands were delineated on clear acetate by trained photo-interpreters. The overall land classification scheme included two general classes, forest and non-forest. The forest land was subdivided into major forest cover types, pine, hardwood, mixed pine-hardwood, harvested, and damaged forest. In turn the major types were further subdivided into specific cover types as follows: two pine types (natural or artificial, depending upon how they had been regenerated), four hardwood types (swamp, bottomland, cove or upland, based on physiographic site types), and three mixed types (26-40% pine, 41-60% pine, or 61-75% pine, based upon the proportion of pine stocking). These specific cover types were felt to be of sufficient difference in biomass productivity to warrant separate delineation and biomass estimates. The area in each specific cover type was estimated for each county from the photographs using a dot grid overlay of 4 dots per square inch (Bonner, 1975) and expressed in acres.

Since forest biomass corresponds closely with tree size and stand density (number of trees per acre), a systematic group of samples was taken on the aerial photographs with a grid dot overlay of one dot per square inch in order to estimate these parameters for each cover type. At each dot a tenth-acre, scaled, circular plot was superimposed on the delineated cover type (stand) and the photo interpreter estimated tree density (crown closure class) and tree height class for that sample. Tree height class was based on the average height of visible crowns within the scaled tenth-acre plot, according to the class limits shown below:

Tree Height Class	Description	Class Limits (feet)
1	Short	10-35
2	Medium	40-85
3	Tall	90+

Crown closure class (stand density) was defined as the percentage of the photo-plot occupied by visible tree crowns when compared to predetermined crown density reference scales. The closure classes used are shown below:

Closure Class	Description	Canopy Closure (percent)
1	Light	0-35
2	Moderate	40-70
3	Heavy	75-100

Biomass per acre on the ground was correlated to the stand crown closure and height classes on the aerial photographs and cover type specific biomass prediction equations were developed using the stand stocking and size parameters, crown closure and height class, as predictive variables, such as described by Mead and Smith (1979) in a similar case.

1.2. Individual Tree Biomass

Local biomass equations were developed for specific use in this survey. These equations were derived from individual tree biomass prediction equations for various species of the Piedmont and mountains of the Southeast provided by the U. S. Forest Service (Phillips, 1980) and were weighted by the frequency with which various species were tallied during ground sampling. All equations were used to predict green weight above ground biomass in pounds for individual trees. Separate local equations were developed for each species group and for the different product components within each species group, e.g., sawlogs, pulpwood, crown, as shown below.

Soft hardwood overstory trees:
Total Tree Biomass (green pounds) = $0.12113D^2H^{1.02190}$

Hard hardwood overstory trees:
Total Tree Biomass (green pounds) = $0.14415D^2H^{1.032200}$

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Loblolly pine overstory trees:
Total Tree Biomass (green pounds) = $0.11448D^2H^{1.03450}$

Shortleaf and pitch pine overstory trees:
Total Tree Biomass (green pounds) = $0.06175D^2H^{1.11931}$

Virginia and white pine overstory trees:
Total Tree Biomass (green pounds) = $0.27765D^2H^{0.95706}$

Hard hardwood understory trees:
Total Tree Biomass (green pounds) = $5.06209(D^2)^{1.15258}$

Soft hardwood understory trees:
Total Tree Biomass (green pounds) = $4.41886(D^2)^{1.20114}$

Pine understory trees:
Total Tree Biomass (green pounds) = $5.06209(D^2)^{1.15258}$

Where: D = diameter outside bark (inches) at 4.5 feet height
H = total tree height (feet)
and: All equations are for green weight, wood and bark in above ground portion of tree. Foliage is included in pine overstory tree equations, but not in those for hardwoods. Specific sources of equations may be found in Nix et al. (1981).

1.3. Area-Wide Biomass Estimates

To estimate total biomass over the six-county study area, regression equations were derived to predict total biomass based on forest cover type, stand crown closure class, and height class. Subsequent estimates of total biomass per acre within cover types and counties were based on photo-interpreted samples. Equations used to predict green weight biomass (in tons per acre) for cover types are given below:

Cover Type	Prediction Equation	R^2
Pine	GW = -78.725 + 26.740(CC) + 51.253(HT)	.847
Hardwood	GW = -42.111 + 21.928(CC) + 37.510(HT)	.897
Mixed	GW = 24.756 + 0.839(CC) + 27.728(HT)	.888
All Forest	GW = -39.201 + 19.662(CC) + 39.201(HT)	.873

Where GW = green weight (tons/acre)
CC = crown closure class
HT = stand height class

Although no ground samples were taken in damaged forest areas (disease, insect, or fire damaged), photo-interpreted plots were used to predict total stand biomass in this cover type by utilizing the equations developed for all forest land.

1.4. Accessibility

Each field plot was classified as (1) readily accessible, (2) accessible under certain conditions, and (3) accessible only with considerable effort. Factors utilized in evaluating field plots included drainage conditions, size and isolation of the forest property, nearness to road network, and topographic configuration which included both degree of slope and terrain variability. These factors were also considered in interpreting accessibility for each photo-plot on the aerial photographs using both planimetric and topographic maps. Accessibility criteria were evaluated for each photo-plot and accessibility classes were assigned based on the above information plus additional physical examination of unusual conditions and constraints that might have influenced accessibility, such as deep streams with no evident crossing, extremely steep or rough topography isolating a stand from all-weather roads or other obstacles like swamps, cliffs, or gulleys. Slopes exceeding 30% were considered difficult, those exceeding 40% were rated very difficult.

Because of the strong influence of slope and ground cover on potential environmental hazard of harvesting (erosion/siltation potential), slope assessment and ground cover evaluation were related to specific cover types delineated and used to rate forest acreage for potential site impact due to harvesting fuel biomass. Hazard ratings closely corresponded to accessibility ratings and were considered equivalent for restricting potentially harvestable acres.

1.5. Logging Residues

The study field crew cooperated with personnel of the South Carolina Forestry Commission in a state-wide collection of logging residue data including the study area. The line-intersect method of sampling (Van Wagner, 1968) was used in estimating the biomass of the branches and cull logs that covered the sites already logged. For the timber left standing, the dbh and height of standing trees was used together with a prediction equation for understory soft hardwoods (Phillips, 1980) to predict standing residual biomass.

RESULTS AND DISCUSSION

2.1. Forest Cover Type Estimates

The basic procedure used in this study for estimating forest acreage is very similar to that used by the U. S. Forest Service, Southeastern Forest Experiment Station to estimate cover type acreage in the detailed and intensive Forest Survey (Sheffield, 1979). Personnel of the U. S. Forest Service (Knight and McClure, 1980) provided data which allowed a comparison of estimates of the number of acres of forest land in the six-county study area to estimates made by the Forest Survey (Table 1). Except for one county, the Forest Survey estimates of forest land area were consistently higher than those of this study. The definition of forest land used in this study does not encompass all forest land termed "commercial" by the Forest Service. The U. S. Forest Service estimates of forest land area include "land at least 16.7 percent stocked by forest trees of any size, or formerly having had such tree cover, and not currently developed for non-forest use" (Snyder, 1978). The current study excluded many acres that were included in the Forest Service definition, i.e., from a practical standpoint there is little

Table 1. Estimates of forest land area in Appalachian South Carolina, including "secondary" forest land that was not inventoried in this survey.

County	Land Area[1] (M-acres)	U.S.F.S. Forest Area (M-acres)	(%)	Clemson Survey Forest Area (M-acres)	(%)	"Secondary" Forest Area (M-acres)	(%)
Anderson	477	208	44	170	36	38	8
Cherokee	253	156	62	130	51	26	11
Greenville	508	300	59	255	50	45	9
Oconee	400	284	71	270	67	14	5
Pickens	321	215	67	198	62	17	5
Spartanburg	531	271	51	272	51	0	0
Total Area	2,490	1,434	57.6	1,295	52.4	140	5.2

[1]U. S. Bureau of Census estimates (includes water). M-acres = 1,000 acres.

liklihood of the harvest of "residential forest," fringe areas or small isolated stands (< 5 acres). In the six-county study area, "primary" forests occupy 52.5% of the total land area (including water), and "secondary" forests occupy another 5.2% (Table 1).

The extent of the forest cover types within the study area and total biomass estimates are summarized in Table 2. It is apparent that hardwoods are the predominant forest type in every county. Based on cover type classification of primary forests, 25.4% of the land area is occupied by hardwoods, 13.2% by pines, and 11.7% is occupied by the mixed pine-hardwood type. The cover type proportion estimates reflect differences in physiographic and land use conditions of the six counties. For example, the most rugged counties (Oconee and Pickens) have high percentages of primary forest while Cherokee County, which has been farmed heavily in the past has substantial (11%) secondary forest land (Table 1).

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2.2. Standing Forest Biomass

There is a significant proportion (26%) of the study area biomass in the non-merchantable category (Table 2); and in addition, low value hardwood pulpwood constitutes a significant proportion (25%) of the biomass in the most prevalent cover type (hardwood). The hardwood cover type also has the highest average standing biomass per acre (94.8 tons). These two factors, high yield and high acreage, make the hardwood cover type the major source of biomass in the study area.

Surprisingly, the amount of biomass per acre differed little among the specific cover types within major cover types, although, as shown in Table 2, the major cover types differed considerably. For example, within the mixed pine-hardwood cover type the various proportions of pine, 26-75%, affected estimates of biomass by less than 1 ton per acre, while within the hardwood cover type biomass estimates differed by as much as 30 tons per acre from the swamp to the bottomland hardwood cover type (data not shown but available - Nix et al., 1981). Thus, subdividing the major cover types into specific types was useful in improving accuracy of biomass estimates in some cases (the hardwood cover type) but not in others (the mixed pine-hardwood cover type).

Large amounts of the standing forest biomass in the six counties will normally be utilized for products higher in value than energy wood, e.g., the 36.2% that is sawtimber and pine pulpwood. Under current economic conditions, forest biomass with potential use for sawtimber products would rarely be used as energy wood. Although manufacture of sawn products results in substantial wood waste much of this material is already being used for fuel by the forest industries. There is a reasonable demand for pine pulpwood products within the study area, although this demand varies locally. Hardwood pulpwood which is 18.3% of the total biomass is of considerably reduced demand and value, and much of this category could be harvested as energy wood. Trees above 3.5 inches dbh but below pulpwood size (4.6"+ dbh), the tops and crowns of trees utilized for pulpwood and sawtimber, and hardwood species that are not used for conventional products constitute an appreciable 'non-merchantable'

Table 2. Proportion of total land area in Appalachian South Carolina in the forest cover types and distribution of biomass by product categories.

Cover Types	Portion of Total Area (%)	Total Biomass (MM G. Tons)	Tons/ acre	Product Category Distribution[1]				
				Sawtimber	Pine Pulp	Hdwd Pulp	Non-Merch.	Trees < 3.6" dbh
				-------- Percent of Total Biomass --------				
Pine	13.2	30.3	91.4	23.1	35.2	3.4	22.2	16.0
Hardwood	25.4	59.0	94.8	24.9	3.7	25.3	26.2	19.9
Mixed	11.7	23.6	82.1	17.7	12.3	21.5	26.7	21.8
Harvested	2.0	2.0	39.2	0.0	0.0	0.0	61.7	38.3
Damaged	0.1	0.2	56.7	23.6	35.9	3.5	22.6	14.4
All Forest	52.4	115.1	88.8	22.4	13.8	18.3	25.9	19.6

[1]Percentages in product categories are for cover types.

category (26% of the total biomass) in the six counties. The non-merchantable standing biomass is the category with the greatest potential for use as energy wood; but because of its low value, its harvest may be linked with conventional product removals. Although technology continues to be developed for utilization of small stems (below 3.6" dbh), it is questionable whether this size material can be harvested economically on a large-scale basis with current logging equipment. The hardwood pulpwood together with the non-merchantable category > 3.5" dbh make up 44.2% of the total or about 51 million green tons of potential fuel wood in the study area.

2.3. Accessibility of Forest Cover Types and Biomass

The percentages of forest cover type areas that were rated in the three accessibility classes are shown in Table 3. Approximately 87% of the primary forest area was rated as 'readily accessible.' An additional 10% was rated as 'accessible under certain conditions,' and only 3% was rated as 'accessible with considerable difficulty.'

Table 3. Distribution of forest cover type acreages in three accessibility classes in Appalachian South Carolina.

Access. Class	Pine	Hardwood	Cover Type Mixed	Cover Type Harvested	Damaged	Total
			Percent of Total Area			
1	94	82	86	95	89	87
2	5	13	11	5	11	10
3	1	5	3	0	0	3

There was little variation in the distribution of forest land among accessibility classes between counties. On the other hand, because of differences associated with physiographic site conditions common to cover types, there was considerable variation in the general accessibility characteristics of the different forest cover types (Table 3). For example, the least accessible type is the hardwood cover type, of which 82% was classed as readily accessible as compared to 94% for the pine cover type.

Because of the very close correlation between accessibility and harvesting hazard and due to the manner in which the two parameters were evaluated, they can be considered equivalent in this study. Thus, an average of 13 percent of the forested acreage in the study area was rated as potentially too fragile to enter with mechanized equipment for fuelwood harvest. In addition, because of cover type-physiographic interrelation, some cover types are more restricted than others, e.g., 18 percent of the hardwood type acreage could be considered in a "harvest with care" category (Table 3). In a careful, detailed examination of data accumulated by the USDA Forest Service's Renewable Resources Evaluation Unit, Dissmeyer (1979) indicates that as much as 20 percent of the forested area of the

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South Carolina Piedmont could be in a high risk category for intensive harvest-related activities. Because of the presence of the mountain site types in the six county area, it would not be unwarranted to assume an even higher proportion of high risk forest acres in the Appalachian counties than for the Piedmont Region as a whole. Thus, for the hardwood type in particular, the 18 percent restricted acreage value may be an underestimate by as much as 10 percent.

The acreage of primary forest in a county is the major reason for differences in total biomass among counties. As shown in Table 4, the amount of total biomass in a county increases directly with the amount of forest land and readily accessible biomass follows the same course. The differences among counties in the amount of biomass that is readily accessible are only slightly ameliorated by the interactions that occur between the total forest acreage and the accessibility and the biomass per acre of individual cover types within counties. Since the least accessible cover type, Hardwood (82% readily accessible), also happens to have the highest biomass per acre (94.8 tons per acre) the counties having a high proportion of hardwood acreage (Oconee - 36% and Pickens - 31%) do not depart appreciably from the high acreage-high biomass pattern typical of the study area.

Table 4. Forested area, total biomass, and readily accessible biomass for counties in Appalachian South Carolina.

County	Total Primary Forest Area (M acres)	Biomass (MM G. Tons) Total	Biomass (MM G. Tons) Readily accessible	Percent of Total
Anderson	170.3	15.3	13.4	87.6
Cherokee	129.7	11.5	10.1	87.8
Greenville	255.2	23.3	19.8	85.0
Oconee	270.4	23.4	20.1	86.0
Pickens	197.6	17.4	14.9	85.6
Spartanburg	272.4	24.3	21.2	87.2
Total Study Area	1,295.7	115.2	99.6	86.4

2.4. Harvest Residues

Based on the results of the cooperative study with the South Carolina Forestry Commission, it was estimated that 21.7 green tons of felled material (crowns, cull, waste) were left per acre after logging. Based on the biomass prediction equations, an average of

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5.7 tons of standing material, greater than 3.5 inches dbh, were left on the average acre after logging. Based on 285 ground samples, the average forested acre contained 17.0 tons of biomass in material less than 3.6 inches dbh. Thus, the average acre could supply 44.4 tons of biomass in addition to the amounts removed as conventional wood products, provided that the material could be harvested economically.

A similar estimate was obtained in a different manner. The product-size categories listed below and estimated from ground sample plots in the field were assumed to have minimal commercial value and would, thus, constitute probable logging residues. The total of 40.1 tons per acre includes undersized and cull material as well as upper stems and crowns. It does not include any hardwood pulpwood, some of which may be left behind in many operations due to its low economic value.

Product-size Category	Average Biomass (green tons/acre)
Pine Non-merchantable	7.5
Pine Understory	1.7
Hardwood Non-merchantable	13.9
Hardwood Non-commercial	1.7
Hardwood Understory	15.3
TOTAL	40.1

The harvested acreages in each county were divided into cleared (site prepared) versus not cleared sites using aerial photographs. The uncleared sites were assumed to contain 44.4 tons of residual biomass per acre. While no biomass estimates were attached to the cleared sites, these should be recognized for their potential to supply an average 44.4 tons/acre of residues prior to clearing. The estimates of acreages and biomass of harvested stands are listed in Table 5. Nearly 2 million tons of logging residue remains after harvest in the six county area.

2.5. Estimates of Potential Productivity (Annual Growth)

In considering the availability of forest biomass for industrial fuel use, the aspect of sustained or stable supply of fuel must be considered. To this point the subject of the standing forest resource has been addressed as if it were a relatively static phenomenon. Forests are, fortunately, not static, but rather are like the principal of a savings deposit that draws compounded interest. As such, the availability of forest biomass for any use should be assessed on the basis of growth or annual increment. Forests are normally managed such that a resource base is established of sufficient size to produce an annual increment or growth that is at least equal to the annual demand placed on the forest. After such condition is reached, sustained or stable supply is assured. In as much as such a sustainable supply of biomass fuel would be highly desirable, it was necessary to estimate current and future annual growth for the six county study area. Additionally, the estimates of growth must reflect accurately the impact of harvest removals and natural mortality, that is, they must be estimates of net growth.

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Table 5. Acreage in cleared (site prepared) versus not cleared logging sites with resulting logging residue estimates for Appalachian South Carolina. (Logging residues are based on 44.4 tons per acre only on sites not cleared.)

County	Area Logged (M acres) Total	Cleared	Not Cleared	Logging Residues (M green tons)
Anderson	6.7	---	6.7	299
Cherokee	6.3	---	6.3	279
Greenville	7.0	1.2	5.8	258
Oconee	11.7	1.5	10.2	451
Pickens	5.6	0.2	5.4	239
Spartanburg	12.8	2.3	10.5	468
Study Area	50.1	5.2	44.9	1,994

Current annual forest growth rates for the six county area were derived from estimates of site quality for each cover type and the known growth rates for commercial species in the cover types as related to site quality. The predicted growth rates in this study were based on expected volume yields of normally stocked stands at age 50 years (Anon., 1976). These growth rates, which are termed mean annual increment, are in merchantable volume units, i.e., cubic feet per acre per year of main stem for trees 4 inches dbh (3.6-4.5" dbh) and larger. Estimates of annual volume growth were converted to green weight of wood and bark using cover type-specific conversion values derived from species conversion values provided by Dr. M. A. Taras, Wood Scientist, Clemson University. Estimates of merchantable annual growth for each cover type are available (Nix et al., 1981). Total merchantable annual growth is 4.395 million green tons of wood and bark. In estimating growth potential of the cover types, harvested and damaged areas were treated as 41-61% pine and 100% pine, respectively. The distribution of annual growth among the six counties is available (Nix et al., 1981). Although these estimates of growth are based on the predicted growth of loblolly or shortleaf pine at age 50, they should serve as reasonable estimates of productivity of the cover types examined in this study, particularly since cover-type specific site index and volume/weight factors were used.

The estimates of growth for merchantable material (conventional products) were converted to total biomass growth for use in fuel availability assessment. Previously in this study, the proportion of the total biomass per acre (average for the study area) that is in each utilization component was estimated (Table 2). For example, the merchantable proportion of total biomass was estimated as being

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54.5 percent based on an analysis of all ground sample data. These proportions were applied to the merchantable growth estimates and the total annual biomass growth and each of its component parts were estimated for the study area (Table 6).

Table 6. Total annual forest biomass growth for Appalachian South Carolina according to cover type and major utilization category[1].

Cover Type	All Merch. (% of Total)	Non-Merch. > 3.5" dbh (% of Total)	Growth Total Biomass (M G. Tons)
Pine	61.7	22.2	1,876.8
Hardwood	53.9	26.2	4,031.9
Mixed	51.5	26.7	1,730.7
Harvested	51.7	26.0	314.3
Damaged	61.7	22.2	15.9
Total	54.5	25.9	8,063.8

[1]Merchantable material includes pine and hardwood pulpwood and saw timber. Non-merchantable material less than 3.6" dbh is part of total biomass growth but is not considered as available in this study because of harvesting constraints.

The annual growth estimates in Table 6 indicate that over 8 million green tons of forest biomass are grown each year in the six county study area. Assuming that the proportions of the various components of total biomass given previously are valid for the growth estimates, then estimates of the annual growth of the different components that are of particular interest as fuel potential can be calculated. Annual growth of non-merchantable material greater than 3.5" dbh is 25.9% of the total growth or 2.088 million tons of wood and bark. Annual growth of the hardwood pulpwood component which is currently the lowest valued merchantable product is 18.3% of the total or 1.476 million green tons of wood and bark. The unmerchantable growth greater than 3.5" dbh and the hardwood pulpwood taken together annually provide 3.564 million tons of potential wood suitable for fuel.

SUMMARY AND CONCLUSIONS

In order to stimulate the consideration of an abundant renewable resource for use as an energy source in South Carolina, a survey was conducted in six upstate counties to find the amount of realistically available forest biomass that might be utilized commercially for fuel. This survey provides information necessary to both non-forest and forest-based industries that are considering the use of forest biomass as their major or supplemental source of energy. Forest biomass information has been compiled in this study utilizing multi-phase inventory methods which include ground samples, low altitude color infrared aerial photographs, and computer-based data assimilation.

The total amount of aboveground forest biomass in six county study area is 115 million green tons of which 51 million tons are economically suited for use as fuel wood. On the average, 87% of this biomass is readily accessible. The annual growth of forest biomass is estimated to be 8 million green tons of which 3.6 million tons are economically suited for fuel use. The average yield of biomass was estimated to be 88.8 green tons per acre and ranged from 57 tons per acre for the damaged forest type to 95 tons per acre for the hardwood cover type. The hardwood cover type is also the most prevalent in the study area, thus, over half (51%) of the available biomass in the six counties and an appreciable proportion (20-30%) of the biomass economically suitable for fuel is hardwood.

The study indicates that there is a considerable amount of forest biomass available for fuel in Appalachian South Carolina (50-100 MM tons). In addition, this biomass is growing at a rapid rate (8 MM tons/year) and could supply a significant fuel wood demand (3-5 MM tons/year) in the six county area on a sustained basis for a meaningful period. In a companion study of the six county area, Harris (1982) estimated that the total demand for fuel wood by industries in the study area with a high potential for converting to wood fuel would not exceed 1 million green tons per year. It is of interest to note that even one small pulp mill can consume in excess of a million green tons of wood annually. Based on these considerations, there is every reason to encourage local industries with favorable economic feasibility to make use of this abundant renewable energy resource in Appalachian South Carolina.

ACKNOWLEDGEMENT

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AN INTEGRATION OF A GIS WITH PEATLAND MANAGEMENT

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1. INTRODUCTION

Peatlands constitute a viable energy source. Europeans have burned peat for heating and cooking for centuries. More recently, electric and district heating plants powered by peat have been built in Ireland, Finland, and the Soviet Union. Estimates indicate that Ireland produces about 20 percent of its energy needs by burning peat (Minneapolis Tribune, 1982).

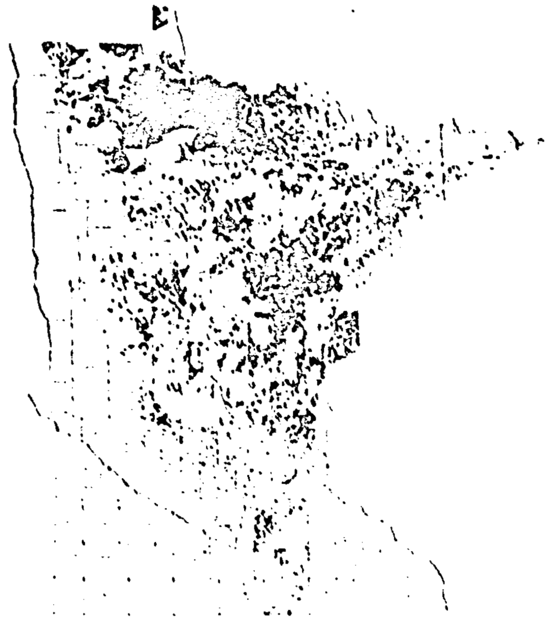
The experience in the United States has not been comparable. Individuals have burned peat for heating, but larger-scale development of the resource has not occurred. In fact, it required the energy crises of the 1970s to awaken most Americans to the potential role of alternative energy sources such as peat.

Our paper examines the complexities of peatland management in Minnesota and the use of a geographic information system, the Minnesota Land Management Information System (MLMIS) in the management process. We begin our discussion with a brief description of what peat is, where it is found, and the distribution and amount of Minnesota's peat resource.

2. WHAT IS PEAT?

Peat is organic matter, in varying stages of decomposition, that accumulates under more-or-less saturated conditions. It is generally composed of the remains of reeds, sedges, grasses, mosses, and wood. The climate, topography, and drainage of an area determine the degree of decomposition of the accumulating organic matter.

Figure 1. Distribution of Peatlands in Minnesota



In Minnesota, peatlands cover about 6 to 7 million acres, or approximately 16 percent, of the land surface. The last glaciation modified the landscape and created many poorly drained areas that were ideal locations for peatland formation (fig. 1). Large, contiguous peatlands formed in the northcentral part of the state on the plains of several glacial lakes. Small, scattered peatlands formed in morainic areas and on outwash plains that occur throughout the state, except for the extreme southwest and southeast corners.

3. PEATLAND MANAGEMENT

3.1 Minnesota Peat Program

The Minnesota Peat Program of the Minnesota Department of Natural Resources (MDNR) is directly responsible for the management of all state-owned or state-administered peatlands. These peatlands comprise an estimated 50 percent of the state's resource.

The Peat Program began in 1975, primarily in response to a lease request by a Minnesota utility, Minnegasco (Minnesota Gas Company). The company requested a 25-year lease for 200,000 acres of peatland, most of which is state-owned, to produce substitute natural gas from peat. Because little was known about the state's peat resource, a moratorium on peatland leasing was imposed to allow time to examine

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questions related to large- and small-scale development. Work began on a peat inventory, baseline environmental studies, and studies of development options and their potential environmental and socioeconomic impacts. The Peat Program was charged with the development and implementation of a peatland management policy.

3.2 Management Policy

Peatlands constitute a multifaceted resource. Although mining peat for energy is a current, primary interest, peatlands can also be mined for horticultural or industrial chemical use. Used in situ, peatlands can be managed for bioenergy crops, agriculture, forestry, wildlife, recreation, or sewage treatment. Several Minnesota peatlands are also being considered for preservation because of unique landforms and rare plant and animal species.

The current MDNR peatland management policy is to

- manage for multiple use,
- identify peatlands for protection,
- control environmental and socioeconomic impacts, and
- direct development.

The MDNR also recommends that leases should not exceed 3,000 acres in size. This recommendation is based on several factors: It is felt that development impacts may be successfully mitigated on lease tracts of this size, European experience suggests that 3,000 acres can support a viable energy production industry, and large-scale development has not been proven environmentally, economically, or technologically. In fact, this summer, Minnegasco released the results of their feasibility studies for large-scale production of substitute natural gas from peat. Their conclusion was that it is not economically feasible at this time.

3.3 Management Process

Peatland management requires matching potential uses with the resource characteristics. This process involves the identification of potential uses, the resource requirements for the uses, availability of the resource, possible constraints and limits to development, and reclamation options.

The Peat Program staff designed a four-phase process to match the peat resource with the requirements of specific uses:

I. Regional analysis
II. County-level analysis
III. On-site inventory
IV. In-house environmental screening.

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The process progresses from generalized resource data at phase I to detailed information at phase IV.

The Peat Program staff decided to use a geographic information system for several aspects of the management process. The decision was based on two primary factors: (1) the availability of an already existing data base with a large number of data variables and (2) the analysis and graphic capabilities of the system.

4. MLMIS: A GEOGRAPHIC INFORMATION SYSTEM

MLMIS was developed at the University of Minnesota in 1968 with the limited purpose of developing an inventory of the state's lakeshore resources. In 1969, the inventory program was expanded to include land use patterns of the state. This data item served as the geographic reference for the system, a statewide 40-acre grid file. Between 1969 and 1977, the data base was expanded, computer software was developed, and case study projects were completed. In 1977, MLMIS was transferred from the university to the state government to function as a service bureau. At this time, the data base and computer programs were fully operational for natural resource planning. MLMIS had now become part of the Land Management Information Center (LMIC) in the Minnesota Department of Energy, Planning, and Development (MDEPD).

The service bureau acts as a clearinghouse between data sources and data users. Data are provided and maintained by various agencies at state, federal, and local levels, and efforts are made to coordinate their collection procedures. Currently, there are hundreds of data variables in the system many of which are based on a 40-acre statewide grid cell. There are approximately 1.35 million cells in a single statewide data variable. The following are the more important data variables:

- Watersheds for Minnesota have been delineated from topographic maps and include eleven major drainage basins, 8[illegible] major watersheds, and 5700 minor watersheds.
- Land use and land cover have been interpreted from high altitude aerial photographs into nine categories.
- Forest cover has been determined for the state providing an inventory of forest community types.
- Land ownership by government agencies has also been recorded for the entire state.
- General soils and geomorphic data have been collected for the state, which allows for nearly 25 capability interpretations of the soil data including productivity ratings, engineering limitations, and physical properties.

Although the statewide data base, which has developed over the past fifteen years, consists primarily of natural resource data such as soils and forest cover, it also contains selected data on demographics, physical development, and administrative boundaries.

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In addition to the 40-acre grid cell data base there are numerous data bases of more generalized data and very detailed data. For example, detailed data bases, consisting of 2.5 acre grid cells, exist for many of the townships surrounding the cities of Minneapolis and St. Paul. A detailed data base consisting of 50 meters x 50 meters grid cells exists for the Minnesota Valley National Wildlife Refuge and Recreation Area. Also, there is a new generation of data currently being developed. One example of these data is the digital terrain information obtained from U.S. Geological Survey maps. These maps were digitized by the U.S. Defense Mapping Agency for use with the cruise missles and are now available in digital format for most of the country. This information has been stored for Minnesota in grid cells of 100 meters x 100 meters as elevation data and can be interpreted to obtain slope and aspect. LANDSAT data are also being collected for the state to enhance the existing 40-acre land use and land cover data. These new data will be stored as 100 meters x 100 meters grid cells.

LMIC not only provides data to users, but also provides a comprehensive set of computer programs, computer hardware, and trained staff to meet users' needs. These include the following:

- Analysis packages for polygon and grid modeling, data base managers, statistical packages, and a bibliographic retrieval system.
- Graphics facilities include polygon and grid display programs, text display, and business graphics. These products are generated on either hardcopy printers or video displays, in color or black and white.
- Computer programming staff that continue to maintain and augment the system and also provide systems design advice to users.

Over the past fifteen years MLMIS, as a part of the University of Minnesota and now as a part of LMIC, has served many users in a variety of capacities. Users have included federal, state, and local government agencies as well as private organizations. Many projects have dealt with environmental assessments for surface water, groundwater, soil erosion, and unique scientific resources on a statewide or local level. Other studies have included the identification of potential sites for the development of power plants, transmission lines, highway corridors, and waste disposal.

5. MLMIS AS A MANAGEMENT TOOL

5.1 Regional Analysis Model

The suitability model developed by LMIC and MDNR staff was designed to fully utilize the capabilities of the MLMIS. Most of the data used in the model already existed in the MLMIS data base, and most of the programs used to analyze the data existed as part of the Environmental Planning Pro-

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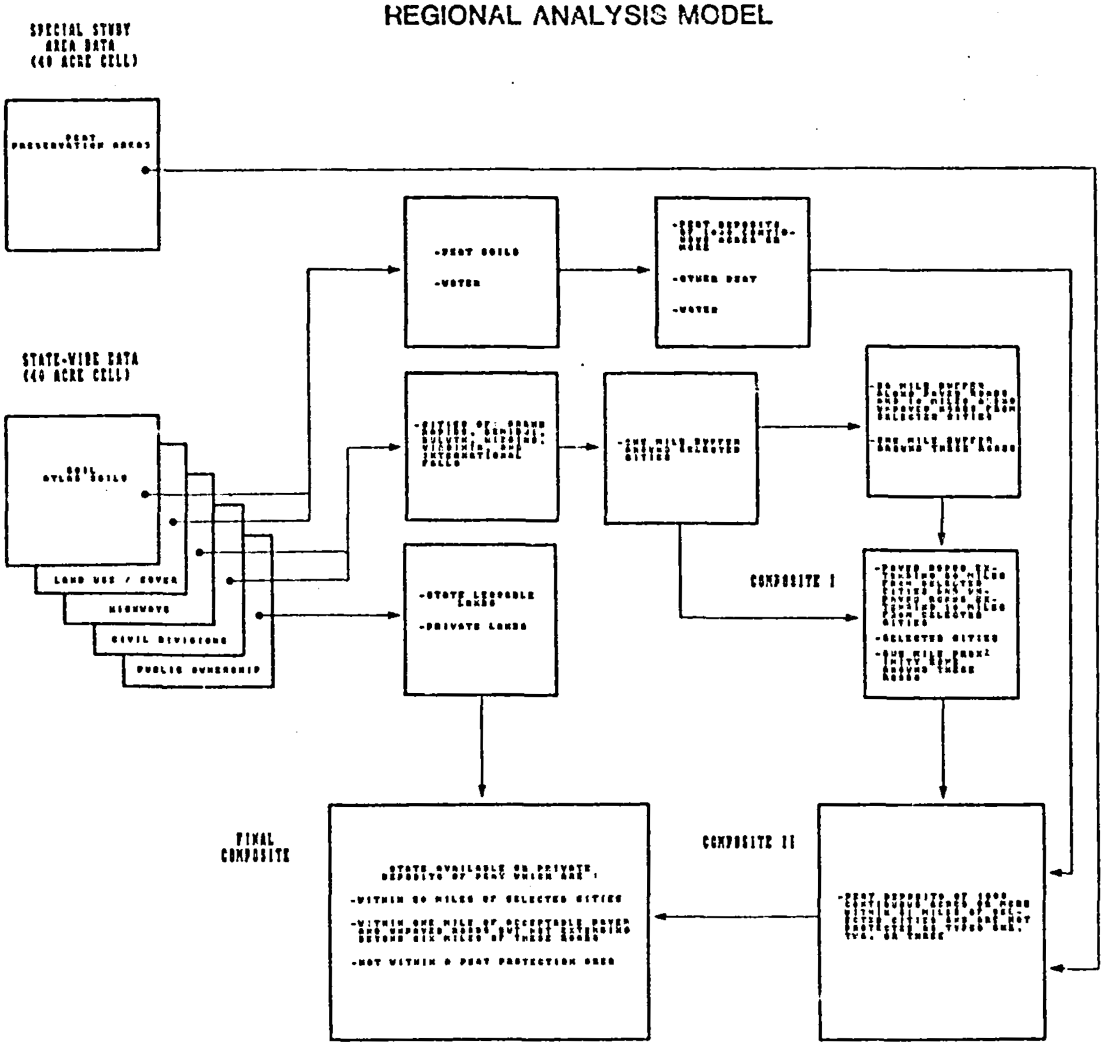
Figure 2. Regional Analysis Model

PHASE 1.

PEATLAND SUITABILITY:
REGIONAL ANALYSIS MODEL



gramming Language (EPPL). EPPL is MLMIS's grid cell analysis package. The objective of the model is to provide management support for the Peat Program staff by determining what peatlands might be available for possible leasing as alternate energy sources. This model is part of a four-phase process designed by the Peat Program staff and is intended to be a regional analysis only. All analysis was performed using a 40-acre data cell.

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The study area defined by the Peat Program staff as part of Phase I of their program includes eight counties in northern Minnesota: Beltrami, Cass, Carlton, Itasca, Koochiching, Lake, Lake of the Woods, and St. Louis. This area contains the vast majority of peat in Minnesota and is of primary interest to both the public and private sector. It is also the area in which there have been lease requests.

The development of the Regional Analysis Model (fig. 2) began by determining what data would be necessary to identify peatlands with development potential:

- Soil Atlas Soils. The Soil Atlas series was designed to provide general soils information for planning purposes. This is the only soils information available with statewide coverage. Peat Program staff use the series to identify the distribution and areal extent of the state's peatlands.
- 1969 Land Use / Land Cover. Land Use / Land Cover provides statewide coverage of nine classes of uses or cover. These data provide the necessary water resource information.
- Highway Orientation. This data variable identifies, statewide, those 40-acre parcels adjacent to or containing roads and intersections.
- County Civil Divisions (CCDS). CCDS identifies all incorporated municipalities, townships, or unorganized territories in the state.
- 1978 Public Land Ownership. This variable describes ownership for land under federal, state, or county jurisdiction in the state.
- Peat Preservation Areas. This data variable was specially created for this study from maps prepared by Peat Program staff. Three classes of protection were used to indentify areas containing unique landforms and rare plant and animal species.

The remaining steps used in developing the Regional Analysis Model used EPPL to analyze the selected data. These steps were as follows:

- By using soils, land cover, and land use data, peatlands and 40-acre parcels dominantly covered by water were identified. These peatlands were then examined to determine those covering at least 1000 contiguous acres.
- Using CCDS, the locations of six cities were identified in the study area: Bemidji, Duluth, Grand Rapids, Hibbing, International Falls, and Virginia. A circle one mile in diameter, placed at the centroid of each city, represent the cities' incorporated areas.
- Next, using Highway Orientation and the revised city locations, a distance analysis was performed. Starting at the edge of a city, a search was done to identify 40-acre parcels which were oriented toward or containing a paved or unpaved road and were within 50 miles or 10 miles, respectively, of the city. Distance was measured along a road using eight points of the compass: N, NE, E, SE, S, SW, W, and NW. A one mile proximity

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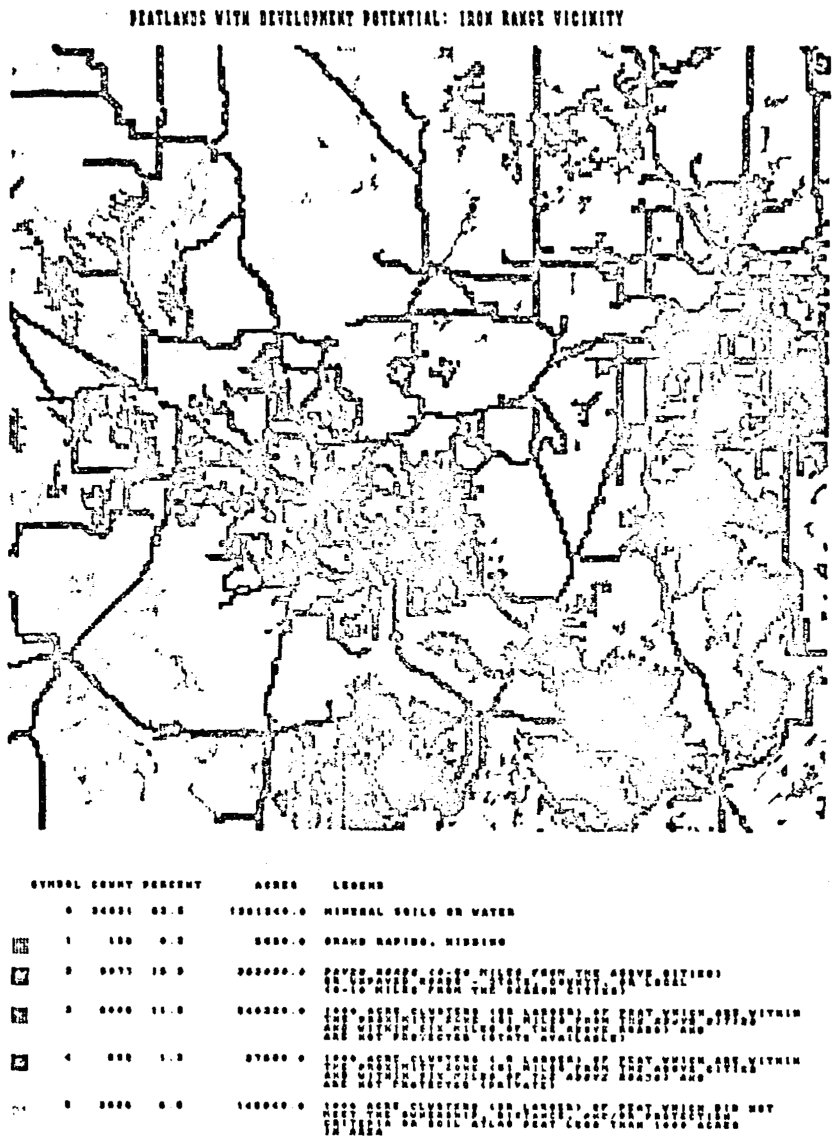
Figure 3. Peatlands With Development Potential



zone was then placed around paved and unpaved roads meeting the distance criteria.

- Using Public Land Ownership, a determination was made by the Peat Program staff as to what publically owned lands should be considered as available for possible leasing. Private lands were considered as a seperate class.
- Finally, through a series of composites, the new data created in

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the previous steps were combined with peat preservation information to yield a final suitability data variable.

The Regional Analysis Model identified those peatlands with development potential as an energy resource. They cover 1000 contiguous acres or more, are within 51 miles (as measured along paved roads) or 11 miles (as measured along unpaved roads) of one of six selected cities, are considered state available, and are not within a preservation area. In addition to the criteria described above, any portion of a peatland that was considered to have development potential, but extended beyond six miles of the proximity zone, was considered not available for development (fig. 3). Statistically, within the study area used by the model, nearly 950,000 acres were identified as being potentially available for state leasing, 123,000 acres met all of the criteria but were on private land, and 2,500,000 acres of peat failed to meet the model's criteria.

6. CONCLUSION

Peatlands in Minnesota constitute a viable energy resource that require careful management to ensure their proper development and protection. As a tool for guiding the development of Minnesota's peatlands, the MLMIS proved to be very valuable through Phase I of the Peat Program. MLMIS will continue to be used by Peat Program staff as a management tool as Phases II-IV are initiated. In Phase II continued refinement of the Peatland Suitability Model will occur so that more detailed county-level analysis can be performed. Two refinements are the entry of more detailed peat resource information and modifications to the distance analysis portion of the model. While more detailed information, required for phases III and IV, will be obtained on-site, MLMIS capabilities will be further utilized to help Peat Program staff monitor the testing and permit processing required before an individual site can be developed.

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GEOGRAPHIC INFORMATION SYSTEMS FOR ASSESSING EXISTING AND POTENTIAL BIO-ENERGY RESOURCES: THEIR USE IN DETERMINING LAND USE AND MANAGEMENT OPTIONS WHICH MINIMIZE ECOLOGICAL AND LANDSCAPE IMPACTS IN RURAL AREAS

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INTRODUCTION

The Management Construct described forms part of an overall Landscape Ecological Planning Model which has as a principal objective the extension of the traditional descriptive land use mapping capabilities of geographic information systems into land management realms. The management construct should be seen to be an abstract or theosophical procedure for ordering the many issues, parameters and variables which require consideration in rural planning today. Current rural planning issues which the construct seeks to assist in solving include the infilling of an accepted knowledge and communication gap between land use planning and land management realms (Held, 1980) (Tlusty, 1979), whilst acknowledging the reconized complexity of interrelationships between the two (Healy and Short, 1981). The construct is therefore proposed as being of probable wide use for not only highlighting present rural planning concerns, but as a means of arranging the large informational and data inputs required to comprehensively address all rural planning issues in a holistic way (Toffler, 1980). The last point is made in awareness that geographic information systems appear to be moving to more comprehensive methods of data handling and storage, such as relational and hierarchical data management systems, and a clear need has simultaneously arisen therefore for planning assessment techniques and methodologies which can actually use such complex levels of data in a systematic, yet flexible and scenario dependent way. The descriptive or mapping method proposed herein therefore broaches such issues and utilizes a current New England bioenergy scenario, stimulated by the use of hardwoods for household heating purposes established in the post oil crisis era and the increased awareness of the possible landscape and ecological ramifications of the continued increasing use of the resource.

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1. EXPLICIT RESEARCH GOALS

Despite the regionalized or New England nature of the research the model as developed to date, has been formulated with a view to meeting several other more universal yet explicit goals. Briefly, these goals are:

1.1. Goal One

To display and re-emphasize the importance of bioenergy as a renewable resource of importance to man's survival at global, national, regional, right down to local scales. For biomass remains the one, relatively cheap, universally available, resource which is efficient in the capture of the dilute energies of sunlight. Plant derived photosynthates, expressed here as biomass and their fuel end use as bioenergy, represent in simple terms one of the few syntropic - or matter creating - processes available to common man (McHarg, 1981). Plant and plant processes therefore offer one of the few prospects of "with-holding" the increased degradational effects due to entropy with many portend is the future, given increasing population pressures, increasing use of finite fossil fuel reserves, and increasing global atmospheric pollution; particularly of carbon dioxide, upon which plants rely for photosynthesis and thence for growth (Ayensu, et al., 1980) (Coates, 1981).

1.2. Goal Two

To utilize an existing geographical information and data management system, in this case the METLAND system as developed since 1972, with a view to extending present capabilities towards greater informational and interpretational contents, as well as a greater flexibility of use which is concomitant with the prospects in larger data base management systems (Fabos and Caswell, 1977; Fabos, Greene and Joyner, 1979). Yet, at the same time recognize and extend the value of earlier systems; particularly their educational capabilities addressed to all levels of users, whether student, business person, or lay user.

1.3 Goal Three

The subject of this paper; which seeks to explore the as yet untapped interpretative capabilities of computer assisted geographical information systems in a way that penetrates into land management considerations, as itemized in the introduction, particularly as actual land management practices could effect the "health" of the regional ecosystem.

The emphasis is however primarily addressed to the development of the management construct and its ordering of the to-

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tal model and its subsequent validation to date on a case study area in the Upper Housatonic Basin, Western Massachusetts. Of several scenarios tested, the one displayed here has been classified as the "most-likely" of any, in respect to economic viability, as well as in respect to a conservationary desire to seek energy efficiencies in all land management operations for the future.

2.0 THE MANAGEMENT CONSTRUCT

The body of definition, belief, and fact, associated with land management is a paradigm or super model in itself because management pervades most of man's considered actions. The context in which management is used here relates, however, to that tendency of man to seek order in his environment, sometimes to simplify it in such a fashion that the parts of interest to him become more comprehendable; and for some, more controllable. But also implied within the construct which follows is that deeper developing conscience of a need to further develop a land ethic which permeates the whole structure of management systems as they might effect the land. (Devall, 1980; Leopold, 1966; McHarg, 1969). Any modelling construct for rural land management that sets out to be an ajuvant process - or aid - to a holistic, or multi-faceted planning approach, must not only have as a primary objective the prospect of formulating positive, rather than exclusionary rural policies, based off the natural resource base, but should also recognize the diverse range of management attitudes and aims which are the prerogative of each and every land user in real-world situations (Healty and Short, 1981). The implications of the preceding statement are as complex as they are profound for clearly, the shades of difference in the use and personal objectives within the term "management" are extremely diversified, and clearly the land commands different levels of respect by different users. Yet, within this diversity a pattern emerges which is seen to be somewhat hierarchical in the questions and at the levels of detail that each person might ask him or herself in determining the economic/ecological/ethical rightness and viability of possible management options in the use of the land.

The levels, herein termed orders, have therefore been set forth within a descendent pattern within the management construct. In the model economic - or dollar related - value systems come first, leading to the second which considers real-world constraints to and conflicts on maximizing both existing and potential resource supplies, and thence to the third which considers energy-efficiency criteria which impress the ethical need to be conservationary in all management operations on the land. The fourth and final order to date developed, expresses an ecological value system within the construct and is related to the need to determine the possible ecological impact of any proposed management action on the land; at a time when decisions on economic viability are being made, rather than after the event, as so often has been proved to be the case in the past. Clearly, the descendent nature and ordering of the construct could be reversed dependent on the value systems of the user. The value of the construct, however, proves to be that both economic decision making and the possible ecological ramifacations of those decisions are placed in concert, and each imbues the other with the wisdoms and values of its system. A further value of the approach to method therefore becomes established in that it serves to communicate and educate in the rationales of different value systems and a demonstration program has been prepared on that basis, primarily for student use.

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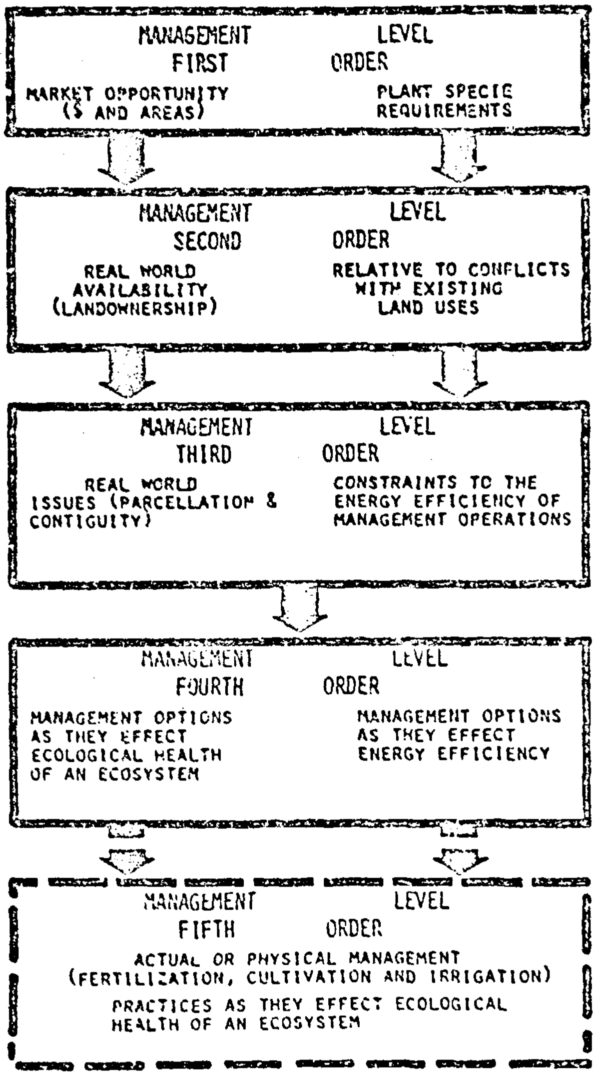

FIGURE 1: THE MANAGEMENT CONSTRUCT WHICH HAS PROVED VALUABLE NOT ONLY IN ORDERING, OR MANAGING, THE DATA BASE COMPONENT AND SCENARIO DEPENDENT AGGREGATION FILES, BUT ALSO IN PENETRATING TO ACTUAL MANAGEMENT PRACTICES ON THE LAND. INDICATIONS OF LIKELY "IMPACTS" ON THE "HEALTH" OF THE REGIONAL ECOSYSTEM ARE THEREFORE MORE ABLE TO BE DETERMINED.

Figure 1. therefore displays the Management Construct: Note that, the Orders of Management follow those just described but, are extended to include a fifth to display penetration into detailed management considerations and the need to ascertain the actual processes of management on the land if likely ecological impacts are to be determined in parallel with economic viability considerations. A further value of the construct could therefore be that it offers the opportunity of being intergrafted with actual land management practices and data storage systems already in use by land managers; which in the example pursued here, implies forestry managers, using such inventory storage systems as CRIS (Comarc Resource Inventory System), 1978. It should also be recognized that this particular diagram of the Management Construct forms part of later, more developed diagrammatic models of figures 3, 4 and 5.

3. RELATING THE MANAGEMENT CONSTRUCT TO LANDSCAPE ECOLOGICAL PLANNING PRINCIPLES

Ecological interactions in the landscape are clearly related to the "transactions" described as occurring between ecosystem compartments by Odum, E.P. (1969); and have been defined as exchanges of matter, energy and/or organisms - or lack thereof - that are conditions for maintaining the biological information, and therefore the "health" of a single compartment in relation to others, as well as to the total ecosystem (Picket, 1976). Hendrix, 1977, has demonstrated that by utilizing the compartment system attributable to Odum that land uses can be classified and mapped according to whether they are Protective, Productive, Compromised, in respect to or Non-vital to, ecosystem "health". Odum's classification has in fact been broadened by Hendrix, to include a fifth compartment in recognition that there is a distinction between the growth characteristics of agricultural production compartments and the growth and accumulated biomass of forestry production compartments, particularly as applied to studies in rural areas. Figure 2. illustrates the five compartmental system according to Hendrix, and as derived from interpretations of available knowledge on the gross primary production/respiration (P/R) conveyed on the diagram. The graphic symbols beside each compartmental box denote maturity and degree of closure which are exhibited by land uses which can be ascribed to each compartment. For example, mature forestry is represented within the Protective compartment by a black rectangle indicative of a relatively closed system with a P/R ratio of 1. In contrast, the white rectangle, representative of Non-vital land uses such as densely developed urban and industrial environments have P/R ratios frequently much less than 1, and are therefore considered open systems, of high entropy, and therefore "non-vital" to ecosystem "health". The arrows linking the compartments are the "transactions"

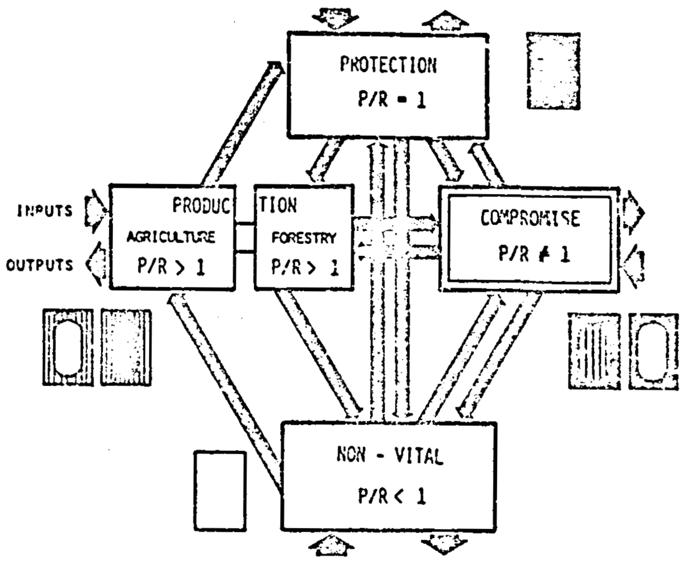

FIGURE 2: THE FOUR COMPARTMENT MODEL, FIRST HYPOTHESIZED BY ODUM, E.P. 1969, WAS SUBSEQUENTLY USED BY HENDRIX 1977 TO CLASSIFY LAND USES. HENDRIX, IN FACT, ADDED A FIFTH COMPARTMENT WHICH ACKNOWLEDGES THE DIFFERENCE BETWEEN GROSS PRIMARY PRODUCTION (P) TO RESPIRATION (R) RATIOS EVIDENT IN AGRICULTURAL GROWTH, COMPARTMENTS OF PRODUCTION AND YOUNGER FORESTRY STANDS. LARGE ARROWS REPRESENT INPUTS AND OUTPUTS EXOGENOUS TO THE ECOSYSTEM; SMALLER ARROWS LINKING COMPARTMENTS REPRESENT THE TRANSACTION FUNCTIONS BETWEEN COMPARTMENTS AS TRANSPORTED BY ABIOTIC, BIOTIC AND ANTHROPIC AGENCIES. THE GRAPHIC SYMBOLS ARE EXPLAINED IN THE TEXT OF THIS PAPER.

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known to occur, but still recognized as very difficult to measure, between compartments. The questions in respect to ecosystem "health" therefore become: how much of each compartmental type of land use, and in what patterns of arrangement, should we be striving for to ensure that the "health" of the ecosystem, independent of scale of consideration, is maintained-or even improved? It is on these two considerations that the ecological impact evaluation method, still in the process of development is based, and it is considered to have a universal applicability; despite some necessary assumptions, be it for bioenergy scenarios for the use of the land as the natural resource base, or not, (Fabos, Jackman, and Oski, 1982).

4. THE FORMAT FOR THE GENERAL MODEL

Clearly, the overall model is structured in such a way that landscape ecological planning principles have played a dominant role in its formulation. Just as clearly, and drawn from the stated goals of this study, the values of an existent geographic information system, namely, METLAND (Metropolitan Landscape Planning Model), have been initially used for assembling the large and scenario dependent data requirements needed to support all the considerations which emanate from the rural research goals and principles stated; as well as from the management construct.

4.1 Abiotic Parameters as the Horizontal Component of Resource Supply Matrices: The format of the model therefore places the abiotic parameters of the physical environment in the preeminent position within a matrix. The abiotic parameters - or physical attributes of site - are seen to be more fixed in time than uses of them (after Overton, 1977), and therefore form the horizontal component of an Existing Supply Matrix as well as a Potential Supply Matrix. The use of the natural land resource base therefore acts as the prime determinator of any of man's uses of, and management actions on the land, and also enforces a conservationary consideration for their value in terms of maximizing the energy efficiencies of different management actions. Figure 3. demonstrates the format of the General Model and displays a limited selection of abiotic parameters, namely soils, slope, aspect, and water at phreatic (ground) levels. Clearly, this list could be extended to include geological and climatological information, but in this case the diagram is framed to meeting the interpretative and individual requirements of different plant species for maximizing natural growth; without the need for highly subsidized inputs of exogenously derived fertilizers, tilling and harvesting operations, and irrigation needs. The data information inputs required are therefore scenario dependent because they rely on the plant group, or specie, under consideration for bioenergy use. The interpretative skills required to do this clearly rest with the individual's ability to do so; but most information can be gleaned from Soil Conservation Service Technical Data Sheets, particularly those for soil types. The interpreted information according to specific plant requirements is then encoded in typical aggregation or data files which attributes each cell of the data base a number as to whether it meets the given criterion or not.

4.2 Biotic and Anthropic Variables as the Vertical Component of Resource Supply Matrices Figure 3. also demonstrates the form of the vertical components of the resultant matrix. Note that in the diagram only one matrix is shown, but in fact it is better to regard it as serving a dual graphic purpose;

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implying that it should be regarded as the format for both the Existing and Potential Resource Supply Matrices, which are best seen to be two separate elements sitting side by side as shown in Figure 4. The vertical components of the matrices are also common as shown in the General Model displayed in Figure 3. The first component in the descendent series are Biotic and Anthropic Variables, seen to be "variable" and inclusive of vegetation and wildlife habitats because they are less fixed in the temporal sense than are the abiotic parameters (Overton, 1977). Existing land uses and land cover attributes ascribable to anthropic sources (man and his actions) are likewise scenario dependent and the aggregation files therefore required for each individual bioenergy scenario tested needs to be interpreted for its own specific requirements. Although the diagram hints at onesuch formulation it must be restated that it is general; with a more specific example to follow which tests the validity of the model for assessing the likelihood of viable economic operations at various scales for fuel-end uses of hardwoods of the oak group.

4.3 Conflicts and Constraints: The vertical components, therefore, serve to display in a descriptive or mapping sense where the Conflicts and Constraints (C/C's - after O'Banion 1980) of real-world situations are likely to occur, both of which serve to reduce the likelihood of maximization of both existing and potential resource uses. In turn failure to maximize resources is related to whether any given scenario is economically viable or not. A particular value of the model having proved to be (although not shown here), that two distinct types of possible conflict (C/•) between land uses can be displayed in map outputs when derived by overlaying certain combinations of aggregation files drawn from both, or either, of the horizontal and vertical components of the matrices. Particularly is conflict display afforded for comparisons of existing land uses with potential uses such as more avante-garde bioenergy scenarios like the growing of aspen poplars for alcohol fuel-end uses. Although not pursued as the example of the model in use herein, a first type or level of possible conflict is clearly established between uses of the land for more traditional crops, such as corn. A second level of conflict can also be established in the end use of corn as a crop for fuel-end uses, rather than stock feed-to-food-end uses. As also displayed in Figure 3, potential land ownership conflicts are also mappable. Note that the considerations of land use, land cover and land ownership are considered to be Second Order Management conflicts (C/•) according to the Management Construct described before and shown in Figure 1. Third Order of Management considerations then follow and as stated they are regarded as constraints (•/C) to maximizing the energy efficiencies of actual management operations. In a general sense the criteria considered to date are those which are important in the study area and in-

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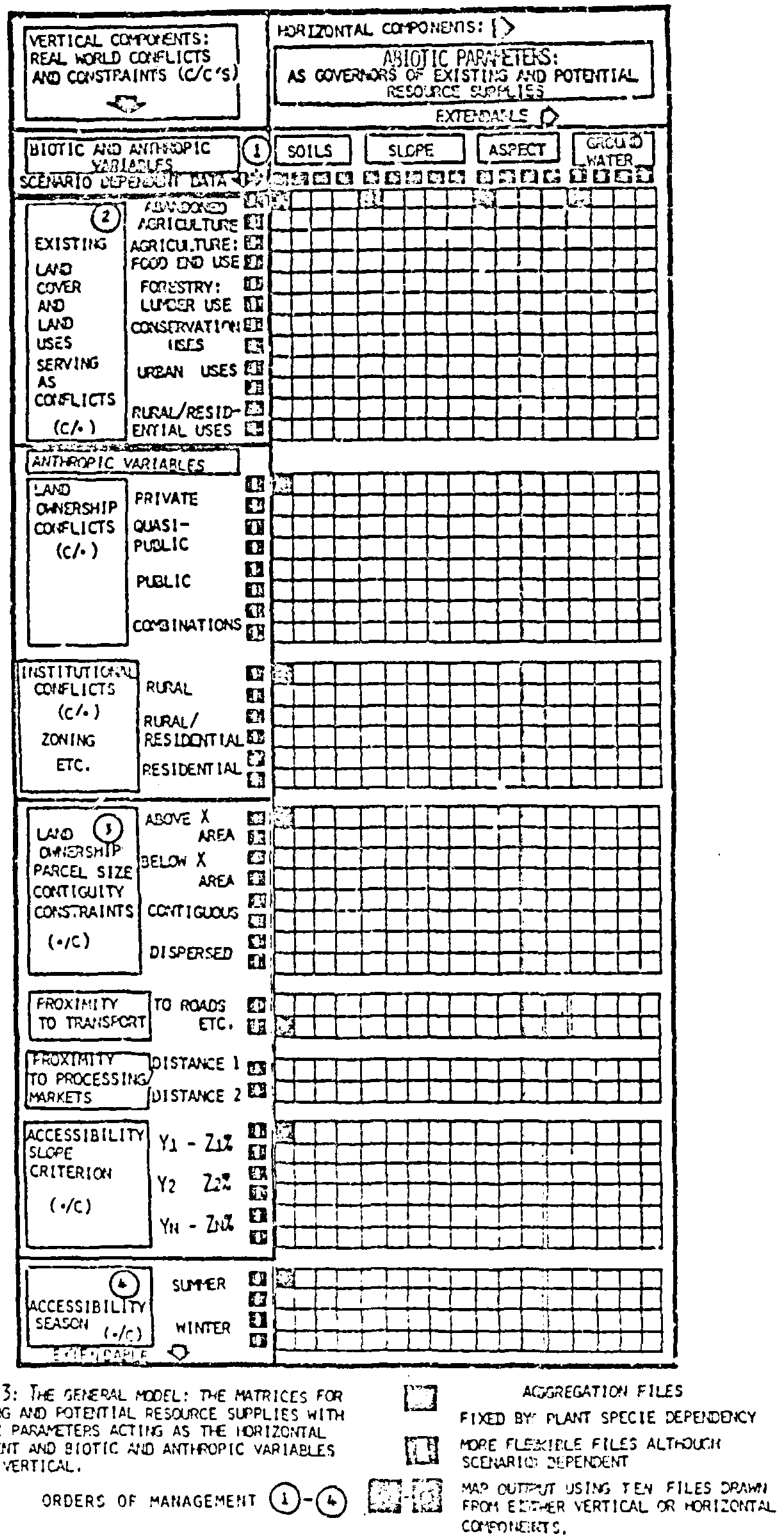

FIGURE 3: THE GENERAL MODEL: THE MATRICES FOR EXISTING AND POTENTIAL RESOURCE SUPPLIES WITH ABIOTIC PARAMETERS ACTING AS THE HORIZONTAL COMPONENT AND BIOTIC AND ANTHROPIC VARIABLES AS THE VERTICAL.

volve such specifically rural issues as parcellation. Increased fragmentation of land ownership, particularly effects the energy and therefore economic efficiency of machinery and plant likely to be used by large and medium-scales of business operation. Contiguous or interconnected parcels of similar ownership class are able to be used with greater efficiency than fractured - or dispersed - parcels. The land ownership component of the data base has been used to prepare aggregation files which meet this criterion of impressing a conservationary desire for increased energy efficiency in management operations (Healty and Short, 1981).

Other available criteria which serve to enforce a conservatory rationale for increased energy efficiency in management operations include, the more traditional factors of proximity to existing roading infrastructures, and accessibility to harvesting sites, which in the case of prospective use of hardwoods is governed by slope. The model could be extended, therefore, to include other marketing forces such as proximity to local and out-of-region processing centers.

Fourth Order Management options then follow and relate, as stated, to actual land management practices such as how the season of extraction could effect the ecological "health" of the local and regional ecosystem. A predictive model with descriptive capabilities in map form being the basis of the concept in which the user of the program elects an area by windowing techniques; let us say, in this case for summer harvesting by clear-cutting, and is provided with a value attributed to the existing "health" of the system. The "impact" of his or her selection is gaged by the difference attributed to the change in "health" values established by his actions. The predictive model is the subject of on-going research.

4.4. Predictive Model for Determining Ecosystem "Health" and Impacts of Management Actions: Briefly, the ecological value system currently is being derived from how distant a certain land use is away from maturity - or closure - of a P/R ratio of 1. See Figure 2. The "impact" being determined by the attributed change in P/R ratio from the assessed existing value to that as a result of the proposed management action. The planning value of the ecological "health" concept clearly relates to the goals stated at the beginning of this paper, which included a consideration of economic forces played in concert with ecological values. The Demonstration Program to date prepared has its emphasis in communication and education in both sets of value systems, hopefully not only useful to business persons, elected officials, and students, but because of its interactive user-friendly nature also of wider popular use.

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5. BIOMASS ESTIMATES:

Figure 4. therefore represents the schematic format of the overall general model. Note that an adjunct procedure for biomass estimates, also derived from Hendrix, 1977, is available as a map out-put routine from the Existing Supply Matrix, throughout the Management Orders. This estimation technique has been developed from the land use component of the data base and is derived from considerations of age, canopy cover and height of vegetation which is then related to what is presently known of biomass and yield characteristics of each land use class of the Massachusetts "MAPDOWN" classification system, attributable to MacConnell, (1960-present). Biomass estimates are presently calculated in joules/meter^2 (4186 joules/kilocalorie) but could be extended to cover more traditional forestry units of measure. The method requires further refinement but is proposed as being of particular use to planners at an intermediate level between remote sensing estimation procedures and ground truthed procedures. For further details see Aston, Fabos, and MacDougall, 1982.

6. CO-OCCURRENCES:

As descriptive map out-puts of the overall model most of the generally-accepted range of mapping requirements generatable by geographic information systems are available; namely, search, overlay and aggregation procedures coupled into one and called "AGGOVER", (METLAND, 1977). Co-occurrences of selected abiotic parameters as well as all anthropically and biotically derived variables are therefore mappable; as are comparisons of where existing supplies meet, or do not meet, potential site suitabilities.

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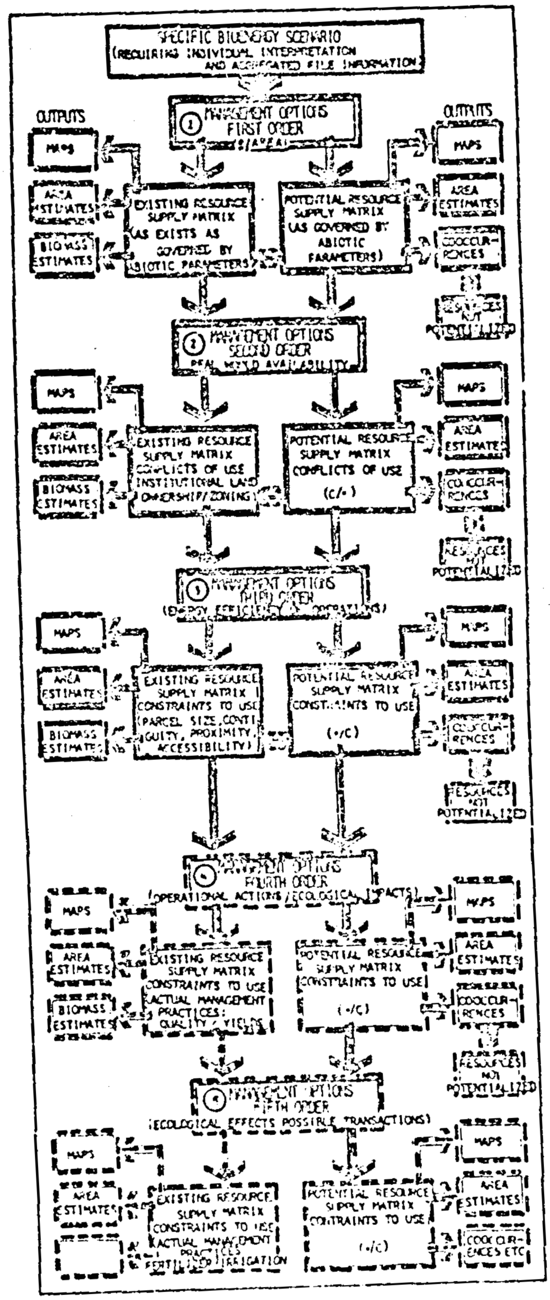

FIGURE 4: THE SCHEMATIC FORMAT OF THE OVERALL MODEL.

7. A SELECTED SCENARIO:

Figure 5. illustrates the network diagram for the Demonstration Program of a scenario which considers the economic viability of existing supplies of oak, in more-pure stands, as determined by a choice of scale of operation governed by the user. This implies a dollar /areal relationship inserted as options in introductory questions; a choice between large, medium and small scales of business operation as related to the $/areas (hectares) requirements of the individual user being called for within the First Order of Management Options-or Questions. Tree group or specie choice are also First Order Options because of their government of the aggregation files used in later questions as the user descends the management orders of the hierarchy previously outlined. The principal value of the Management Construct, therefore, is that it serves to ultimately penetrate to levels of actual land practices which in themselves are principal governors of likely ecological "impacts". The construct also serves to arrange the information in a rational - perhaps, relational - way designed to suit the stated educational and communicational goals of the Demonstration Program.

7.1 Classification of Scenarios as to Likelihood: Figures 6, 7 and 8 are selected map out-put from the program, and are drawn from the scenario for existing oak in more-pure stands, which has been classified subsequent to map results as the "most-likely" of all bioenergy scenarios tested to date. Note on Figure 5 where the figures 6, 7 and 8 are drawn from. Other scenarios which have been considered include the prospects and impacts of "total-tree-removal" which involves the removal of all the tree including roots from non-rocky sites and probably therefore a summer season operation; with high potential impacts on soil horizon development and the movement of soil fines associated with water as the abiotic agency. A scenario which tests the likelihood of cattails (Typha spp.) as a bioenergy crop on wetter to persistently wet lands has been classified along with the scenario for total-tree-removal as being of the "least-likelihood" for the study area. Demonstration Programs for these two scenarios are to be run concurrently for such combinations display another capability of the overall model. Other scenarios, classified as of "moderate-likelihood" for the study area, include the use of abandoned agricultural lands with a view to displaying a further use of the model in minimizing land use conflicts (·/C). Poplars of the aspen group with either fuel or alcohol as the end-use is the tree potential tested. This scenario has also been prepared in a concurrent fashion with a scenario for corn with alcohol fuel as the end-use, since on pre-mapped results both are considered of only "moderate-likelihood". The value of the combination, however, being that both scenarios could compete for similar land

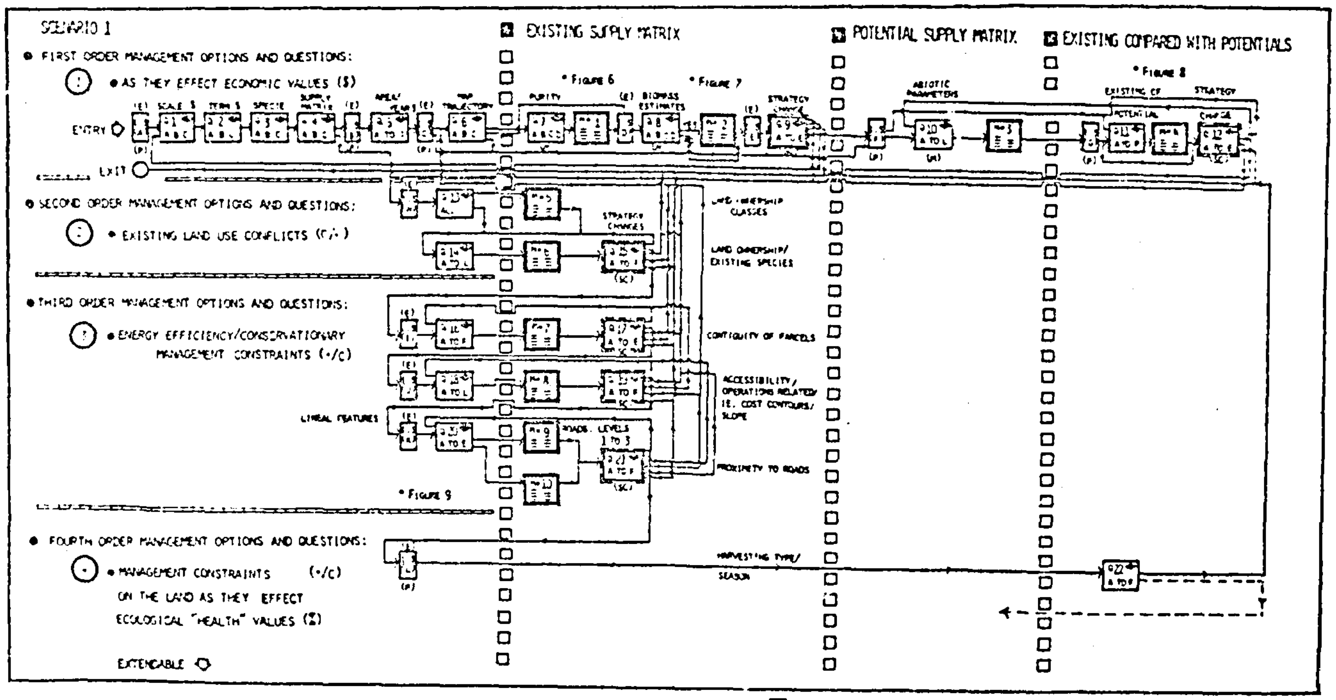

FIGURE 5: THE FORMAT, OR NETWORK DIAGRAM, FOR THE DEMONSTRATION PROGRAM FOR THE SCENARIO WHICH CONSIDERS EXISTING AND POTENTIAL RESOURCE SUPPLIES FOR OAK, AS A HARDWOOD FUEL RESOURCE OF HIGH ENERGY QUALITY (B.T.U.'s OR JOULE EQUIVALENTS), IN RESPECT TO THE STUDY AREA IN THE UPPER HOUSATONIC BASIN, WESTERN MASSACHUSETTS. THIS SCENARIO HAS PROVED THE "MOST-LIKELY" OF ANY OF THE 5 TESTED TO DATE.

LEGEND

INFORMATION STATEMENTS = I.S (A-L)
QUESTIONS = Q 1-22
MAP OUT-PUTS USING AGGREGATION FILES = M=1-10
STRATEGY CHANGES = (SC)

(E) = APPLIES TO EXISTING SUPPLY MATRIX
(P) = APPLIES TO POTENTIAL SUPPLY MATRIX
(M) = MAP OUTPUT FOLLOWS
1-4 ORDERS OF MANAGEMENT

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resources in the future, and the display of such competing uses can assist in shaping policies dependent probably on the ultimate economic viability and energy efficiencies embodied in actual and comparative management operations. That is, resolution of such conflicts is not pretended, since comparative solutions will probably best be accomplished in the future by consideration of not only economic and ecologic values but consideration also of more detailed analysis of the comparative embodied energies involved in the actual management practices (Odum, H.T. and Odum, E.C., 1981).

8. CONCLUSION: The value of the overall model is therefore not only seen to lie in its recognition of different value systems counterposed against each other, with a view to displaying that such do exist, but also in displaying the positive nature of developing rural planning policies off the natural resource base before the event of ecological impacts. Rather than formulate negative - or exclusionary and sectorial rural policies aimed at protecting the resource base in response to continued urban expansionary trends and styles; the results of which have described multifariously as "buckshot" urbanization, and as the "countryfied city", (American Land Forum Report, Number 1, 1979) (Fuguitt, Voss and Doherty, 1979).

The value of the management construct rests with the reasons for its formulation, for it has proved a valuable guide to ordering complex but interrelated rural planning to management issues in a relatively simple manner which ensures their consideration, rather than their dismissal as being too complex for resolution.

The value of the bioenergy scenarios used to validate the general model lies in the reinforcement of the need to consider biomass derived renewable energy sources as a global issue of immediate importance, particularly in countries and regions which are not blessed with an abundancy of fossil related energy resources. That the general model requires individual interpretive skill dependent on the bioenergy scenario under test may appear to offer an unduely complexified approach to solving land use planning issues, but it is contended, that it is only when one does that many current rural planning issues present themselves for resolution.

The value of using computer assisted techniques therefore becomes established from all preceding points, for manual techniques can not match the map out-puts and many permutations of the parameters and variables offered by the use of geographic information systems of the present, and prospectively more so in the future.

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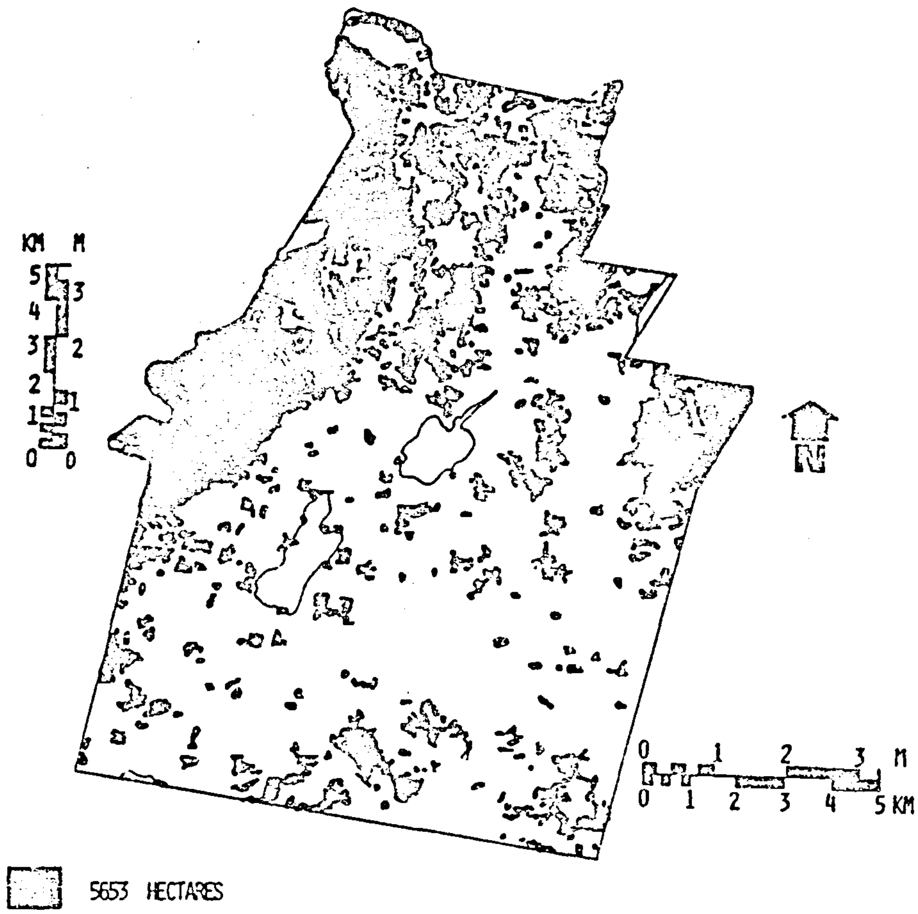

FIGURE 6: MAP OUT-PUT SELECTION 1; FOR THE SCENARIO WHICH ASSESSES BOTH EXISTING AND POTENTIAL SUPPLIES OF OAKS AS A HARDWOOD RESOURCE AND UTILIZES THE DATA BASE COMPONENTS AND AGGREGATION FILE INFORMATION DISCUSSED IN THE TEXT OF THIS PAPER. IN THIS CASE EXISTING OAK IN MORE-PURE STANDS IS DISPLAYED AND IS DERIVED FROM LAND USE MAPS AND GROUND TRUTHING. IN THIS CASE ONLY THE EXISTING SUPPLY MATRIX HAS BEEN USED AND USES THE SECOND ORDER OF MANAGEMENT VARIABLE OF ANTHROPOICALLY DERIVED/LAND USE AS THE DATA BASE COMPONENT. THE INTRODUCTION OF THE VARIABLE OF PURITY OF STANDS HAS CONSERVATIONARY OVERTONES IN THE SENSE THAT GREATER ENERGY-EFFICIENCIES IN ACTUAL HARVESTING OPERATIONS ARE RELATED TO IT; ALTHOUGH THIS IS A "TWO-EDGED" SWORD IN RESPECT TO MAINTAINING THE GREATER SPECIES DIVERSITY ASSOCIATED WITH MIXED STANDS.

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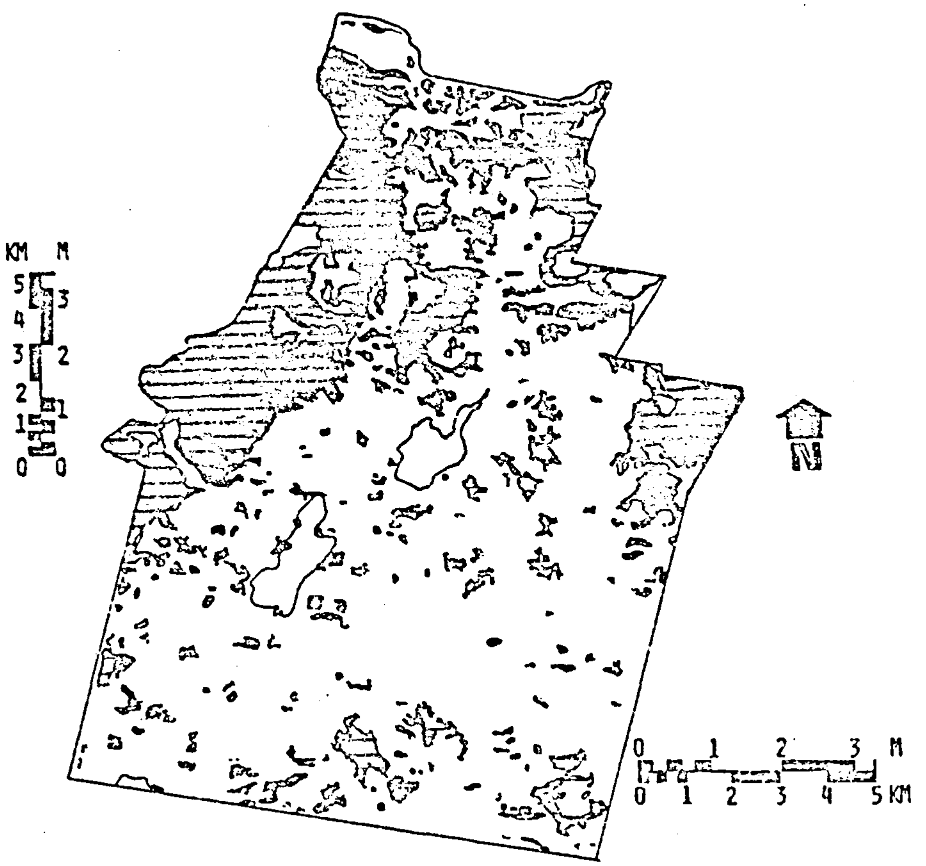

516 HECTARES

RANGE: 2.5×10^8 TO 3.5×10^8 JOULES/METER^2
AVERAGE: 3.0×10^8 J/M^2
TOTAL FOR AREA: $3.0 \times 10^8 \times 516$ (HA) = 1.5×10^{11} (IN JOULE EQUIVALENTS)

4971 HECTARES

RANGE: 1.5×10^8 TO 2.49×10^8 JOULES/METER^2
AVERAGE: 2.0×10^8 J/M^2
TOTAL FOR AREA: $2.0 \times 10^8 \times 4971$ (HA) = 9.9×10^{11} (IN JOULE EQUIVALENTS)

166 HECTARES

RANGE: 2.9×10^7 TO 1.49×10^8 JOULES/METER^2
AVERAGE: 0.90×10^8 J/M^2
TOTAL FOR AREA: $0.90 \times 10^8 \times 166$ (HA) = 1.5×10^{10} (IN JOULE EQUIVALENTS)

FIGURE 7: MAP OUT-PUT SELECTION 2; BIOMASS ESTIMATES FOR THE SCENARIO FOR ASSESSING EXISTING AND POTENTIAL SUPPLIES OF OAK AS A HARDWOOD RESOURCE. THE BIOMASS ESTIMATION TECHNIQUE IS AN ADJUNCT PROCEDURE AVAILABLE AS AN OPTIONAL MAP OUTPUT AND COULD PROVE ON REFINEMENT A USEFUL TECHNIQUE INTERMEDIATE BETWEEN SATELLITE AND AERIAL REMOTE SENSING ESTIMATIONS AND GROUND CRUISING TECHNIQUES. THE METHOD HAS BEEN DERIVED FROM THE MASSACHUSETTS LAND USE CLASSIFICATION SYSTEM, "MAPDOWN", ATTRIBUTABLE TO MACCONNELL, AND DERIVED FROM STAND AGE, CANOPY COVER, AND HEIGHT.

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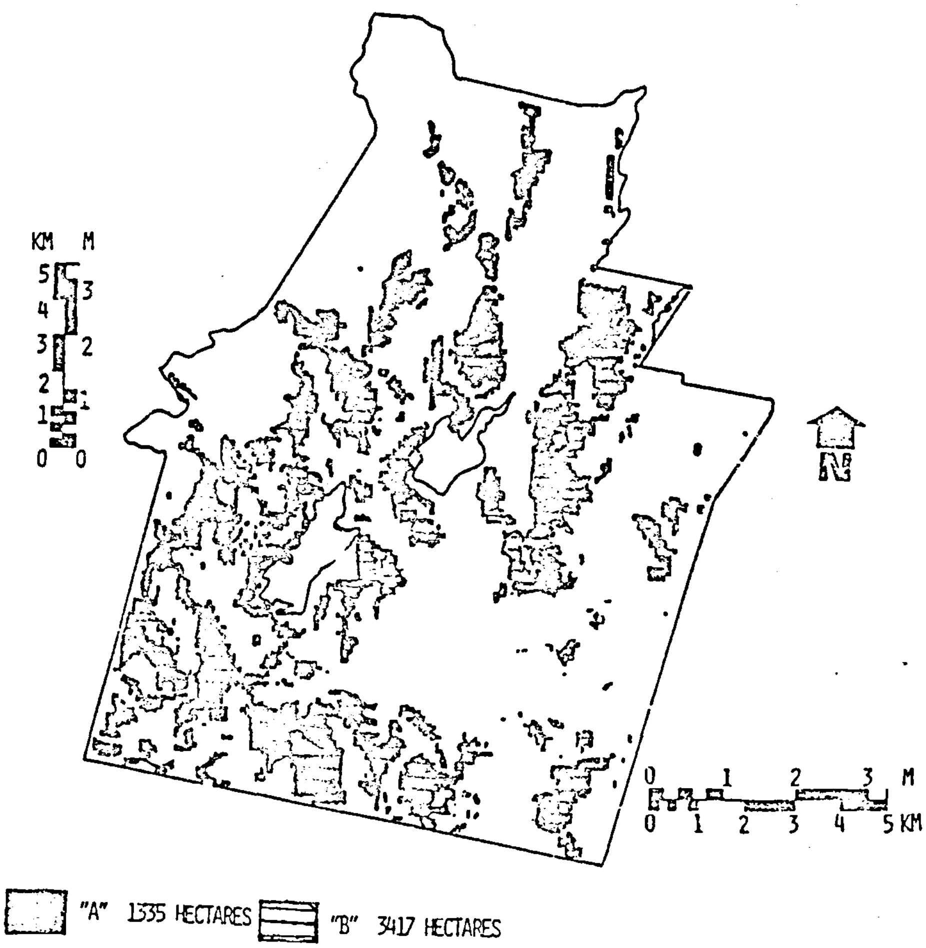

"A": COOCCURRENCE OF EXISTING OAK IN MORE PURE STANDS WITH HIGH POTENTIAL SITE SUITABILITIES.

"B": AREAS OF HIGH POTENTIAL NOT PRESENTLY USED.

FIGURE 8: MAP OUT-PUT SELECTION 3; SCENARIO FOR EXISTING OAKS IN MORE-PURE STANDS, COMPARED WITH SITES SUITABLE FOR OAKS AS GOVERNED BY THE ABIOTIC PARAMETERS OF FAVORABLE SOILS, SLOPES AND ASPECTS. COOCCURRENCE OF EXISTING OAK WITH POTENTIAL SITE SUITABILITIES ARE DISPLAYED, AS ARE AREAS WHICH ARE SUITABLE BUT ARE CURRENTLY NOT USED FOR THE PURPOSE. IN THIS CASE THE INFORMATION WITHIN THE A GREGATION FILES OF THE SECOND ORDER OF MANAGEMENT OF THE EXISTING SUPPLY MATRIX ARE OVERLAYED WITH THE THREE ABIOTIC PARAMETERS GOVERNING THE POTENTIAL SUPPLY MATRIX. CLEARLY, MANY OTHER COMBINATIONS OF DATA FILE INFORMATION ARE POSSIBLE, INCLUDING THE CONJOINT MAPPING WITH OTHER SCENARIOS SO THAT EXISTING AND POTENTIAL LAND USE CONFLICTS CAN BE DISPLAYED.

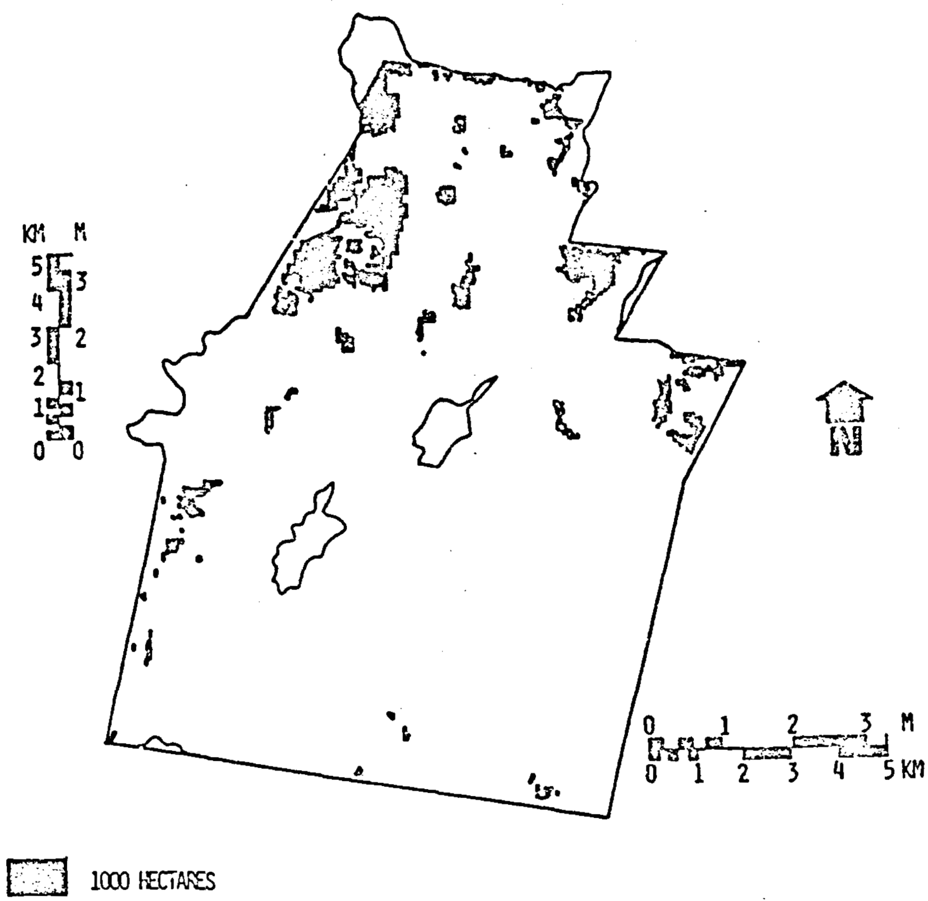

FIGURE 9: MAP OUT-PUT SELECTION 4; SCENARIO FOR EXISTING OAKS IN MORE-PURE STANDS. THIS MAP USES THE EXISTING SUPPLY MATRIX AND CONSIDERS THE ANTHROPIC VARIABLES WHICH SERVE TO CONSTRAIN (·/C) THE LIKELIHOOD OF SUCCESSFUL OPERATIONS. THE VARIABLES IN THIS CASE ARE THOSE MENTIONED IN THE TEXT RELATED TO THE THIRD ORDER MANAGEMENT CONSIDERATIONS OF: PRIVATELY OWNED LAND PARCELS OF OVER 5 HECTARES (12.35 ACRES), OF AT LEAST TWO CONTIGUOUS OR LINKED LOTS, WITHIN 5 KILOMETERS (3.1 MILES) OF LEVEL 1 ROADS (INTERSTATE HIGHWAYS) AS THE PROXIMITY FACTOR, AND OF MACHINE ACCESSIBLE SLOPES BETWEEN 8-25%.

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ASSESSMENT OF COASTAL DETERIORATION USING HISTORICAL PHOTOGRAPHY AND A GIS

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The goal of this project was to utilize the capabilities of a geographic information system to quantitatively assess the amount, rate, and location of marsh deterioration in a 945 km^2 (365 sq mile) subsystem of Barataria Basin, Louisiana. Forty-one percent of the coastal wetlands of the contiguous United States lie within the deltaic plain of Louisiana. These wetlands and the large commercial fishery they support represent a valuable renewable resource. Rates of loss from 1940 to 1970 were determined to be only 43 km^2 (16.5 sq miles) per year. Loss of this resource in Louisiana is presently occurring at an increased rate of 130 km^2 (50 sq miles) per year. Some of this marsh loss can be directly attributed to human activities such as agricultural and residential development, and to the dredging of canals for oil and gas exploration and production. However, over 50 percent of this loss is conversion of marsh to open water which results from some combination and/or interaction between natural processes and the indirect effects of humans. Causal mechanisms for this marsh deterioration have not yet been fully determined.

Raw data for this project consisted of aerial photography acquired in 1945, 1956, and 1980. These data were manually photointerpreted using a classification system developed to resolve marsh states into discrete categories based on size and spatial distribution of water bodies. These maps were mosaiced into a controlled data base, digitized in polygon format, and then converted to a grid format compatible with the NASA developed Earth Resources Laboratory Applications Software (ELAS). ELAS allowed definition of the temporal sequence of marsh deterioration and identification of spatial trends. Spatial resolution was determined by a 1.0 ha minimum mapping unit and a 0.25 ha grid cell size, while the attribute resolution was determined by the 20 categories of the classification scheme.

Results show differential rates of marsh loss between the first, 11 year interval (1945-1956) and the second, 24 year interval (1956-1980). Summary data from a spatially integrated change detection analysis between 1945 and 1956 yields a rate of marsh loss of 2.3 km^2 (0.9 sq miles), or 0.2 percent, of the study area per year. Only 44 percent of this loss is accounted for by direct human activities. The rate of marsh loss for the 1956 to 1980 interval is 8.2 km^2 (3.6 sq miles), or 0.9 percent, per year. Only 43 percent of this loss is accounted for by direct human activities. The loss for the earlier interval agrees with the corresponding national rate of 0.2 percent per year, while the second interval is markedly higher than the corresponding national rate of 0.5 percent per year. Total area of marsh loss between 1945 and 1980 is 220 km^2 (85 sq miles), or 23 percent of the study area.

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Preliminary spatial analysis indicates five discrete areas, each of which has a unique characteristic sequence of change over time. These spatial patterns are being synthesized with existing environmental data which are being reinterpreted with respect to spatial attributes. This, in turn, is generating new hypotheses to explain changes in marsh patterns and the ecological processes they represent.

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LANDSAT APPLICATIONS FOR THE STATE OF DELAWARE

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ABSTRACT

This paper summarizes the first phase of a cooperative demonstration project between the Eastern Regional Remote Sensing Applications Center (ERRSAC) and the Delaware Department of Natural Resources and Environmental Control with support from the University of Delaware's College of Marine Studies. Separate land cover classifications were performed for three counties in Delaware using multiseasonal Landsat data from April 3 and July 20, 1974. The objective of the New Castle County and Kent County classifications was to provide general land cover information with special emphasis on existing farmland and deciduous and coniferous forest, respectively. A detailed study of existing inland and coastal wetland vegetation communities was attempted for Sussex County. Detailed accuracy assessments were conducted for general land cover in New Castle and Kent Counties and for wetland communities in Sussex County. The classifications were combined to provide a statewide Level I land cover map and acreage statistics. Based on these results, the participating state agencies determined that Landsat is a viable tool for mapping and monitoring land cover within the state.

1. INTRODUCTION

On April 30, 1979, ERRSAC sponsored a remote sensing applications workshop in Delaware for state and local resource managers and university personnel, as part of its mandate to transfer NASA-developed remote sensing technology to state and local government agencies in 19 northeastern and north-central states. This workshop introduced state personnel to the characteristics of Landsat data and applications, especially for water resources and coastal zone management, and to active applications programs being conducted in other states. This was followed by a demonstration of Landsat data analysis capabilities at the Goddard Space Flight Center (GSFC) on May 22, 1979, to 25 people from Delaware. Representatives from Delaware state government also attended ERRSAC's first Remote Sensing Applications Conference in Easton, Maryland, October 2-5, 1979 (1).

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These events resulted in a meeting on October 29, 1979, to discuss the feasibility of Delaware using Landsat data for resource management. Considerable interest was expressed in exploring the capabilities of Landsat data for meeting the state's information needs. As a result, a questionnaire outlining 17 possible Landsat demonstration projects was circulated among state and local government personnel by the Delaware Department of Natural Resources and Environmental Control (DNREC). The project areas that elicited the greatest response were:

- Mapping land cover change.
- Mapping development of wetlands.
- Mapping conversion of agricultural land to other uses.
- Integration of Landsat land cover data into an existing data base.

Based on this response, a letter was sent to Governor Pierre DuPont in April 1980 requesting his support for the cooperative program. The following September, DNREC reached an agreement with ERRSAC to conduct a cooperative remote sensing applications program and convened a detailed planning meeting with ERRSAC and the University of Delaware.

DNREC, as Delaware's principal natural resources agency, took the leading role for the state. ERRSAC provided technical expertise, project guidance, and the primary capability in processing and analysis of Landsat data. The University of Delaware's College of Marine Studies provided additional technical assistance in establishing an operational remote access capability to the Pennsylvania State University Office of Remote Sensing of Earth Resources (ORSER) and the Earth Resources Data Analysis Systems (ERDAS), Inc. image processing software available at the University of Delaware Center for Remote Sensing.

Three remote sensing demonstration projects were selected, study sites identified, and project plans discussed during this meeting (see Figure 1). The first, an agricultural land conversion study, was prompted by the requirements of House Bill No. 307 on Agricultural Land Preservation passed by the Delaware State Legislature in 1981. In this legislation, the Secretary of Agriculture is required to report to the Governor, the General Assembly, and the Governor's Council on Agriculture about the extent, location, and causes of farmland loss presently occurring in the state. The Division of Soil and Water Conservation of the DNREC became involved in the Landsat demonstration project to see if Landsat could help identify these farmland losses. Since New Castle County has the largest population and most pressure for development, it was chosen as the test area for evaluating Landsat data as a tool in monitoring farmlands.

The general land cover change project was of particular interest to DNREC's Division of Parks and Recreation [which is now part of the Department of Agriculture (DOA)] for examining changes in the distribution of forest cover. Kent County was selected as the most representative county in which to test this application.

Finally, the Wetlands Section of DNREC's Division of Environmental Control wanted to use Landsat for mapping and monitoring wetland communities, particularly in Delaware's rapidly developing Sussex County.

For the demonstration project, only one of the two change detection years would be examined. The state would be responsible for analyzing the second year. Moreover, since all of Delaware's three counties were to be studied, a statewide land cover classification was possible. Therefore, the data analysis was designed and conducted to ensure that the results would be compatible and could be combined to form a statewide land cover classification.

2. DATA COLLECTION

Initially, the project plan called for the classification of a single Landsat scene. Since the accuracy of a preliminary unsupervised classification of the July 20, 1974 data set used by itself proved to be unacceptable, an alternative approach was attempted. To increase the classification accuracy, an April 3, 1974 Landsat scene was merged with the July data set to provide a multiseasonal data set acquired within a single year. In addition, USGS 7.5 minute series topographic maps and 1973/1974 color-infrared aerial photographs at scales of 1:24,000 and 1:126,000 respectively were used in the data analysis. Field observations and the recently available National Wetlands Survey Maps (based on 1979 aerial photography) were used in support of the accuracy assessment.

3. PRECLASSIFICATION METHODS

As noted above, an April 3, 1974 Landsat scene was merged with the July data set. This effort was accomplished by utilizing the following procedures:

- Preprocessing to minimize radiometric noise in the Landsat multispectral scanner (MSS) data.
- Spatial registration of multitemporal images to a common map projection.
- Classification by county of the eight spectral/temporal channels using an iterative unsupervised clustering approach followed by manual cluster labeling.
- Wetland training site selection and supervised classification of wetland areas in Sussex County, subsequently merged with unsupervised land cover clusters.
- Final statistical summary and accuracy assessment.

The image processing software used to accomplish the above tasks included the following systems:

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- ERRSAC's Interactive Digital Image Manipulation System (IDIMS).
- ERRSAC's Geographic Entry System (GES).
- Goddard Space Flight Center's Video Image Communication and Retrieval (VICAR) System.
- University of Delaware's ORSER System.
- University of Delaware's Earth Resources Data Analysis System (ERDAS).

IDIMS and GES were developed for an HP-3000 computer by the Electromagnetic Systems Laboratory (ESL) Inc., a subsidiary of TRW Inc. in Sunnyvale, California. VICAR is an IBM-based image processing software system developed by the Jet Propulsion Laboratory (JPL) in Pasadena, California. ORSER is an IBM-based image processing software system developed by the Pennsylvania State University Office for Remote Sensing of Earth Resources and modified to run on the University of Delaware's Burroughs B7700 computer. ERDAS is an image processing and geographic information system developed by ERDAS, Inc. of Atlanta, Georgia for a Z-80 microprocessor.

3.1 Radiometric Preprocessing

When entered into IDIMS, the two-date digital Landsat data were reformatted and corrected for distortions introduced by earth-rotational skew and inclusion of synthetic pixels. The data were unleaved line-by-line and digital values were converted into 256 quantization levels. However, aspect ratio, mirror scan velocity profile, panorama effect, band-to-band misregistration, and radiometric recalibration are not compensated for by this IDIMS software. Visual examination on an interactive video-display device revealed no significant geometric distortion.

Two radiometric distortions evident in the data were line dropouts and six-line striping. Digital values in bad data lines were replaced by the average of the digital values in the preceding and following lines. Based on the assumption that each of the six sensors in each band had been exposed to scene radiances with approximately the same probability distribution, a non-linear approach was used for destriping. Sensor values were modified so that each one would be related in the same way to the actual scene radiance. This procedure, available within the VICAR image processing software, adjusts or "equalizes" every striped sensor's cumulative histogram to the scene cumulative histogram (2). No multidate radiometric calibrations such as a sun angle correction or a band-to-band radiometric calibration were performed. Bands 4 and 5 of the April scene were left in the original high-gain mode, set at the time of overpass to maximize water penetration.

3.2 Geometric Adjustment and County Stratification

The two dates of image data were spatially registered to a common map projection, the Universal Transverse Mercator (UTM). Prior to spatial registration, common image lines were found in the two July scenes (path 15, rows 32 and 33). Two subscenes were extracted and mosaicked together top to bottom. Complete state coverage was not used for the April data. A northern portion of New Castle County was missing from the April date because of cloud coverage.

Image coordinates for about 60 uniformly distributed ground control points were located within each county for each date. The points were simultaneously marked on USGS 7.5 minute series topographic maps to tie common features in both dates of imagery to a selected base map. Using these maps the UTM coordinates were digitized on a digitizing table with software in the Geographic Entry System (GES). The multitemporal imagery was registered for each county separately. A UTM origin was selected for each county and the corresponding digitized ground control points were rescaled to image coordinates representing 50-meter square pixels. Third-order polynominal equations were used to provide a least squares transformation between raw image coordinates and the rescaled UTM coordinates. Control points with large residuals were iteratively deleted until the final least squares residuals ranged between $\pm$ 1.5 pixels. The average residual error was always less than 0.5 pixel for each of the six registrations.

A simple bilinear interpolation was used to resample the input image density values to the desired output pixel location. Bilinear interpolation was chosen because it produces a less blocky appearance of linear features than that associated with nearest-neighbor interpolation. Although high-order interpolation improved the visual appearance of images, analysis techniques such as classification could be sensitive to the resampling method employed (3). For a general land cover classification such as that developed in this study, it was felt that the bilinear method would not have a significant effect on the classification, although no tests were done to verify this assumption. Ethridge and Nelson (4) found no significant difference between the maximum likelihood classification results of the three resampling methods. However, Logan and Strahler (5) found that the average forest training class mean decreased by 4.56 digital counts and was accompanied by an increase in the standard deviation of 42 percent for bilinear resampled data and 60 percent for cubic interpolation.

Multidate registration was verified on a video display by flickering between the two image dates. The base map registration was verified by overlaying raster plotter gray maps on the 7.5 minute topographic maps. Visual examination revealed that the registration deviated no more than one pixel in any area. After this spatial adjustment was applied to the raw data, a copy was recorded on magnetic tape and sent to the University of Delaware for input to the ORSER and ERDAS image processing systems. Here, the data could easily be accessed by DNREC and DOA analysts.

The county and 7.5 minute topographic map boundaries were digitized as separate polygon overlays with the GES software. Each overlay was converted into a raster image with the same origin and pixel size as the spatially adjusted Landsat data. The county image was used to stratify the Landsat data by county and eliminate any data outside of the State of Delaware. The topographic map image was used to produce 7.5 minute map overlays on a raster plotter to (1) validate the Landsat geometric adjustments, and (2) produce classification maps for the accuracy assessment. An example of the digitized boundaries is shown in Figure 2.

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4. CLASSIFICATION METHODS

Two approaches to classification were used as part of the Delaware state projects. For the general land cover surveys, separate unsupervised classifications were performed for each county. A supervised approach was used for the more specific classification of wetland communities in Sussex County.

4.1 Unsupervised Clustering

An unsupervised approach was used to develop ground cover classification signatures for each county. The aim of unsupervised clustering was to partition the multispectral/multitemporal data into disjoint sets of spectrally homogeneous clusters without prior knowledge about the actual signature distribution of individual land cover categories. The most important feature of this approach was that it defines not only the pure ground cover types in a Landsat scene, but also the mixture classes that were present. The term unsupervised can be misleading because a high degree of analyst interaction was required to successfully use this technique. As diagrammed in Figure 3, this was an iterative procedure. The analyst first selected an algorithm suitable for the application and then iteratively changed the numerical parameters until an acceptable result was obtained.

The algorithm used was the ISOCLS software available in IDIMS. This program was both versatile and complicated because the algorithm subjected the multivariate data to a certain number of split and combine iterations. The number and order of iterations were determined by the analyst. On a split iteration, clusters which exhibited standard deviations (in one or more channels) greater than the analyst-specified standard deviation were split. On a combine iteration, pairs of clusters were evaluated to see if their means were less than an analyst-specified distance apart. If the separation was less than this distance, the clusters were merged. In addition to an output cluster image, a statistics file describing the statistical distribution of each cluster's spectral/temporal signature was generated.

The spatial location of each cluster was displayed on an interactive video display device and manually assigned a land cover label. Topographic maps, aerial photographs, and two-band spectral plots were used as labeling aids in the process. The analyst made an initial visual interpretation as to the land cover category to which each cluster belonged by examining the spectral plot of means and covariances. When the most appropriate land cover type was determined for a cluster, the analyst interactively assigned a color to it. Cluster labeling was a very subjective procedure. As a result, the analyst needed to have good aerial photointerpretive skills, a physical understanding of the spectral data to interpret the spectral plots, and adequate field knowledge of the study site. In this application, the label of each cluster was evaluated by the DNREC or DOA analyst who was the most familiar with the corresponding area.

4.2 Masking and Reclustering

Adding a second date to the unsupervised classification increased the variability within the data set, and therefore, the clustering algorithm should have generated more clusters to characterize the seasonal variability in spectral response. However, as the number of channels increased, the maximum number of clusters that could be generated by the IDIMS ISOCLS algorithm decreased. For an eight-channel data set the maximum number of clusters was 64. A thresholding and masking technique was used to generate more clusters in a two-phase approach to clustering.

In the first phase masks for the water class were created for both dates by finding a binary threshold in Landsat MSS band 7. These two masks were combined (i.e., multiplied together) and used to mask out water by multiplying the eight-channel data set by the water mask. The area of missing data in the April scene was eliminated from the July scene. This masking technique eliminated water classes, forcing the ISOCLS algorithm to produce more land cover clusters. The water mask was subsequently added back to the cluster classification to recreate the water category.

The resulting 63 land cover clusters were aggregated for each county to obtain nine land cover categories for New Castle County, eight categories for Kent County and six categories for Sussex County (see Results section). Evaluation of each county classification revealed some areas of confusion between wetlands and forests, commercial/industrial and agriculture, and residential and agriculture. In part, this problem was due to the large variation added to the data by the addition of data for a second date without a comparable increase in the number of clusters generated. Examination of the covariance matrix of each cluster revealed a larger covariance within the data for each date than between dates. Thus the multitemporal variation was well segmented, but the within-date variations were not adequately segmented into meaningful clusters.

In the second phase of clustering, an attempt was made to reduce the variance within clusters by doubling the number of clusters generated by the ISOCLS program. For example, twenty-seven of the clusters with the largest within-date variances were grouped together to form a mask in New Castle County. The remaining data formed a second mask. Each mask was multiplied with the raw data, clustered into 63 clusters, and subsequently added to form 126 new clusters. The new cluster image was cross-tabulated with the previous land cover classification to speed up the labeling process. Using a simple plurality decision rule, cluster labels were assigned based upon the predominant land cover present in the previous classification (6).

4.3 Stratified Cluster Labeling

Each state participant visited ERRSAC for a 1-day intensive analysis session to help refine the cluster labelings. For the northern portion of New Castle County, the small area of single-date data was clustered separately, labeled and merged with the county classification map. An evaluation by the state participant revealed some remaining confusion between agriculture, urban, and wetland cover types. In particular, the commission errors of the urban categories were too high.

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To save time and to reduce commission errors, a stratified approach to cluster labeling was pursued. Using 7.5 minute topographic maps, the three cluster images were segmented into two zones, one corresponding to areas of major urban influence (i.e., residential, industrial, commercial) and the other with no urbanization (Figure 4). Clusters that were previously labeled as urban in the non-urban strata were grouped into wetland or agricultural cover types. This classification was merged with the urban classification to create the final land cover classification. A color negative of this image was sent to DNREC, from which 1:50,000-scale color prints of the county classifications were made.

4.4 State Level Aggregation

For the state level classification, the categories in the unsupervised classifications of each county were aggregated into six categories: agriculture, developed, wetlands, coniferous woodland, deciduous woodland, and water. In New Castle and Kent Counties, shallow water and water were grouped into the water category, and commercial/industrial, residential, and construction/bare soil were grouped together into the developed category. The three counties were mosaicked together and the county boundaries were digitally superimposed onto the final state level classification map.

4.5 Supervised Wetland Classification

Since the objective of the wetland classification was a delineation of several marsh species as well as the separation of freshwater and tidal species communities, a more intensive approach combining supervised and unsupervised techniques was used for Sussex County. The wetland species communities included (1) reed grass (phragmites communis), (2) salt hay (spartina patens), (3) cord grass (spartina alterniflora), (4) brackish marsh (a mixture of salt-tolerant and freshwater species), (5) freshwater marsh, (6) evergreen swamp (cypress and cedar), and (7) hardwood swamp (water oak, black gum, sweet gum, and red maple).

First, unsupervised clustering was used to generate 64 multitemporal/multispectral clusters. These clusters were grouped into six general land cover categories: (1) water, (2) developed, (3) wetlands, (4) coniferous woodland, (5) deciduous woodland, and (6) agriculture. Next, supervised training sites were located within the wetland communities and other cover types that were mistakenly classified as wetlands. A number of iterations were required before most of the wetland seasonal spectral responses were characterized. Final mean vectors and covariance matrices were generated for 60 wetland training sites distributed throughout Sussex County with the aid of the DNREC analyst and 1973 color infrared aerial photographs. Each training site was either accepted or rejected during this process based on the statistics for each band of data. For example, any site with a bimodal distribution was rejected.

After each iteration, the Landsat data were classified using a maximum likelihood decision rule for each of the 60 sites. Each class was then displayed and selectively thresholded, using the likelihood value of each pixel to eliminate areas not belonging to the class.

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Finally, several of the unsupervised wetland signatures were merged with the supervised classification using an image overlaying technique to create a final wetland map.

5. RESULTS

Presented below in Table I are the results of the three individual county classifications aggregated for the State of Delaware, along with overall accuracy levels. There are no correlative sources of information available from the state for comparison, but the high accuracy levels confirm the reliability of the tri-county classification.

The other tables in this section present the results of the individual county accuracy assessments, and the Sussex County wetlands classification. A general land cover accuracy assessment was not done for Sussex County because the project was designed to map wetlands at the species level. Therefore, the percent accuracy figures in Table I are the combined land cover accuracies for the New Castle and Kent Counties.

TABLE I

ACREAGE COUNTS

Category	New Castle	Kent	Sussex	State	Percent Accuracy
Developed	64212	15035	23581	102828	91.5
Agriculture	138658	221605	298851	659114	93.4
Deciduous	50796	92308	185392	328496	93.9
Coniferous	880	6626	59630	67136	100.0
Wetlands	19469	42858	36963	99290	75.7
Water	23188	130345	154809	308342	94.5
Totals	297203	508777	759226	1565204	92.4

(Water acreages for Kent and Sussex Counties include the Delaware Bay).

5.1 Kent and New Castle Counties

The accuracy assessments for New Castle and Kent Counties were carried out using a total of seven USGS 7.5 minute topographic quadrangles, and selecting either a 5 or 10 percent random sample of pixels on each quad sheet. This represented a 4.5 percent sample of Delaware's land area statewide.

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The accuracy assessments were conducted by overlaying thematic plotter maps of the Landsat classification and photographic mylars of the ground truth information (1973 black-and-white aerial photography) onto the 7.5 minute quads. Both the photo mylars and plotter maps were reproduced at a scale of 1:24,000 in order to fit the 7.5 minute quad sheets. A grid with a cell size of 25 pixels (5 x 5 pixel blocks), numbered along its x and y axes, then was superimposed on the other products. Using a random numbers table, 251 cells were sampled for each quad in New Castle County, or a total of 6275 pixels per map, and 125 cells were sampled for each quad in Kent County, or a total of approximately 3125 pixels per map. Each cell of the plotter map was compared with the photo mylar (ground truth) on a pixel-by-pixel basis. Areas which could not be identified on the aerial photography were checked in the field. A count of the number of correct and incorrect pixels was recorded, and these results are summarized in the following tables.

TABLE II

NEW CASTLE COUNTY ACCURACY ASSESSMENT

LANDSAT IDENTIFICATION

VERIFIED CATEGORY	DECID	AGRIC	DEVEL	CONIF	WETLDS	WATER	TOTAL	% CORRECT	MAP ACCURACY*
Decid.	2055	205	36		13		2309	89.0	85.3
Agric.	65	7838	756		19		8678	90.3	83.0
Devel.	2	371	4486		4	3	4866	92.2	77.9
Conifer.				58			58	100.0	95.1
Wetland	31	185	61	3	510	4	794	64.2	56.7
Water	3	4	43		70	1470	1590	92.5	92.0
Total	2156	8603	5382	61	616	1477	18295	89.7	
% Commis.	4.7	9.9	16.6	4.9	20.8	.5			

(Combined contingency table for Middletown, Newark East, and Wilmington South quadrangles; 10 percent sample of pixels per quad)

*map accuracy equals the total number of pixels correctly identified, divided by the total number of pixels in the ground truth category, plus the number of pixels incorrectly included in that category by the Landsat data classification.

The only category that was classified with less than adequate accuracy in New Castle County was wetlands, which the Landsat interpretation confused mostly with agriculture. All other categories were classified with approximately 90 percent accuracy (i.e., percent correct). This is particularly important in New Castle County, because here Landsat data may be used in conjunction with other information to monitor the conversion of large blocks of farmland to other land use types.

There are several reasons which explain why confusion exists between the major land cover categories. These can be summarized as follows:

- misclassification due to edge effects created when multiple categories appear within a small area;

- errors that can be attributed to out-of-context classification; e.g., parkland within urban areas being classified as agriculture;

- seasonal differences between aerial photos (March 1973) and Landsat data sets (April and July 1974), as well as actual land cover changes due to construction; and

- misregistration among the Landsat dates and ground verification data.

TABLE III

KENT COUNTY ACCURACY ASSESSMENT

LANDSAT CLASSIFICATION

<CATEGORY>	AGRIC	WETLD	RESID	COMM'L	CONIF	DECID	WATSH	WATER	TOTAL	% CORRECT	MAP ACCURACY (%)
AGRICULTURE	6903	84	34	22	3	57	--	--	7103	97.2	94.6
WETLANDS	48	595	5	12	--	3	2	--	665	89.5	78.7
RESIDENTIAL	59	1	259	24	--	7	--	--	350	74.0	64.0
COMMERCIAL/ INDUSTRIAL	11	--	13	155	--	2	--	--	181	85.6	64.9
CONIFEROUS	--	--	--	--	143	--	--	--	143	100.0	97.9
DECIDUOUS	79	6	3	1	--	3188	--	--	3277	97.3	95.3
WATER, SHALLOW	--	--	--	--	--	--	34	--	34	100.0	89.5
WATER +	--	--	--	--	--	--	2	548	550	99.6	99.6
TOTALS	7100	686	314	214	146	3257	38	548	12303	96.4	

Only the developed categories (commercial-industrial and residential) in Kent County were classified with moderate accuracy; all others were once again in the 90 to 100 percent range. Many of the same problems which affected the New Castle County classification were also present here, including the edge factor, time changes, and confusion between similar spectral classes representing different land use or land cover categories. The overall Kent County classification, however, had excellent accuracies for agriculture, forest and water. It can be stated that in general, both Kent and New Castle Counties were accurately classified over large areas, and that most of the classification errors occurred in small areas, such as along boundaries or in other transitional areas.

5.2 Sussex County Wetlands Inventory

The classification of wetland communities in Sussex County, including several individual species, was only partially successful. Hardwood swamp (52 percent of all wetlands) was by far the largest category as mapped by Landsat; while no doubt extensive, this figure is obviously overestimated. Similarly, coniferous swamp is well underestimated. The state analyst, however, confirms that the estimates of brackish marsh, cord grass (spartina alterniflora), and salt hay (spartina patens) are reasonable, while those for freshwater marsh and reed grass (phragmites) are somewhat uncertain. This is mirrored in the accuracy assessment by the fact that only spartina alterniflora, water, and the other general land cover (non-marsh) categories were mapped with acceptable ($\geq$ 50 percent) accuracies. Freshwater marsh was delineated with only approximately 30 percent accuracy, brackish marsh with approximately 40 percent, and hardwood swamp, coniferous swamp, and spartina patens were mapped at approximately the 46 percent accuracy level.

TABLE IV

SUSSEX COUNTY, DELAWARE

1974 LANDSAT WETLANDS INVENTORY

WETLAND COMMUNITY	ACREAGE	% OF AREA
Hardwood Swamp	36701	52.0
Coniferous Swamp	2506	3.6
Freshwater Marsh	6191	8.8
Phragmites	2162	3.1
Brackish Marsh	6047	8.6
Spartina Alterniflora	15066	21.3
Spartina Patens	1900	2.7
Total	70573	100.0

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Reasons for these low accuracies include the difficulty of selecting reliable training sites for the various marsh types, the need for data from other or additional seasons, and the limited spatial and spectral resolution available with the Landsat MSS (7). It is possible that if the study area had first been stratified into upland and lowland types as reported in Ernst et al. (8), much higher map accuracies could have been achieved.

TABLE V

1974 ACCURACY ASSESSMENT

WETLANDS CLASSIFICATION, SUSSEX COUNTY, DELAWARE

LANDSAT IDENTIFICATION (8-BANDS)

	Hardwood Swamp	Coniferous Swamp	Freshwater Marsh	Water	Phragmites	Brackish Marsh	Spartina Alterniflora	Spartina Patens	Other	Total	% Correct
Hardwood Swamp	205	12	16		10	12	2	1	193	451	45.5
Coniferous Swamp	6	30	1			3	4		22	66	45.5
Freshwater Marsh	5	44	76	1	20	21	22	7	66	262	29.0
Water	1	31	40	1399	1	16	139	3	75	1705	82.1
Phragmites	1	1	6		23	4	3		44	82	28.0
Brackish Marsh	5	1	9	1	7	114	31	5	113	286	39.9
Spartina Alterniflora				27		47	535	60	59	728	73.5
Spartina Patens					1	5	17	25	6	54	46.3
Other	205	6	21	4	71	48	80	80	6836	7351	93.0
Total	428	125	169	1432	133	270	633	180	7414	10985	
% Commission	52.1	76.0	55.0	2.3	87.7	57.8	35.8	86.1	7.8		

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6. CONCLUSIONS

Multitemporal Landsat MSS data produced an accurate and useful inventory of farmland, forest and general land cover for the state. Comparison of land cover classifications from different years therefore would provide the change detection information required by Public Law 307. Based on the success of these applications, the State of Delaware has established an image processing capability at the University's Center for Remote Sensing in Newark, and plans to explore further applications of Landsat data. Specifically, a more recent (crica 1980) statewide land cover classification for examining land use change is anticipated. Although Landsat MSS data were found to be only marginally useful for mapping communities of wetland species, the Landsat 4 Thematic Mapper, an advanced remote sensor launched in July 1982, holds special promise for improving discrimination of wetland types. The State and University of Delaware plan to investigate the capabilities of this new sensor in future resource monitoring projects.

7. ACKNOWLEDGMENTS

The authors would like to thank Roger Caves, Patrick Redden, and Jane Squires of the Delaware Department of Agriculture, and David Hardin (Wetlands Section), William Moyer (Manager, Wetlands Section), and Lynn Sprague (Division of Soil and Water) of the Delaware Department of Natural Resources and Environmental Control; and V. Klemas of the College of Marine Studies (University of Delaware). Their participation and valuable contributions were crucial to the success of the Delaware demonstration program. The authors also express their appreciation to Yun-Chi Lu of the Computer Sciences Corporation, who provided initial technical guidance for this program.

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FIGURE 1. Delaware State Projects

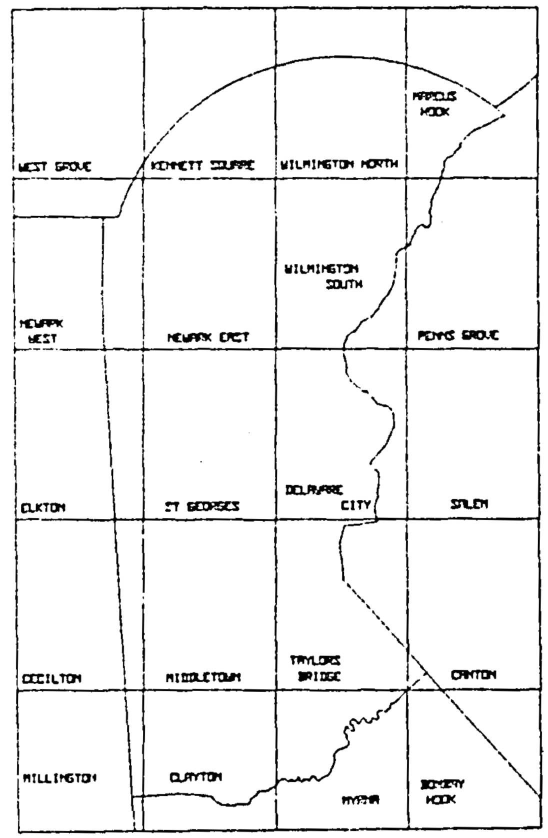

FIGURE 2. Quadrangle Boundaries for New Castle County

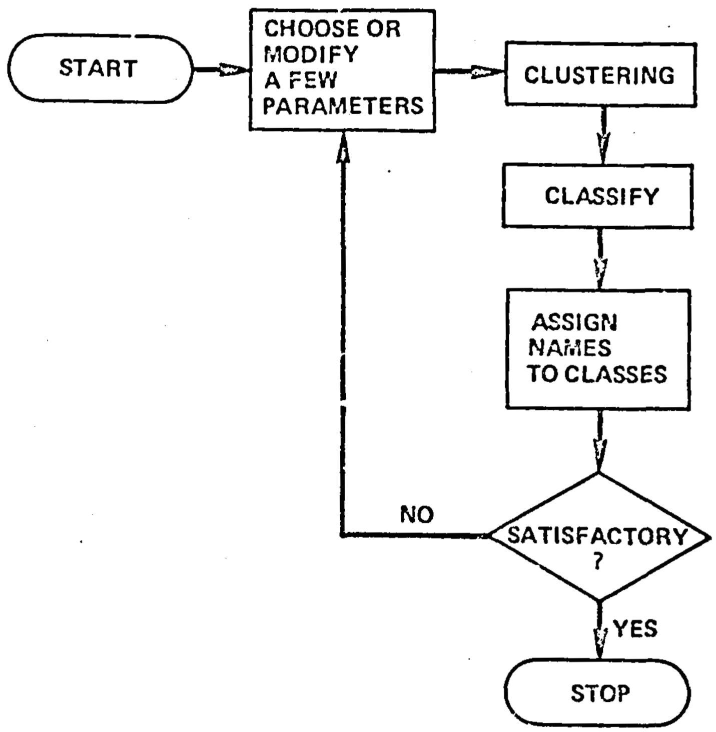

FIGURE 3. Strategy for Unsupervised Classification

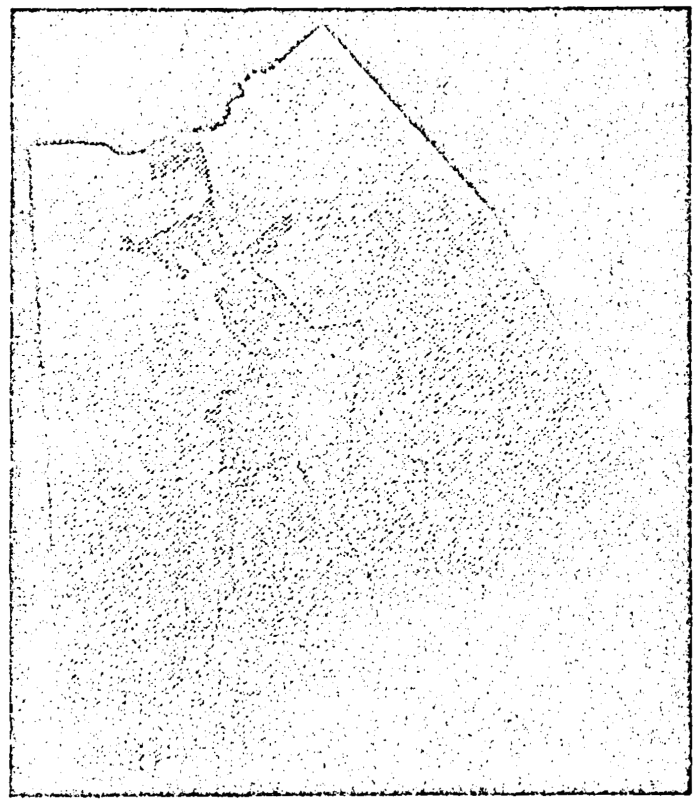

FIGURE 4. Urban versus Non-urban Influence Mask

Part 2

ENERGY FACILITY SITING

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IMPACT OF DEMOGRAPHIC SITING CRITERIA AND ENVIRONMENTAL SUITABILITY ON LAND AVAILABILITY FOR NUCLEAR REACTOR SITING

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1. INTRODUCTION

Development of a comprehensive policy for the integrated management of the nation's energy resources is hampered by a lack of detailed data bases. Continuing advances in computer mapping technology enable the efficient processing of detailed data for large regional analyses. For example, Dames & Moore conducted a study for Sandia National Laboratories and the U.S. Nuclear Regulatory Commission (NRC) to assess the effect of population and certain environmental characteristics on the availability of land for siting nuclear power plants. The study area, consisting of the 48 contiguous states, was divided into 5 kilometer (km) square grid cells yielding a total of 600,000 cells. Through the use of a modern geographic information system, it was possible to provide a detailed analysis of a quite large area. Numerous maps and statistical tables were produced, the detail of which were limited only by available data.

The study arose from the 1980 Nuclear Regulatory Commission appropriation authorization which directed the NRC to develop population density and distribution criteria for nuclear facility siting. Because the U.S. Congress further stated that the NRC should develop these standards so as not to preclude further siting of reactors in any region of the United States, the study was enhanced by examining the environmental suitability as well as the demographic characteristics of the nation. The analysis assessed and compared the impacts of a variety of individual and complex siting criteria which included population density and distribution, and environmental/engineering cost factors.

2. METHODOLOGY

The analytical method was an iterative-type analysis based on computer mapping technology. The investigation utilized Dames & Moore's Geographic Information Management System (GIMS), which analyzes data in a uniform sample based on abstraction in a grid cell format. GIMS provides a comprehensive approach to recording, storing, manipulating and displaying the mappable information used in spatial analyses as well as a dynamic data base which can be readily updated, and simultaneously allows evaluation of many alternatives that would otherwise be explored by time-consuming manual

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procedures. In addition to simple overlay techniques, its capability includes weighted overlays and cost modeling based on distance and impedance functions.

The selection of a base map and grid cell size on which to perform the analysis was based on consideration of four related factors: (1) characteristics of the study area; (2) nature of the input data; (3) analysis methodology; and (4) desired output or display products. By using an equal area projection, and a square 5-km grid cell, the visually implied regional relationships regarding the amount of land area affected by siting criteria became valid.

3. EVALUATION ISSUES

To meet the objectives of this study, a set of general siting issues was used to identify and discriminate more suitable siting areas from less suitable ones. The issues cover a variety of demographic criteria and a diverse set of environmental siting criteria that relate normally to cost considerations. It is important to note that the term "environmental" is being used in a somewhat limited sense. The factors considered in this guise relate to implementation, engineering, construction, or cost issues which share a common link to the physical environment -- hence, the label.

Three issues were defined for the population criteria:

- Stand-off zones -- Restrictions imposed by distance from urban centers of a particular size;
- Annular population density -- A measure of population density within a specified (circular) area; and
- Sector population density -- A measure of the distribution of population by sectors within circular areas of specified density.

Four issues were defined for the environmental criteria:

- Restricted lands -- Those areas in which the development of a nuclear power plant is difficult due to legal constraints or the predominance of wetlands;
- Seismic hardening -- The additional cost or difficulty of compliance with seismic design criteria; assumed to be measured by the maximum expected (50-year) horizontal ground acceleration expressed in fractions of gravity (g);
- Site preparation -- A relative measure of ruggedness or topographic character expressed as an index which indicates the percentage of land with access and construction difficulty; and

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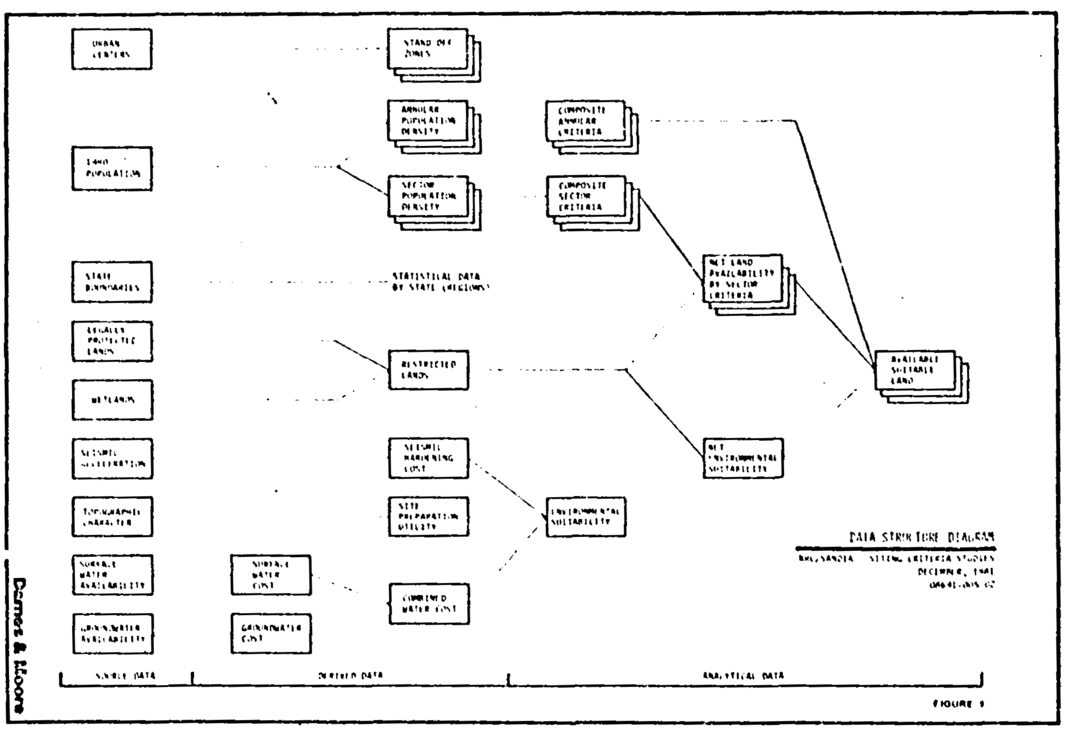
- o Water availability -- An index reflecting the relative cost of obtaining water for cooling, from both surface and ground water sources.

The latter three cost data were further combined to yield information regarding overall environmental suitability.

To describe the flow of data and the development of analysis through this project, a data structure diagram was used (Figure 1). It illustrates how information about the evaluation issues was derived from source data as well as how these were combined to yield the impacts of siting criteria on land availability. For the most part, each box on the diagram represents a map that was created or a data file that could be displayed either as a map or table.

4. DATA BASE

Detail of data employed in past studies considering large geographic areas was often limited by the effort and cost of computing huge map files. Today's limitations on detail, as in this study, consist more of the availability of detailed digital nationwide data bases as GIS modeling has become more efficient. Demographic data were the most detailed,



easiest to obtain in a digital format, and consisted of population counts geographically referenced by enumeration district centroids and urban centers. Environmental data were lacking in both format consistency and level of detail. They included the location of protected national and state resources such as forest and parks, major wetlands, seismic acceleration and associated construction costs, a measure of terrain ruggedness for access and construction considerations, and hydrologic data indicating sustained availability of both surface and ground water. While it is beyond the scope of this paper to illustrate all of the data employed and thoroughly discuss their strengths and weaknesses, the use of these data illuminated the need for vastly improved data bases. The issues defined, however, did support an analysis that showed trends and identified areas that could subsequently be considered for selection of power plant sites.

4.1. Urban Centers

Data concerning urban centers were extracted from the publication NUREG-0348 [1]. This publication categorizes urban centers into three groups: those centers with populations in excess of 25,000 people; greater than 100,000 people; and greater than 200,000 people. The listing was later updated with information provided by the NRC to include population figures for urban centers greater than 250,000 people, greater than 500,000 people, and greater than 1 million people

4.2. Population Density

To calculate population density for annuli and sectors, analyze various criteria, and ensure that the results be reliable in the face of changing national population trends, it was necessary to obtain the most up-to-date and detailed population figures. Figures from the 1980 Decenial Census were not available in time for use in this study. In their place, estimates for 1980 population were used as supplied by the National Planning Data Corporation (Ithaca, New York). The data were formatted on magnetic tapes with population figures geographically referenced by the latitude and longitude of enumeration district centroids.

4.3. State Boundaries

Using an Albers Equal Area Base Map at a 1:3,168,000 scale, all coastlines, international boundaries, and state boundaries were digitized. The area within each state was assigned a unique code to identify it for further use. The state boundaries map file was used to analyze data and display the results graphically and statistically both on an individual state basis and by groups of states.

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4.4. Restricted Lands

The nature of certain areas of the country causes them to be protected or restricted from development. Two types of lands were considered as restricted: a large group of lands that are legally protected; and existing major wetlands.

The Energy Reorganization Act of 1974 (Section 207) states that national forests, parks, historic monuments, and wilderness areas should be excluded from consideration as potential nuclear energy center sites. Regardless of a national policy on this matter, the utility industries tend to avoid such areas because of the possibility of time-consuming and costly legal battles. With this in mind, the list was expanded to include a variety of other protected lands such as: national grasslands, wildlife refuges, recreation areas, seashores; state parks, forests, reserves/refuges, recreation areas; and military and Indian reservations.

Three different map sources were used to obtain the locations of these protected lands: the United States base map utilized in this study (compiled by the U.S. Geological Survey, 1965); sectional sheets at a scale of 1:2,000,000 from the National Atlas [2]; and the 1980 Rand McNally Atlas as this was one of the most detailed, up-to-date, and uniform sources of information. Because this study dealt not with site selection, but with the general patterns of land availability, a minimum size screen of 100 square miles was used for some of the resources.

It is the policy of the Water Resources Council to ensure the protection of wetlands from adverse impacts and degradation [3]; consequently, the location of major wetlands were mapped as an additional constraint. However, no uniform nationwide database exists regarding the location of major wetlands. After consideration of several approaches defining the extent of wetlands in an efficient manner, it was decided to use the 1:2,000,000 scale sectional sheets of the National Atlas [2]. At this scale, only major wetlands can be shown. A comparison of these source data with more detailed map data of a larger scale shows that some of the wetland boundaries have been generalized and most wetlands less than 60 square miles were probably not shown on the sectional sheets.

4.5. Seismic Hardening

The data necessary to evaluate the potential problem from the standpoints of rupture hazard and dynamic soil stability (liquefaction) were not uniformly available throughout the United States. For this reason, seismic hardening was evaluated solely on the basis of vibratory ground motion.

While the detailed investigations required for the determination of the Safe Shutdown Earthquake (SSE) for each 5- by 5-km grid cell were clearly beyond the scope of this study, it was possible using available data to probabilistically evaluate the relative severity of the strong ground motion hazard in the study area and consider costs of seismic hardening.

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This was accomplished using probabilistic studies of seismic risk prepared by Algermissen and Perkins [4], and the Applied Technology Council (ATC) [5], and supplemented with information from a U.S. Geological Survey professional paper [6]. The resultant map showed accelerations in bedrock expressed as a fraction of gravity (g).

The general impact of seismic design requirements is assumed to be proportional to the specific costs of the necessary additional design and construction features. In NUREG/ CR-1508 [7], seismic hardening costs were calculated and related to the SSE expressed as a fraction of gravity by estimating changes in cost. Applying the cost information to the map of probabilistic seismic acceleration yielded a map which was transformed into a cost surface showing the additional cost of seismic hardening.

4.6. Site Preparation

An increase in slope or ruggedness of terrain translates directly into increased cost for construction. This includes the difficulty that may be encountered in excavation for foundations, construction of the access roads where low grades are required (due to the extreme weight of components such as turbine or pressure vessels), and finally measures that must be taken to mitigate environmental disturbances such as control of runoff and erosion from cut slopes.

Data representing a general index of both the steepness of slopes and the aerial extent of such slopes were found in a paper by E.H. Hammond [8] and his map which was adapted and found in the National Atlas [2]. Regions on the map were characterized by the percentage of their area classified with a topographical gradient of less than 8 percent slope (gently sloping). The 8 percent slope is not strictly a critical threshold value for land utilization. It does, however, indicate a value beyond which movement of vehicles becomes impeded, and in general, construction and operation becomes more difficult.

4.7. Water Availability and Cost

Cooling system cost has become a major component of the total power plant cost. Several factors are involved in this issue: the type of cooling system -- mechanical draft wet towers, natural draft wet towers, cooling ponds, once-through cooling, or dry cooling; climatic temperature distributions; existing priorities for use of available water; and restrictions such as wild and scenic rivers. A methodology was developed to present a general picture of water availability and the cost involved in its use by taking a conservative approach and considering the cooling system to be the water consumptive draft wet towers.

Sources of both surface water and ground water were mapped and costs (for satisfying 100 percent of the cooling water need) were determined for each. A computer model was used to calculate, for each cell, the cost of obtaining water as a function of vertical and horizontal pumping costs over a variety of terrain and, if necessary, the use of a reservoir. Cost estimates included both an initial capital expenditure and 30-year operating and maintenance requirements. The model determined the least of the cost alternatives for supplying either surface or ground water to a cell; the two map files were then overlaid to produce a map showing the least cost of available water.

Surface water. Hydrological implications of water consumption by nuclear power plants have been discussed by Giusti and Meyer [9]. In siting plants along rivers, one must consider the periods of low stream flow when the impact on the water resources of total water consumed in the cooling process is at a maximum. Stankowski, Limerinos, and Buell [10] have examined the low flow in the United States to provide information regarding potential sources of cooling water. They prepared a map which identifies those streams for which the average 7-day low flow with a recurrence interval of 10 years is at least 300 cubic feet per second (cfs). (The 7-day, 10-year low flow or 7Q10, is the average low flow that occurs over 7 consecutive days with a probable recurrence of 10 years.) Their map shows those stream reaches that: (1) have a 7Q10 of at least 300 cfs; or (2) could furnish a sustained flow of at least 300 cfs if storage were provided. For their study, 300 cfs was selected as the required flow in this stream on the assumption that many states will not permit more than 10 percent of the dependable flow to be withdrawn for a consumptive use. Ten percent of 300 cfs equals 30 cfs, which is the amount of water that might be considered necessary to cool a 1,000 megawatt (MWe) nuclear power plant if cooling towers, sprays, or ponds were used.

Ground water. A viable source of cooling water in many parts of the country is ground water. Although, characteristics of ground water can vary quite dramatically within a small region, an attempt was made to locate a source of information that would satisfy the broad scale requirements of this study. Using the USGS water supply paper 1800 [11], major regions and subregions of the country were mapped as source data. The areas were further defined by supplementing this data with such maps as the Hydrogeologic Investigations Atlas [12], Tectonic Map of North America [13], and Shaded Relief of the U.S. [14]. Even though variability exists within any one of the regions or subregions, and they do not account for local water availability such as in alluvial valleys and other locations, they do show regional differences regarding characteristics of quality, quantity, depth to water, and required well field size.

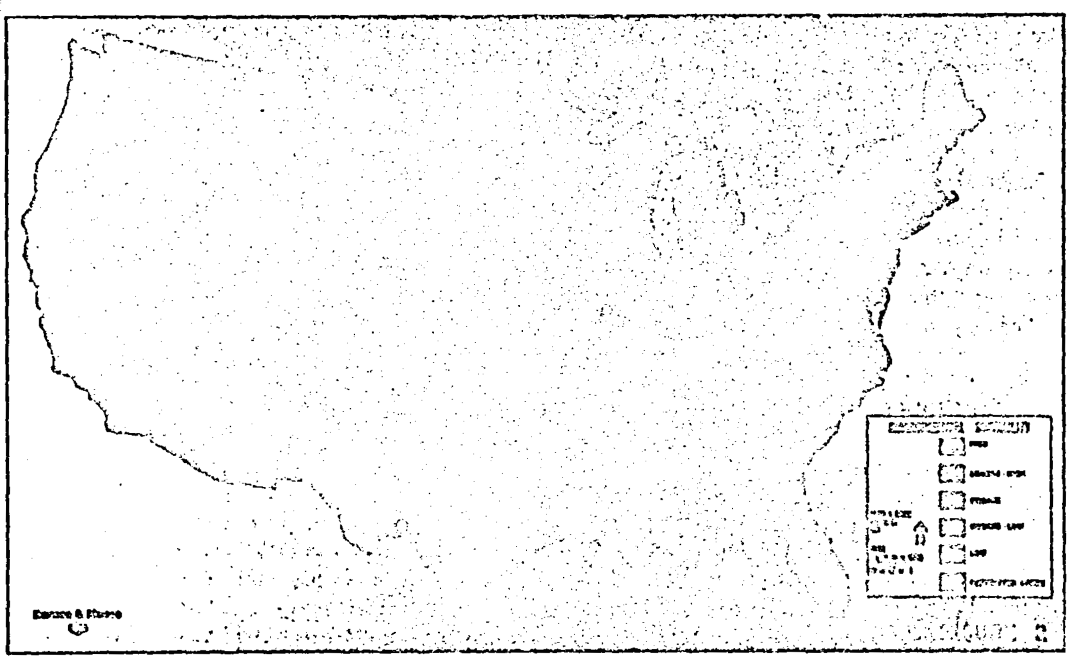
5. ENVIRONMENTAL SUITABILITY ANALYSIS

The overall goal of this study was to provide information about the impact of siting criteria, especially demographic criteria, on land availability. To determine this impact and identify potential siting areas for nuclear power plants, a suitability analysis was first conducted and was based on the environmental criteria. As the data structure diagram (Figure 1) shows, the costs of seismic hardening, site preparation, and water availability were combined into an environmental suitability file. The restricted lands file was then added to result in a map file indicating availability of land and showing levels of environmental suitability.

The suitability analysis proceeded as follows: an evaluation of each issue map was made independently to determine those areas that are more or less suitable for plant location; the issue maps were then overlaid, forming a composite that considered all issues simultaneously. The evaluation of each issue independently was accomplished by defining a utility function for each issue such that the characteristics of a specific site area could be translated into a value on a defined suitability scale. This was a numeric scale, ranging from 1 to 9, where 1 was the lowest level of suitability and 9 was the highest.

To create the composite suitability map, the three utility value map files were added together and the resultant map contained cells with values ranging from 4 through 25 -- each value having a different frequency of occurrence. The distribution of the composited utility values was divided into five intervals such that each interval characterized an equal amount of land area -- approximately 20 percent of the area available for siting. The result is shown in Figure 2.

When the three maps were overlaid, each carried an equal importance weighting. It was felt that the reconnaissance nature of this study -- not being a site-selection -- as well as the broad-scale representation of environmental data did not justify a more sophisticated manipulation of files.



DAMES & MOORE GEOGRAPHIC INFORMATION MANAGEMENT SYSTEM TABLE 1

ENVIRONMENTAL SUITABILITY UTILITY FUNCTION ***
STATE AREAS IN SQUARE MILES AND % OF STATE

TABULATION	LOW	MEDIUM-LOW	MEDIUM	MEDIUM-HIGH	HIGH	RESTRICTED LANDS	
UTILITY VALUE	1	2	3	4	5	1	
ALABAMA	58	6871	11387	19657	11860	2075	51903
	.0%	13%	22%	38%	23%	4%	
ARIZONA	2220	4101	16040	30759	1814	59405	114343
	2%	4%	14%	27%	2%	52%	
ARKANSAS	5211	7614	7788	10190	16193	6263	53259
	10%	14%	15%	19%	30%	12%	
WEST VIRGINIA	4121	10364	6523	145	232	2721	24106
	17%	43%	27%	1%	1%	11%	
WISCONSIN	116	3860	6620	24617	16781	5028	57022
	0%	7%	12%	43%	29%	9%	
WYOMING	17824	13703	20757	15710	4767	25225	97986
	18%	14%	21%	16%	5%	26%	
TOTAL	425114	433053	466810	649193	508122	557673	
	14%	14%	15%	21%	17%	18%	

With better data, however, it would have been a simple matter to weight or rank each of the issues and derive a weighted overlay.

To quantify the impacts of various siting criteria, tables were prepared which used the data files created during the visual or map analysis. Statistics regarding the amount of area in each data category were computed for each of the 48 states, and an example of a portion of one of these tables is shown in Table 1.* The numbers in each column indicate the amount of land in the specified category. The area is shown in square miles as well as percent of the total state area.

6. DEMOGRAPHIC ANALYSIS

All of the demographic criteria investigated and mapped were done so at the request of NRC and Sandia. The reasons for choosing specific values to represent annular area, density threshold, and sector width related to the results of reactor accident consequence calculation performed by Sandia as an integral part of this study.

6.1. Stand-Off Zones

Table 2 shows the 13 stand-off zone maps that were created:

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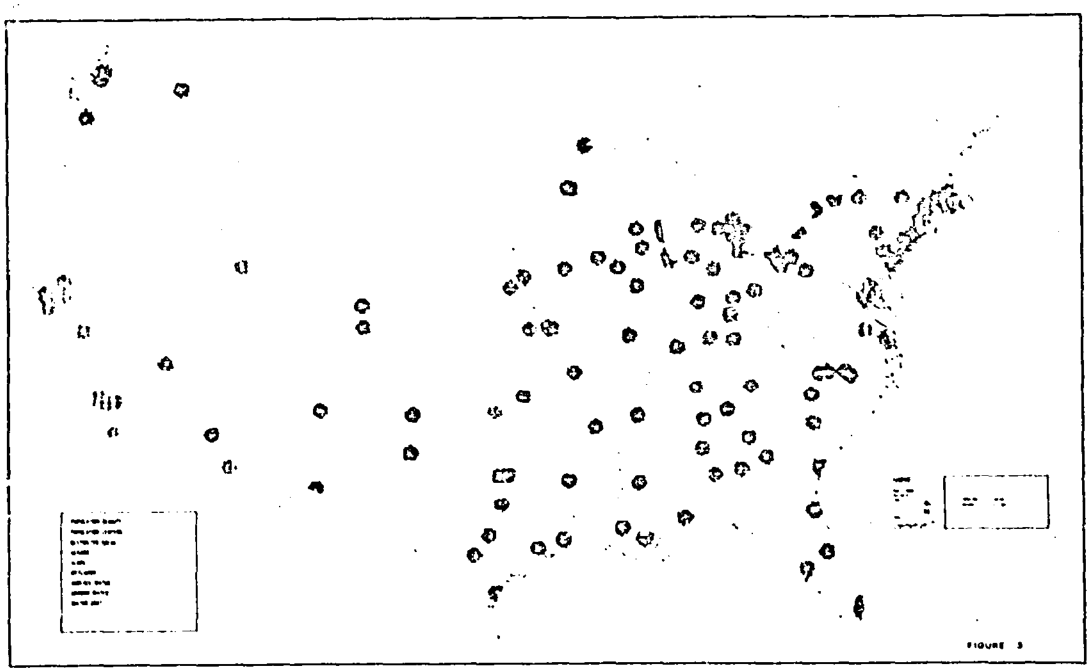
*Due to space limitations, only portions of computer output tables are presented in this paper. However, the majority of maps and tables produced can be examined in NUREG/CR-2239 (scheduled for publication in September, 1982) or by contacting the author.

TABLE 2

STAND-OFF ZONE CRITERIA MAPS

SIZE OF URBAN CENTER	MAPPED STAND-OFF DISTANCE (in miles)
25,000	5, 10
100,000	10, 15, 25
200,000	25, 30, 40, 50, 100
250,000	12.5
500,000	18
1,000,000	25

As an example, Figure 3 shows a stand-off zone criterion of 25 miles from population centers of greater than or equal to 100,000 people. It should be noted that the location of urban centers was identified by a single point corresponding to the city center. Stand-off zone criteria are based on a specified distance from that point -- not from the edge of the urban population. To ensure the effectiveness of stand-off zone criteria, one must assume a relationship between the magnitude of the metropolitan population and the size of the area it occupies and increase the stand-off distance accordingly.



6.2. Annular Population Density

A wide variety of population distributions based on density were studied for their impact on land availability. Densities were calculated for annular areas shaped as both circles and rings. The matrix shown in Figure 4 indicates the simple map files that were produced regarding annular population density.

In addition to calculating and mapping the impacts of these individual demographic criteria, combinations were created to produce files representing composite population density criteria. The first such of these was produced for the 2- to 30-mile annulus, which represents a large area -- approximately 2,815 square miles. If a single density threshold, for example, 500 people per squre mile, were established for the area, a total of 1,407,500 people would be allowed within the annulus. Because annular population criteria did not consider the distribution of population, this threshold possibly could have allowed a large portion of the population to be located relatively close to the center of the annulus, creating an unsafe situation. Or perhaps, several highly dense concentrations of population might exist at critical distances from the center. Identifying these areas was an important safety objective.

The method devised to overcome this potential problem considered thresholds at a variety of radii which were then composited. Using the example of

ANNULUS RADII IN MILES	DENSITY PEOPLE/SQUARE MILE >100	>150	>200	>250	>350	>400	>500	>750	>800	>1000
0-2	x			x			x	x		
0-5	x		x		x		x			
0-10	x		x		x		x			
0-20			x							
0-30							x			x
5-10		x			x		x			
5-20									x	
10-20						x	x			x
20-30							x			x
30-50							x			x

ANNULAR POPULATION DENSITY DATA FILES

FIGURE 4

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mapping any cells that exceeded the 500 persons per square mile threshold for the 2- to 30-mile annulus, density calculations were made for six portions of the annulus. First, any cell that exceeded the 500 persons per square mile threshold within the 2- to 3-mile annulus was recorded. Next, unsuitable cells in the 2- to 4-mile annulus were recorded. This process was repeated for the 2- to 5-mile, the 2- to 10-mile, the 2- to 20-mile, and the large 2- to 30-mile annuli. These six individual files were then added together, creating a file in which a cell that was shown to be unsuitable in any of the six was also considered unsuitable for the 2- to 30-mile composite annulus. In this manner, data files were created for the 2- to 30-mile composite annulus applying the following density thresholds:

- o 250 persons per square mile;
- o 500 persons per square mile;
- o 750 persons per square mile;
- o 1,000 persons per square mile; and
- o 1,500 persons per square mile.

Besides creating a composite map file for a particular annulus (such as 2 to 30 miles) and a particular density (such as 500 persons per square mile), another type of composite was created. This consisted of two separate annuli -- each with its own given population density threshold. Above, for example, six individual data files were added together to create the 2- to 30-mile composite annulus. Now, a different annulus with a different population density threshold was added to the 2- to 30-mile composite annulus, thereby creating a much more complex data file. Six different combinations of density thresholds for the 0- to 2-mile annulus and the composited 2- to 30-mile annulus (consisting of the addition of six separate annuli) were created and are shown in Table 3.

TABLE 3

COMPLEX COMPOSITE POPULATION DENSITIES

0 TO 2 MILES	2 TO 30 MILES (composite)
100	250
100	500
250	500
250	750
500	750
500	1,500

Figure 5 is an example of applying both a 100 persons per square mile density threshold within the 0- to 2-mile annulus and a 500 persons per square mile threshold in the 2- to 30-mile composite annulus.

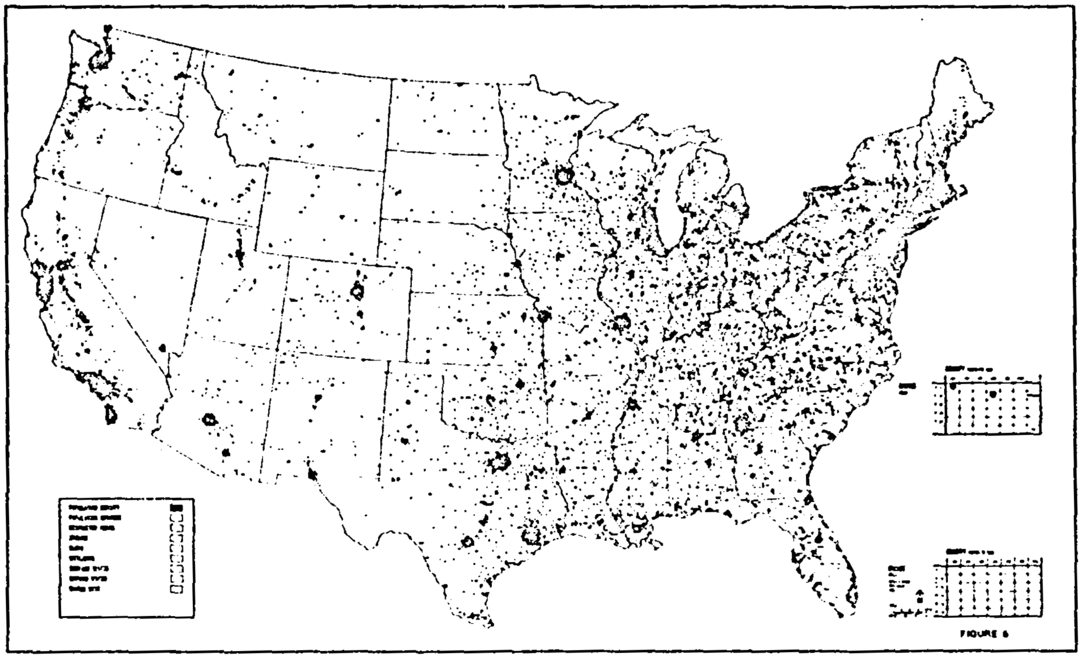

FIGURE 6

6.3. Sector Population Density

Composite criteria had been developed as a solution to population concentrations located near the center of an annulus. However, results of reactor accident consequence calculations at Sandia indicated that certain risk characteristics depend strongly on the maximum number of persons within any given direction sector. Therefore, the NRC considered criteria regarding the maximum allowable population within sectors in addition to total population surrounding a site. The impact on land availability was examined for alternative sector criteria and compared to the impact of uniform density criteria.

Sector criteria were stated in terms of allowing up to a particular fraction of the allowed total number of people to be located in any sector of a particular width. For example, a sector criterion might be stated: up to one-sixth of the people allowed by a uniform density of 500 persons per square mile can be located in a 45-degree sector within 30 miles of a site.

The NRC requested that the impact of sector criteria be investigated with regard to several variables. The parameters were:

- o Distance: radii of 2, 5, 10, 20, and 30 miles (these were all composited within the 0- to 30-mile annulus);

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- o Sector width: 22.5, 45.0, and 90.0 degrees (360 degrees for uniform density);
- o Fraction: 1/16, 1/8, 1/4, 1/3, and 1/2 the population allowed by uniform density; and
- o Density: 250, 500, 750, and 1,500 persons per square mile.

Population counts were determined within 2, 5, 10, 20, and 30 miles of potential sites (grid cells) and within sector widths of 22.5, 45.0, and 90.0 degrees. The maximum number of persons found in a sector of a stated width for a particular radius was recorded. Alternative criteria were then applied to the count data on the basis of allowing a certain fraction of the total number of people allowed within the circle (by a density threshold) to be located in any sector. Being consistent with previously computed impacts, the impacts for sector criteria for any particular density or fraction were composites of radii out to 30 miles.

Sector criteria were of interest to the NRC regarding their impact on land availability above and beyond that already affected by uniform density criteria. To depict and quantify this information, tables were created to show the amount of land available/constrained for siting in each state if a particular sector criterion were established. As an example, a portion of one of these tables is shown in Table 4. Each table considered a unique combination of allowable population density and sector width and showed the impact of alternative fractional criteria as well as the uniform density criteria on land availability.

DAMES & MOORE GEOGRAPHIC INFORMATION MANAGEMENT SYSTEM TABLE 4

POPULATION SECTOR ANALYSIS - TOTAL U. S.
DENSITY = 500 #/SQ MI. *** DOUBLE SECTOR (45.0 DEGREES)
STATE AREAS IN SQUARE MILES AND % OF STATE

TABULATION		AVAILABLE LAND	> 1/8 ALLOWABLE POP	> 1/6 ALLOWABLE POP.	> 1/4 ALLOWABLE POP.	> 1/3 ALLOWABLE POP.	> 1/2 ALLOWABLE POP.	UNIFORM DENSITY	RESTRICTED LANDS	
ALABAMA	1.0	26453	1718	3937	5192	5832	3146	3329	2075	51908
		51.3%	3.3%	7.6%	10.0%	11.3%	6.1%	6.4%	4.0%	
ARIZONA	2.0	47353	454	1312	1259	1351	1187	2026	59405	114347
		41.4%	0.4%	1.1%	1.1%	1.2%	1.0%	1.8%	52.0%	
ARKANSAS	3.0	33910	329	4304	2799	2499	1379	1756	6263	53258
		63.7%	0.6%	8.1%	5.3%	4.7%	2.6%	3.3%	11.8%	
WEST VIRGINIA	46.0	10673	174	2374	2606	2963	1129	1467	2721	24107
		44.3%	0.7%	9.8%	10.8%	12.3%	4.7%	6.1%	11.3%	
WISCONSIN	47.0	31334	685	5423	4593	3648	2403	3900	5028	57022
		55.0%	1.2%	9.5%	8.1%	6.4%	4.2%	6.9%	8.8%	
WYOMING	48.0	70233	0	743	540	502	330	405	25225	97986
		71.7%	0.0%	0.8%	0.6%	0.5%	0.3%	0.4%	25.7%	
TOTAL		1761966	28968	143927	136449	140331	91495	177165	557673	
		58.0%	1.0%	4.8%	4.5%	4.6%	3.0%	5.8%	18.3%	

Table 4 has been formatted such that the numbers in the columns represent the amount of land that is uniquely constrained by the specified criteria and the columns are arranged so the total magnitude of constrained land decreases from left to right. The left-most column, "Available Land," shows the amount of land considered available for siting if the criterion stated in the adjacent column were applied; that is, no more than one-eighth of the population allowed in the annulus (composite of 5 radii to 30 miles) at a density of 500 people per square mile can be located in any 45.0 degree sector. The right-most column, "Restricted Lands," shows the amount of land constrained by being either legally protected or a major wetland. (No demographic criteria affect these numbers.)

The numbers in each of the middle columns show the amount of land that is uniquely constrained by the specified "fraction" criterion. This magnitude of constraint is above that already constrained by the total of all columns to its right. The column, "Uniform Density," shows the area constrained by applying a simple density threshold, regardless of sector distribution.

7. COMPARISON OF IMPACTS

The data structure diagram (Figure 1) graphically shows the ultimate information product of the study to be an analysis of the combined impacts of environmental suitability and demographic criteria on the availability of land for siting nuclear power plants. While the overlay of transparent maps provided a quick look at potential land availability, the combination of a map containing six levels of environmental suitability, when o[illegible]laid with a variety of population criteria, produced numerous groupings [illegible] sta. To clearly illustrate the combined effect of various siting criteria, tabular statistics were produced.

To quantify these data, five population cases were first defined on the basis of complex composite annular density criteria as shown in Table 5.

TABLE 5

COMPLEX COMPOSITE POPULATION CASES

POPULATION CASE	TO 2 MILES	2 TO 30 MILES (composite)
1	100	250
2	250	500
3	250	750
4	500	750
5	500	1,000

The numbers in the columns underneath the specified annulus represent population density thresholds. Note that the 2- to 30-mile annulus was a composite data file; that is, six different annuli were analyzed at a specified density threshold and the files were added together. Population

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Case 1 was the most constraining as it applied the lowest density thresholds; while population Case 5 was the least constraining.

As in the case of most demographic criteria, tables were created in two different formats to show the maximum amount of information clearly. Tables 6 and 7 are examples of portions of these tables.

DAMES & MOORE GEOGRAPHIC INFORMATION MANAGEMENT SYSTEM TABLE 6

POPULATION CASE 1 and
ENVIRONMENTAL SUITABILITY LEVELS ***
STATE AREAS IN SQUARE MILES AND % OF STATE

TABULATION	LOW SUITABILITY	MEDIUM-LOW	MEDIUM SUITABILITY	MEDIUM-HIGH	HIGH SUITABILITY	DENSITY RESTRICTIONS	DENS & LAND RESTRICT	RESTRICTED LANDS	
ALABAMA	48	5250	8930	15758	8904	10962	164	1911	51907
	0%	10%	17%	30%	17%	21%	0%	4%	
ARIZONA	2113	3631	15517	27502	1727	4246	1901	57504	114341
	2%	3%	14%	24%	2%	4%	2%	50%	
ARKANSAS	4680	6958	6321	8975	14195	5867	106	6157	53259
	9%	13%	12%	17%	27%	11%	0%	12%	
WEST VIRGINIA	3503	8145	4429	48	68	5192	40	2673	24106
	15%	34%	18%	0%	0%	22%	0%	11%	
WISCONSIN	116	3628	5614	20091	12246	10239	241	4786	57021
	0%	6%	10%	35%	21%	18%	0%	8%	
WYOMING	17611	13920	20564	15469	4449	1148	154	25071	97906
	18%	14%	21%	16%	5%	1%	0%	26%	
TOTAL	381599	382005	400812	531013	373547	413309	23024	534650	
	13%	13%	13%	17%	12%	14%	1%	19%	

DAMES & MOORE GEOGRAPHIC INFORMATION MANAGEMENT SYSTEM TABLE 7

ENVIRONMENTAL SUITABILITY AND POPULATION CASES 1 - 5 ***
<<< HIGH SUITABILITY >>>>>
STATE AREAS IN SQUARE MILES AND % OF STATE

TABULATION	AVAILABLE LAND	POPCASE 1	POPCASE 2	POPCASE 3	POPCASE 4	POPCASE 5	OTHER SUITABILITIES	RESTRICTED LANDS	
ALABAMA	8904	1698	191	425	135	425	37773	2079	51900
	17%	3%	0%	1%	0%	1%	73%	4%	
ARIZONA	1727	29	40	0	0	10	53121	59405	114342
	2%	0%	0%	0%	0%	0%	46%	52%	
ARKANSAS	14195	1216	106	222	125	320	30803	6263	53258
	27%	2%	0%	0%	0%	1%	58%	12%	
WEST VIRGINIA	68	116	0	19	2	29	21191	2721	24106
	0%	0%	0%	0%	0%	0%	88%	11%	
WISCONSIN	12246	2451	367	328	197	1033	35211	5028	57021
	21%	4%	1%	1%	1%	2%	62%	9%	
WYOMING	4449	193	59	29	19	58	67994	25225	97906
	5%	0%	0%	0%	0%	0%	69%	26%	
TOTAL	373547	67677	11202	12729	10914	31971	1974160	557673	
	12%	2%	0%	0%	0%	1%	65%	19%	

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Table 6 shows the comparison between the environmental suitability levels and population Case 1. The statistics indicate the amount of land in each of the five environmental suitability levels that would be available for siting nuclear power plants if a given set of population criteria; e.g., population Case 1, were applied. In addition, the numbers in the columns labeled "Density Restrictions" show the amount of land uniquely constrained by the given population case. The numbers in the column "Dens & Land Restrict" indicate the amount of land constrained by both the population criteria and the restricted lands (legally protected or major wetland) designation. Thus, the total amount of land affected by a given population case would be equal to the sum of these two columns.

It was found that the application of any population case as demographic siting criteria had its greatest impact on land in the high environmental suitability category. In fact, the impact usually increased as the level of suitability did. This is not too surprising as residences and power plants are both engineered structures and share similar requirements.

To illustrate the effect of applying alternative population criteria (the five population cases) on the availability of land within each environmental suitability class, statistics such as those presented in Table 7 were produced. The numbers represent the amount of land available for siting nuclear power plants in a given environmental suitability class as well as the amount of land uniquely constrained by each of the five population cases. The columns representing population cases have been arranged such that in moving from left to right, the stringency of the criteria decreases. The left-most column of the table, "Available Land," shows land that is available for the given environmental suitability class (in this case -- high) even if the most stringent population criterion (population Case 1) is applied. The second column "Population Case 1" represents an additional amount of land considered available if that particular population criterion were relaxed, which would also imply the application of population Case 2. Similarly, the next column "Population Case 2" represents the additional increment of land available if the criteria for population Case 2 were also relaxed and population Case 3 were applied. It follows that if no population criteria were established, the amount of land available in a particular environmental suitability class would be equal to the total of the first six columns in the table; the only land considered constrained would be that by a restricted lands designation. The numbers in the column "Other Suitabilities" show the amount of land existing in the four environmental suitability categories which are not specified in the title of the table.

8. CONCLUSIONS

The analytical methods used in this study were designed to explore the impact of various demographic siting criteria on the availability of land considered suitable for the siting of nuclear power plants. Maps were created so that impacts could be easily visualized and tabular statistics were prepared to allow more rigorous analysis.

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The determination of land considered suitable for siting was accomplished through multi-objective environmental suitability analysis. The analysis was performed using factors generally related to engineering costs as well as conservation of specific resources. Because this investigation concerned the entire 48 contiguous United States and was not a site-selection project, environmental factors were analyzed at a relatively general level of detail and were each considered to be of equal importance. However, the capabilities of modern geographic information systems would have allowed the production of perhaps more significant results and sophisticated analysis if better data were available.

The most suitable areas were characterized by an adequate water supply, low seismicity and gentle topography as well as an absence of protected resources. Although the map of environmental suitability (Figure 2) shows the eastern one-half of the country to be more suitable than the western, it is felt that there are numerous suitable sites available in the western portion.

Three types of population criteria were investigated: stand-off zones, annular density, and sector density. The effects of stand-off zone criteria are straight-forward. There is a direct relationship between the stand-off distance and the amount of land area constrained.

The analysis of annular density thresholds showed that the use of smaller radii to define the annulus resulted in constraints on both large and small urban populations as well as some locally dense rural areas. Larger radii tended to constrain a greater amount of urban population, but only around major cities; small urban and rural areas were not constrained. These findings led to the use of complex composite criteria in which different thresholds were applied to a variety of annuli and the results of all constraints were added together to form one map file.

Because results of reactor accident consequence calculations indicated that certain risk characteristics depended strongly on the maximum number of persons within any given direction sector, sector population criteria were designed. Their impacts were investigated to determine the amount of land area that would be constrained additional to that affected by annular density criteria. It was found that the effects of sector criteria occurred in the same areas and adjacent to those of annular densities. Also, the area of impact responded to changes in annular radius the same as for annular density criteria. For this reason, all sector criteria were complex composites of different thresholds and radii.

Transparent overlay maps and tabular statistics were provided to the U.S. Nuclear Regulatory Commission for use in establishing siting criteria which would be numerically based upon population density, distribution, and exclusion distance. Using both a map overlay procedure and a comparison of statistics, it was found that the greatest impacts of demographic criteria occur in the areas of high environmental suitability.

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Demographic criteria have not yet been established by NRC. Thus, the impacts described in this report are considered to be contingent upon future siting rule-making. What has been shown are the results of an "if-then" exercise. The study illustrated that geographic information systems are capable of efficiently performing sophisticated and detailed analyses for large regions. The availability of data appears to be the most significant overall limitation to such studies.

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MULTIDIMENSIONAL PROGRAMMING METHODS FOR ENERGY FACILITY SITING: ALTERNATIVE APPROACHES

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ABSTRACT

This paper reviews the use of multidimensional optimization methods in solving power plant siting problems, which are characterized by several conflicting, noncommensurable objectives. After a discussion of data requirements and exclusionary site screening methods for bounding the decision space, classes of multiobjective and goal programming models are discussed in the context of final site selection. Advantages and limitations of these approaches are highlighted and the linkage of multidimensional methods with the subjective, behavioral components of the power plant siting process is emphasized.

1. INTRODUCTION

Although most regional power plant siting or planning decisions have traditionally been at least partly based on analytical methods [14] [50] [38] [47] [3], the use of formal multidimensional methods--principally multiobjective mathematical programming and game theory--have gained popularity in recent years [31-34] [11-13] [16] [19] [1] [56]. This is not surprising, considering the growing acceptance of multidimensional methods in the field of operations research and the numerous planning applications [15] [16] [45] [49] [57] [61].

The purposes of this paper is twofold: (1) to update and broaden the Hobbs [31] [32] survey and critique of multiobjective decision methods for power plant siting, giving more attention to goal programming, and (2) to speculate on the possibility and promise for multidimensional programming approaches to power plant siting problems in the future.

The next section of the paper discusses the nature of power plant siting data and the issue of site-suitability scaling. This is followed by a review of common exclusionary site screening methods and a more detailed section on site selection algorithms. A final section presents a summary and some conclusions of the paper.

2. THE NATURE OF SITING DATA AND SUITABILITY SCALING

A large and diverse data set may be important in power plant siting analyses. One role of the siting team is to reduce the data base to the

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most important siting factors. The data can then be ordered hierarchically to streamline the siting analysis. For example, water availability might be followed in importance by local population density, air pollution impacts, water withdrawal rate, etc. Doing this can ensure that the most important siting factors will be considered if some factors have to be neglected due to locational constraints.

Power plant siting data are expressed in noncommensurable units, encompassing engineering, economic, social, and other physical dimensions on all measurement scales. For example, population density might be expressed in inhabitants per square mile, while transmission distance would be expressed in miles and water withdrawal rate would be measured in cubic-feet per second (cfs). Comparing and amalgamating such diverse data in site-suitability (or desirability) terms is extremely difficult, especially when it is necessary to transform the data to a lower measurement scale to make it commensurate, which will often improve decision making.

Most of the important siting data are available and standardized on the ratio scale of measurement, and are fairly reliable over a small time horizon. Nevertheless, important information may be lost in the transformation process, and siting analysis can be based on the original physical data. If site-suitability scaling is undertaken, it is often desirable to have suitability data expressed on the interval scale so that basic arithmetic operations can still be performed. However, a siting factor that is ratio-scaled with respect to a physical characteristic (e.g., water withdrawal in cfs) might be only ordinal-scaled with respect to suitability (a flow below 200 cfs is inadequate, but above that is sufficient). Although ratio-scaled data might be more meaningful to the analyst, it is usually not necessary for siting purposes since this requires an extra step, and only the power law site-suitability amalgamation method requires ratio-scaled data [28].

Interval-scaled site-suitability transformations usually involve indifference analysis. In one approach, the decision maker is asked to compare alternative sites that have different levels of two impact and site characteristics, per siting factor. When different sites with different factor levels are equally preferred, decision maker desirability levels eventually can be deduced.

Fishburn [24] and Hobbs [31] review several alternative methods that can be used for suitability scaling. Most of these methods do not account for possible uncertainty involved in impact and site characteristic assessment, or risk in successfully obtaining the desired site. It is possible to use the lottery method of decision analysis for the latter purpose [27], although it has been found that people do not follow the necessary principles of probability theory in judging the likelihood of uncertain events [54]. If this approach is taken, a few important assumptions must hold true for the analysis to be valid, such as the property of utility independence between lotteries for different siting fac-

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tors. However, it is likely that this assumption will be violated in most facility siting problems. This would invalidate both decision analysis and other amalgamation methods for power plant siting, since all methods that reduce site-suitability to a scalar make such restrictive assumptions.

3. EXCLUSIONARY SITE SCREENING METHODS

The energy facility siting process is characterized by a series of location constraints, both land use restrictions established by government regulation, and financial and production constraints confronting the siting team. These restrictions correspond to conventional constraints in a mathematical programming problem, and usually can be represented by interval-scaled data simply as

$$Bx \leq b \text{ or } Bx \geq b \tag{1a}$$

and

$$x \geq 0, \tag{1b}$$

where B is a matrix of order N x I (i.e., the constraint set contains N side conditions for I decision variables), x is a vector of decision variables, $x_1, x_2, \ldots, x_I$, and b is a vector of N x 1. Such constraints might include allowable population density, thermal pollution of a water source, water withdrawal and consumption rates, sulfur oxide emission rate, energy resource supply and demand, transmission distance, etc. Nominal or ordinal constraint data, such as seismic activity level ratings or national park restrictions, can often be converted to the interval scale, but when this is not possible nominal and ordinal data still may be used for site screening (without the aid of a computer algorithm).

Two general methods are available for exclusionary site screening, which can be used for all common levels of data measurement. The lexicographic method considers constraints by means of a decision maker-determined importance hierarchy, while the conjunctive method considers all constraints simultaneously.

3.1. Lexicographic Ordering

The lexicographic ordering method allows the siting team to consider constraints in a decreasing hierarchy of importance [25]. Thus, an important site constraint such as water availability might be followed in importance by local population density, air pollution impact, thermal water pollution impact, etc. This method ensures that the most important siting constraints are met and, if desired (for sensitivity analysis), lower priority constraints can be neglected if they actually are nonbinding (e.g., transmission distance). The neglect of lower priority constraints often may be deemed necessary if few or no sites survive the higher level screenings. An alternative approach is to consider severe site limitations as a rationale for technological change, where possible, such as for more effective (albeit costly) pollution control devices, which requires interaction with decision makers.

3.2. Conjunctive Screening

Conjunctive screening methods make no discrimination in importance between the siting constraints, although again, if desired, some of the constraints can be ignored for each site. The full or reduced set of siting constraints are then considered simultaneously, which results in the same group of acceptable sites as the lexicographic method when all of the same constraints are considered. This is because neither method distinguishes between the sites that survive the screenings, but only serve to bound the final decision space. These general methods have been used to evaluate alternative geothermal energy sites for land related impacts [46] and to evaluate electric power plant location patterns [13] [22] [35].

4. SITE SELECTION ALGORITHMS

Two major classes of multidimensional site selection algorithms can be identified: multiobjective mathematical programming and goal programming (Table 1). Multiobjective programming, the least understood and more recently developed of the two, was pioneered by Marglin [42] [43] and Major [41] in the context of water resources planning, and actually refers to a class of analysis and algorithms. It has been proposed and used for power plant location analysis (not siting) [11] [19] [56] and critiqued by several reviewers [18] [31-34] [12].

Goal programming was developed by Charnes and Cooper about 1952 (also [6]), formally recognized in 1961 [4], and is now considered a subcategory of multiobjective programming methods. Although goal programming has never been applied to power plant siting, it has been superficially explored in a power plant siting framework [50] [55]. There apparently is some promise of utilizing such methods for siting problems, especially in the form of a "satisficing" model or goal interval programming, also attributed to Charnes and Cooper [4].

Both multiobjective and goal programming have been developed for problems where unidimensional decision criteria does not reflect actual decision making processes, such as in power plant siting. Goals or objectives are recognized as noncommensurable and optimizing one objective function, such as for air quality, usually results in a different site than when optimizing for another objective function, such as for transmission distance. The purpose of the following discussion is to examine the utility of these two related classes of multidimensional optimizations for power plant siting problems.

Table 1

Classes of Multidimensional Site Selection Algorithms

Class of Algorithm	Pioneer(s)	Field of Origin	Past Applications to Power Plant Siting Problems	Potential Use in Power Plant Siting Problems
Noninferior Curve Generating Techniques or Efficient Programming	Marglin [42] [43] & Major [41]	Water Resources	Several	High
Preference Weighting	Geoffrion [26]	Operations Research	Few	Medium
Multiple Decision Maker Amalgamation	Dorfman & Jacoby [23]	Water Resources	Few	Medium
Goal Programming: Classical Model	Charnes & Cooper (circa 1952)	Management Science	None	Low
Goal Programming: Satisficing Model	Charnes & Cooper [4]	Management Science	None	Medium if goal targets can be specified
Goal Interval Programming	Charnes & Cooper [4]	Management Science	None	Medium if goal intervals can be specified
Hierarchical Programming	Charnes, Cooper & Niehaus [8]	Manpower Planning	None	High for multilevel analyses

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4.1. Multiobjective Programming

The multiobjective or vector optimization problem can be stated simply as:

$$\text{Max } Z(x) = [Z_1(x), Z_2(x), \ldots, Z_p(x)] \tag{2a}$$

$$X \in K, \tag{2b}$$

where Z(x) is a p-dimensional objective vector encompassing the successive decision criteria, and K is a set of feasible solutions to the optimization problem.

At least three groups of multiobjective programming algorithms can be applied to power plant siting [16]: noninferior curve generating or efficient programming methods, preference weighting, and multiple decision maker amalgamation. A fourth approach is hierarchical programming [8] [21], which is only applicable tc multilevel analyses since land must be treated in a nested fashion for the technique to work.

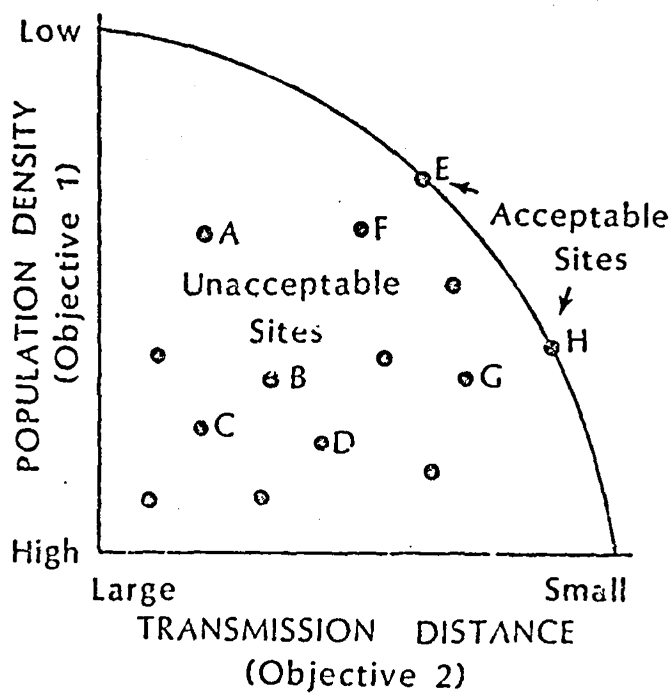
Noninferior curve generating techniques. Noninferior solutions to the multiobjective problem are ones that are feasible but are not "dominated" by other feasible solutions on one objective. That is, where $Z_A = (Z_{1A}, Z_{2A}, \ldots, Z_{PA})$ is an ordered set of solutions in attribute space to the P separate objective functions comprising alternative site A, Z_A is noninferior if there exists some $Z_{iA} > Z_{i.}$, $i \in \{1, 2, \ldots, P\}$ and $Z_{i.}$ is the set of all other solutions to the Z_i objective function. By definition, an alternative site is noninferior if it has at least one unique objective function solution which is maximal to all other alternative feasible solutions, per that objective.

Also known as efficient programming, these techniques generate multiple solutions to the optimization problem. If two objective functions can be considered at a time, the noninferior set corresponds to the curve in Figure 1, where alternatives inside the curve are inferior.

In this example, two noninferior sites exist, sites E and H. The convexity of the curve indicates diminishing marginal returns in tradeoffs between the two objectives. The process of curve generation is repeated with the other objectives, and the logic can be generalized to the n-criteria case. The result is a set of noninferior sites, and the curves supply decision makers with trade-off information among sites on the curves for the sets of objective functions, which is used to establish a satisfactory solution.

Several noninferior curve-generating techniques have been developed [11] [17]. These techniques are the most flexible, since siting factor preference weights do not have to be determined in advance. But if the number of objective functions is greater than three and the number of ef-

FIGURE 1
The Noninferior Curve of Energy Facility Sites



ficient solutions is large, decision makers will have major difficulties in visualizing the trade-offs, which may make these approaches impractical. A method to use the efficient programming solutions to articulate decision maker preferences (by involving them in the analysis) is known as interactive or compromise programming. Hafkamp and Nijkamp [29] use an adjusted version of Zeleny's [61] interactive method of displaced ideals for an economic-environmental trade-off problem, while others [58] suggest the use of interactive programming for power plant siting. These methods are actually a cross between efficient programming and preference weighting, and should be categorized with other iterative techniques [16] [49].

Preference weighting. Preference weighting methods, often referred to as multiple criteria utility assessment, addresses the problem of amalgamating noncommensurable objective function desirability levels more directly, to explicate the relative value of changes in factor desirability levels. In general these methods are less computationally intensive than generating techniques, since not all of the noninferior set is explored [16]. Preference-oriented methods can be used to provide decision makers with sensitivity analyses of alternative preference functions. Although a very large number of such methods exist, they can be categorized as either decision maker-revealed or observer-derived. All of these methods attempt to reveal decision maker preference functions between siting factor desirability levels. Once this is accomplished, a noninferior solution can be found as the preferred alternative, which is known as the best-compromise solution.

A good summary of decision maker-revealed, or client-explicated, techniques can be found elsewhere [33] [34]. The most popular methods include ranking, categorization, rating, ratio questioning, Saaty's method, Metfessel allocation, indifference trade-off, and decision analysis. Weighting methods are surveyed and evaluated by Hobbs [31] [33] in terms of flexibility, ease of use, the use of theoretically valid weights, and their popularity. But once decision maker indifference curves are derived (which realistically are nonlinear and thus have nonconstant slopes), a choice must be made between the many forms that a utility amalgamation model can take. Decision analysts typically use either the weighting summation or pure product utility amalgamation model. Of these, the most popular is the simple weighting summation model, expressed by the equation:

$$S_i = \sum_{v=1}^{N} C_{vi} W_v , \qquad \forall i \tag{3}$$

where S_i is the suitability score of site i, C_v are the utility levels, v are the siting factor objectives, and W are the preference weights. Others have applied similar site-suitability screening algorithms in power plant siting studies [35] [22]. Although it is necessary to use interval-scaled utility levels and ratio-scaled weights, many siting analysts have incorrectly used ordinal values in this equation [32].

There are many other flaws with the weighting summation model. Its linear form implies that all indifference curves are linear, which usually is unrealistic. It also assumes that decision makers will be willing to reveal preference functions without a complete profile of the sites comprising the noninferior set. Further, this model assumes that there is no change in the attitude of a decision maker toward uncertainty in a given desirability level as other desirability levels may vary.

When the decision maker is not indifferent toward risk and uncertainty between desirability levels and the desirability levels are not known with certainty, the pure product utility amalgamation model seen in equation 4 is applicable:

$$S_i = \{[\prod_{v=1}^{N} (1 + KW_v C_{vi})] - 1\}/K, \qquad \forall i \tag{4}$$

where K is a scaling constant, chosen so that utility ranges from 0 - 1.

A choice between the form of the utility amalgamation model can be

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made by the use of decision analysis. When the indifference curves are recognized as nonlinear, the weight of each objective function must be a function of the others and thus ratio-scaled. If this does not occur, the amalgamation procedure may produce biased results. Although its assumptions are more realistic and applicable to siting problems, the pure product model is less popular with facility siters due to its more complex form and reliance upon decision analysis. Fortunately, it has been demonstrated that in practice the results of the two most popular forms of the utility amalgamation model rarely differ [31] [50]. Thus, the use of the simple weighting summation model is probably justified.

Observer-derived methods can be used when it is impossible to derive decision maker objective preferences otherwise. An overall site evaluation scale still may be determined, which can be regressed on the desirability levels for each objective function at that site, for all sites. The parameter estimates for each objective become the preference weights. A large number of site evaluations must be made in order for the multiple regression procedure to work and be useful. This *de facto* approach to preference weighting, also known as the policy capturing technique, has been recommended for evaluating factors in transmission line routing studies [30]. Unfortunately, this approach will not necessarily give the same results as those of decision maker-revealed methods, will probably suffer from high multicollinearity, and may not be very reliable. Indeed, it has been shown that decision maker-revealed methods usually perform as well as the regression method, even though the latter method theoretically should perform better [36].

Multiple decision maker amalgamation. The amalgamation of multiple decision maker preferences, whether within a single organization or from several conflicting interest groups, is thought to be the most complex and least understood class of multiobjective programming algorithms. The methods include techniques for the aggregation of multiple preference orderings into a single ordering, methods to counsel a single decision maker, methods for the prediction of political outcomes from a decision process, and the method of fuzzy sets.

Aggregation techniques are a major focus of welfare economics, as well as of mathematical programming. Saaty's [51] analytic hierarchy process has been extended and applied to power plant siting based on the objectives and influence of a set of regional policymakers [2]. Most energy facility siting analyses involve either a few or several decision makers within one organization. The two most popular group techniques for amalgamating individual preferences, although not programming algorithms, are the Delphi method and the nominal group technique [52] [20]. The latter method has been applied to power plant siting [59], which was used to derive factor preference weights for a national site screening study [35]. It also should be possible to adapt client-explicated methods that ensure valid weights to groups.

Contrary to the aggregationist viewpoint, counseling methods assume

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that only the decision makers can define the overall interest, and it is incumbent upon them to do so. The role of the analyst is once again relegated to that of information provider, and the mechanistic aggregation of individual interests to derive an overall interest is either extremely difficult and unreliable or invalid. A related approach to counseling methods is bargaining theory, which has made some progress in modeling two-participant multiobjective problems [40].

The prediction of political outcomes is different from the other two amalgamation approaches in that it is a positive analysis, albeit with normative consequences. Powerful political interest groups are recognized for their influence or control of decision making, and the methods which fall into this category include paretian analysis, game theory, and several methods of voting procedures. Although a few applications of these methods to power plant siting have been made [27] [53], the usefulness of these approaches is highly questionable since utility functions and payoff matrices are usually unknown.

The method of fuzzy sets was developed for decision criteria or constraints that are not sharply defined, so that partial set membership is possible [60]. Although this method is not in an operational stage [37], future applications to power plant siting may be possible. For example, this approach could allow for decision maker grouping of alternative sites in terms of their degree of overall acceptability to different individuals, although no clearly superior alternative may result.

4.2 Goal Programming

The predecessor, close relative and subclass of multiobjective programming is goal programming. This method has never been applied to power plant siting problems, most likely due to the extreme difficulty or impossibility of specifying target goals, and the unrealistic penalty for overachievement in the classical model. In addition, Rowe, et al. [50] have explored the use of goal programming for power plant siting and found that the method often chose inferior sites, and the results were often quite different from those of other methods.

Goal programming problems originally were solved by means of linear programming equivalents, although explicit solutions to convex goal programming problems have been developed by Charnes, et al. [7]. Three types of goal programming models will be examined below: the classical model, the satisficing model, and goal interval programming models.

The classical model. The classical mathematical form of the goal programming problem can be stated succinctly as:

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$$\text{Min} \sum_{j=1}^{N} W_j |d_j|^P, \qquad (5a)$$

$$x \in K$$

subject to the N goal equations

$$Z_j(x_j) - d_j = V_j, \qquad \forall j \qquad (5b)$$

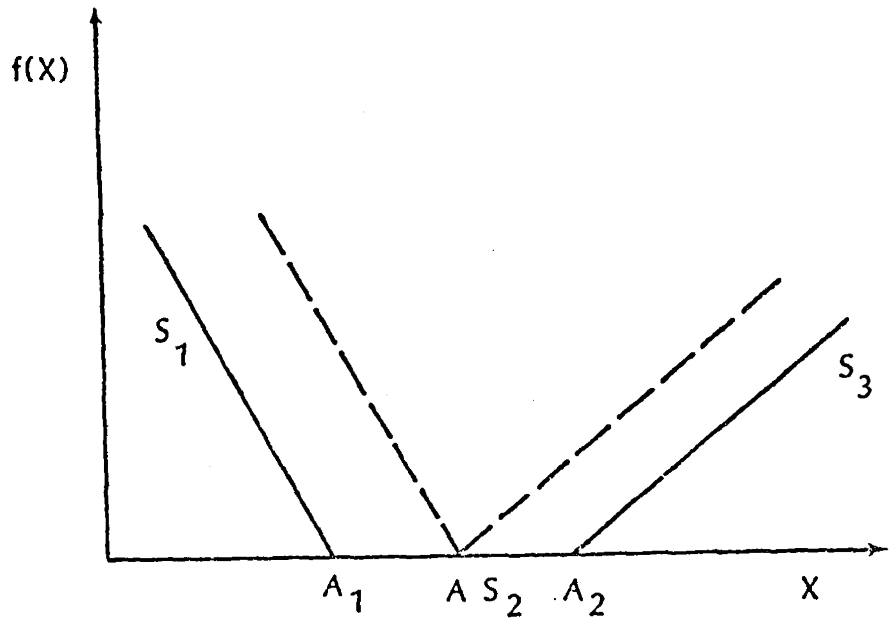
where $Z_j(x_j)$ is a j-dimensional goal vector which associates the magnitude of the policy variable, x_j, with the achievement level of the goal j; d_j is the positive or negative deviation from the preferred goal level for the jth goal, which is valued equally; W_j is the weight for variable, X_j; P is a positive parameter, usually 1 or 2; and V_j is the target level for the jth goal. This form of goal programming can be seen as a special case of a weighting summation model. It is particularly inapplicable to most power plant siting problems due to the equal valuation of positive and negative goal deviations; siting attributes are typically monotonically changing with respect to suitability.

Since the absolute deviation is non-linear in nature, Charnes and Cooper [4] proposed the linear programming equivalent which requires real valued preference weights for the deviation variables. An ordinal ranking of goals, also referred to as pre-emptive priorities [39], results in the hierarchical problem. This problem can handle noncommensurable goals [9], which would help to make such an algorithm applicable to power plant siting problems, at least in a nested, multilevel problem. However, the serious problem of specifying target goal and preference weights remains. Even if these problems could be overcome, lower level goals might not be considered. The use of cardinal preference weights would guarantee the consideration of all goals, but this would require the expression of goals in commensurable units, and returns us to the suitability scaling problem.

The satisficing model and goal interval programming. The satisficing or generalized model differs from the classical model in that it only minimizes the underachievement of goals. If the target goals (and preference weights) can be specified, this model would then be more applicable to power plant siting, since again most siting factors are either monotonically increasing or decreasing with respect to site-suitability (e.g., water availability, aquatic ecosystem impact, cost, population density, etc.). But again, applications to power plant siting have not been made.

Related to the satisficing model is goal interval programming [5] [10]. While the "goal programming functional" in the single variable x reaches its minimum when x = A in Figure 2, the "goal interval functional" reaches the same minimum value for all $A_1 < x < A_2$. However, the

FIGURE 2
Graph for Goal Programming
and Goal Interval Programming Functions



slopes of the two different functions, given by S_1 and S_3, are the same as those for the corresponding goal program; in this case, for which also $S_2 = 0$.

If the goal interval can be set to closely bound the upper or lower feasible limit of policy choice x, the solution will converge to that resulting from several multiobjective programming algorithms. However, the implicit assumption that attribute levels within an interval are equally desirable is unlikely to be true, and the extra work involved in goal interval programming may outweigh the few advantages [31]. Nevertheless, if the aforementioned problems common to all goal programming methods can be overcome, another interesting avenue of power plant siting research will be opened.

5. CONCLUSIONS

The power plant siting process is complex, time consuming, and not totally amenable to analytical methods. This is due to the great variation of siting situations that actually occur, and the important behavioral role of political negotiation and compromise involving government

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and interest groups in final site selection. In addition, a facility site found through optimization methods may, in turn, suboptimize the location of future power plants that have not been planned for [44]. Thus, there is an important need for a systematic evaluation of the behavior pattern related to this kind of decision making. Further, the facility siting process involves siting data that is expressed in noncommensurable units, and the need for suitability scaling often discourages the adoption of more systematic siting methods. However, numerous multidimensional programming methods have been developed, applied, or have promising applications to power plant siting or location analysis. These multidimensional methods are most useful when they are considered as alternative ways to provide decision makers with information at different stages of the overall site selection process.

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AIRPHOTO INTERPRETATION AND THE SELECTION OF A POWERLINE RIGHT-OF-WAY IN VERMONT

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In July of 1981, Hans Klunder Associates was retained by the Vermont Electric Power Company (VELCO) to find a route for a ±450 KV Direct Current (DC) powerline which would provide a tie between the New England system and that of Hydro-Quebec. Early indications were that the line would be carried on wooden H-frame structures about 100 feet high and would require a right-of-way about 150 to 200 feet wide.

The line was to enter Vermont and the United States somewhere between Lake Memphremagog and Wallace Pond (Figure 1) and terminate at a yet to be constructed DC/AC converter station to be located either at Moore Dam or Comerford Dam, both on the Connecticut River. This resulted in a study area encompassing approximately 2000 square miles, an area which includes almost all of the three counties in northeastern Vermont called the Northeast Kingdom.

Since construction of the line would require about three years and Canadian power would be available in 1986, VELCO asked that the preliminary plans for constructing the line be ready for filing with the Vermont Public Service Board by October 15, 1981 - about three and a half months away.

In addition to the time and location constraints placed on the project by VELCO, there were several other areas of concern for the project to consider. Vermont has some of the strongest environmental legislation and review procedures in the United States. Prior to receiving a Certificate of Public Good (an agreement in principle to construct the facility) from the State of Vermont, a utility must prove that such a project, be it a powerline or generating facility, will not unduly affect the environment and will be designed in a manner to protect the public health and safety. The legislation requires, among other things, that "....the project will not unduly interfere with the orderly development of the region with consideration having been given to the recommendations of the municipal and local planning commissions and municipal legislative bodies." The project must not have an undue adverse effect on the aesthetics, air and water purity, the natural environment, historic sites, or the public health and safety.

Because of the competition between flat land for agriculture and urban development, the Governor, in 1980, issued Executive Order 52 which requires justification for any publicly funded or assisted project or one regulated by any state agency or board to consume active farms and/or prime

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agricultural soils. Regulations developed by state agencies to comply with this Order make routing a powerline through highly developed agricultural regions rather difficult.

Perhaps the most difficult constraint was that which was the most elusive, the perception by some that there are health and safety effects related to high voltage DC transmission lines that are not present in AC lines. Although this was only a perception or feeling, avoiding concentrations of population became a major additional objective. While current research suggests that there are no inherent effects from high voltage DC transmission, to those who believe that there is a problem, no amount of evidence is likely to persuade them differently.

These constraints give an indication that a straight line, or the shortest distance between two points, was unlikely to succeed as a possible routing for the corridor. Consequently, the following elements had to be inventoried by various techniques. Through literature research, historic districts and sites, archaeologic sites, land ownership patterns, areas of unique biologic and geologic significance, wildlife habitat areas, and local zoning and planning, considerations were established. Airphoto interpretation provided data concerning land use, population distribution, wetlands, flood hazard areas, slopes over 15 percent, soil and subsoil conditions, depth to bedrock and types of groundcover. A combination of literature and map analysis, photographic interpretation and field study provided an inventory of the scenic elements of the region.

Within the frame-work of the project parameters established by VELCO and the constraints by the State and other sources, a technique was devised to quickly focus attention on those geographic areas which would warrant further consideration. This technique, involving rapid inventory procedures, identified those areas of major constraints which would eliminate them from consideration.

Immediately upon project authorization, extensive literature research on the state, regional and local level was conducted. These included sources such as local and regional planning agencies, the State Geologist, various state-wide planning studies, Fish and Game publications, Forest and Parks data, listings of important natural areas, historic site lists, and lists of archaeological sites.

Probably the most significant contribution in the evaluation process was the use of airphoto interpretation. To carry out this task, Photographic Interpretation Corporation joined Hans Kiunder Associates. For the initial phase, 1:84,000 color infrared (CIR) airphotos were enlarged to 1:42,000 or 1 inch equals 3,500 feet (Figure 2). These aerial photographs were available in the Northeast Kingdom from wetland studies performed for the United States Corps of Engineers and the National Wetland Inventory. The photographs allowed mapping information on a regional basis for initial planning. Land use and land cover, surficial materials, depth to bedrock, and general geologic characteristics were readily identifiable at this scale.

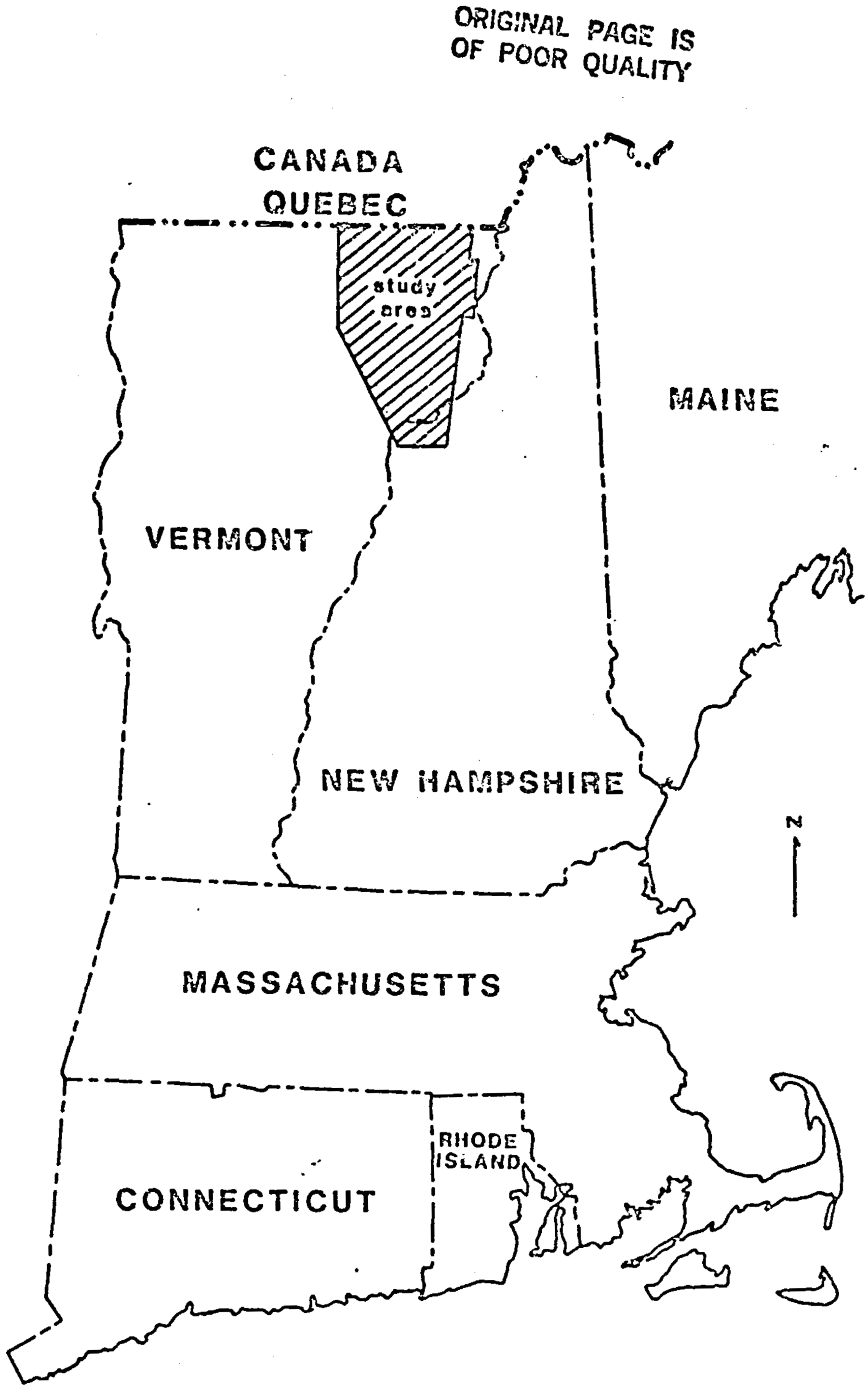

Figure 1. Project Study Location

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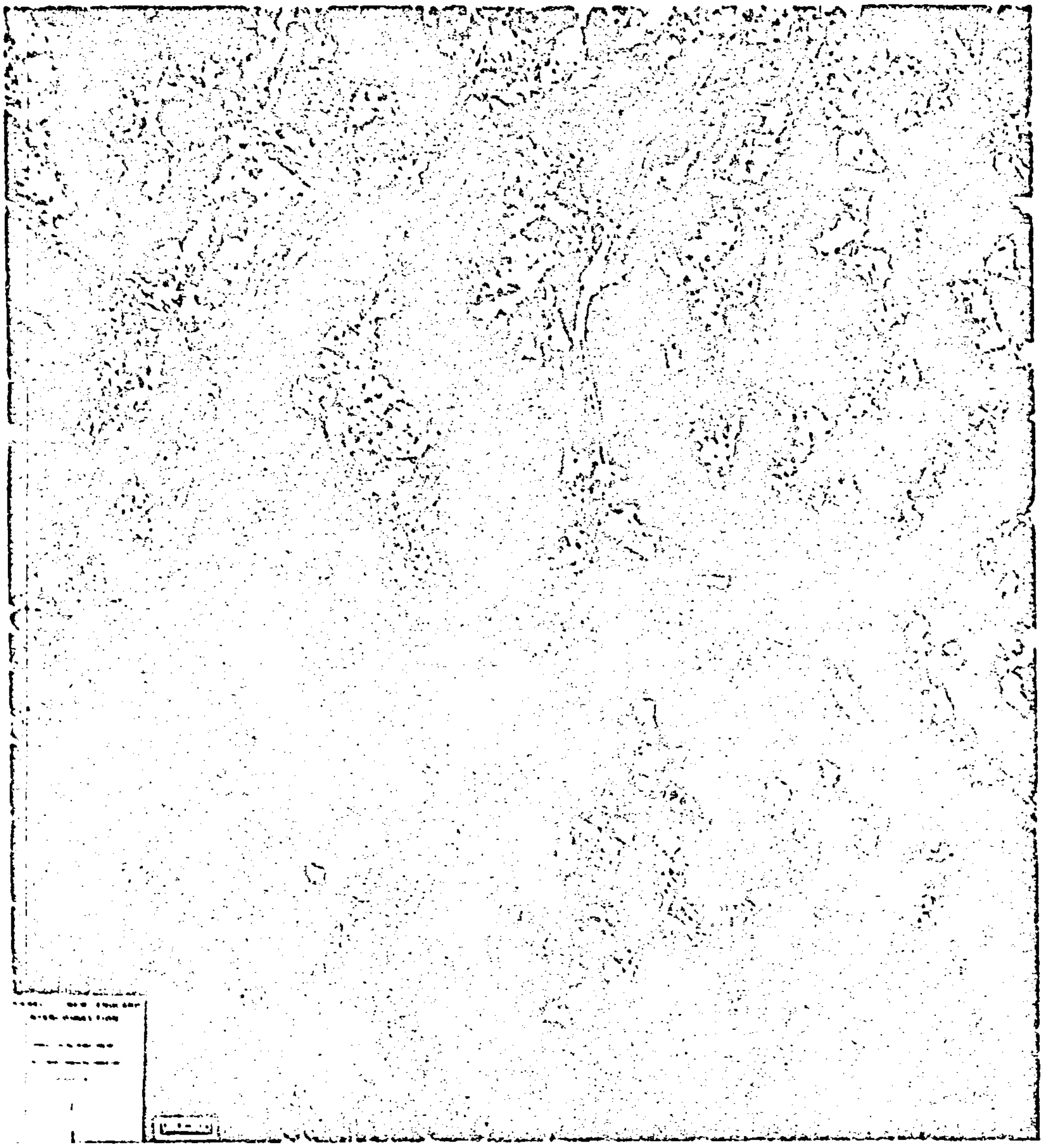

Figure 2. Black and White Copy of a Typical Infrared Photograph.
(Original Scale: 1:84,000)

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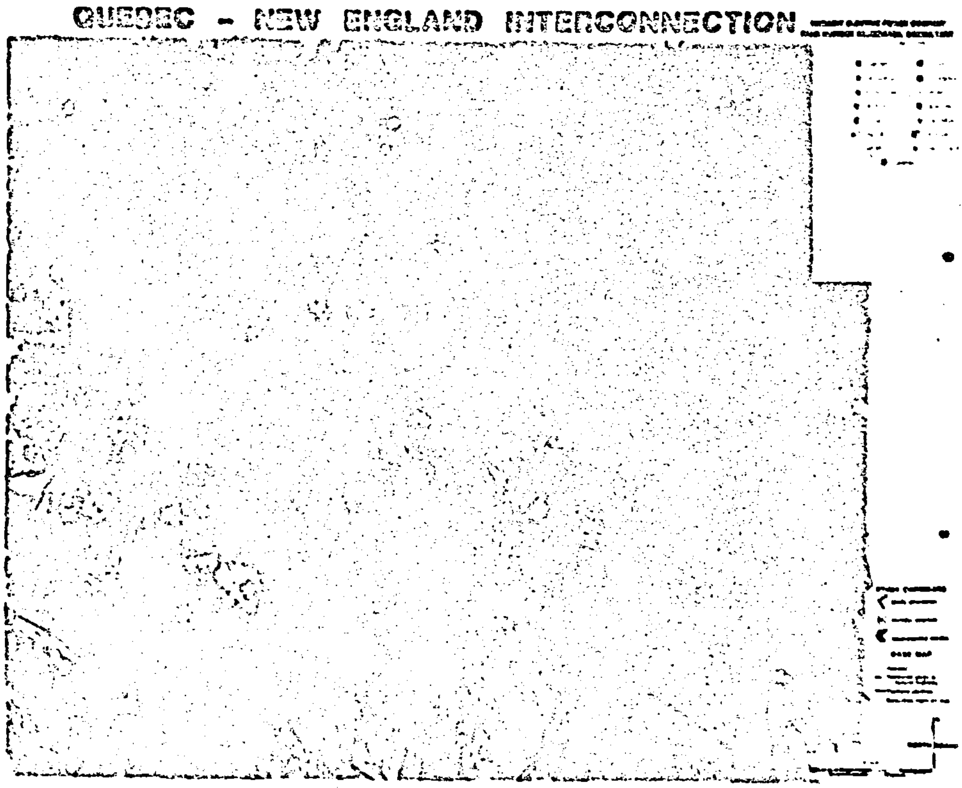

Figure 3. Reduced Scale - Land Use Map of Northern Half of the Study Area.

A team was established to analyze these aerial photographs and interpret them to develop information pertaining to land use, wetlands, mineral resources, unique geologic areas, excessive slope, high elevations, and depth to bedrock. In addition, accessibility to any particular corridor via private and public roads was determined through photographic interpretation.

The initial mapping process identified land use and cover in fifteen relevant, broad categories ranging from forest land to urban areas. Of particular concern were those categories which should be avoided, such as lakes, major wetlands, agriculture, built-up areas, and major recreation areas - ski areas and golf courses. Units as small as five acres were delineated in this effort. Figure 3 is an example of the land use mapping which resulted from this phase.

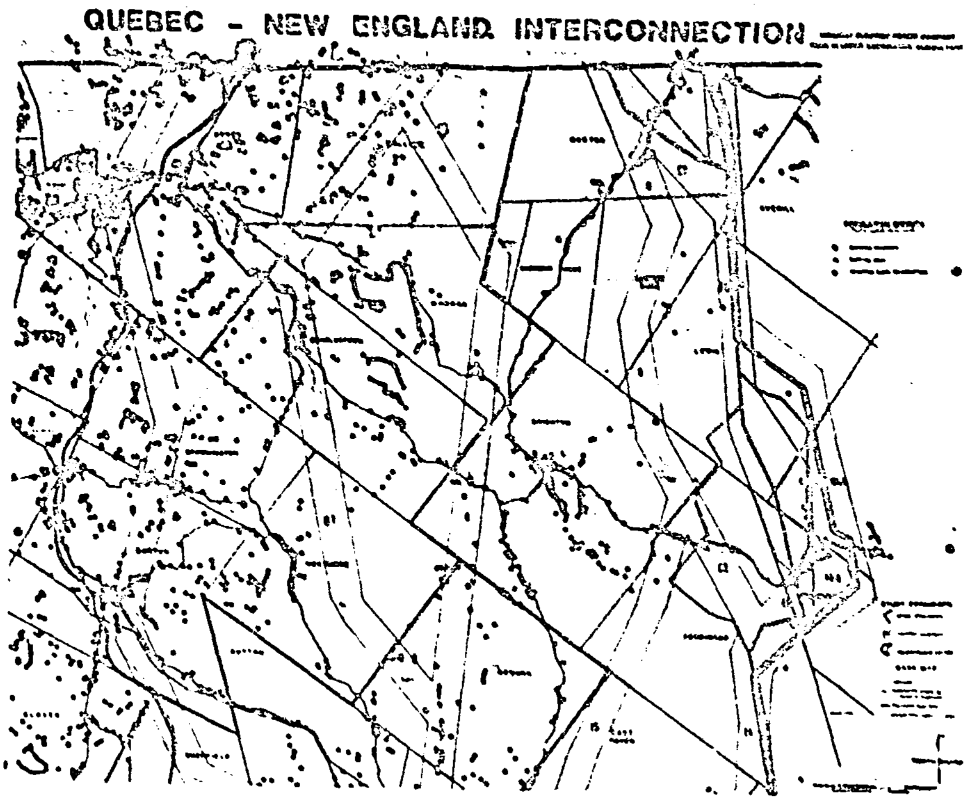

Figure 4. Reduced Scale - Population Distibution Map of the Northern Half of the Study Area.

Because a powerline is not a thing of beauty, and because it was advisable to find a route which avoided disturbing people, one factor that needed mapping was population distribution. For the population distribution indicator, all residential structures in the Study Area which could be identified on the airphotos were mapped. At the regional scale, it was decided that the categories for this factor be limited to three. In sparsely settled areas it was only necessary to note the location of individual residences. In those areas where the small scale made the identification of individual structures difficult or impossible, the area was mapped as a built-up unit and identified as being primarily permanent or seasonal, as may be noted in Figure 4.

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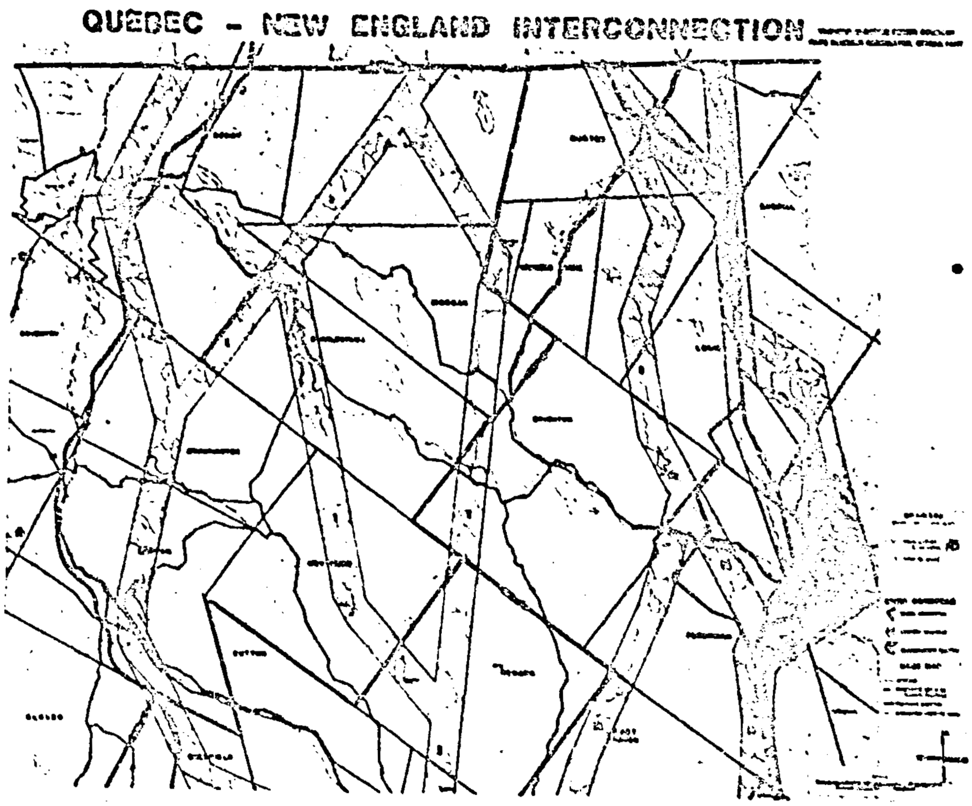

Figure 5. Reduced Scale - Drainage Map of the Northern Half of the Study Area.

One of the primary indicators of geologic conditions in an area, such as soil and subsoil types, bedrock types, and depth to bedrock, is the surface drainage pattern. Changes in the spatial arrangement of drainage ways, lengths of drainage ways, and the number of channels indicate changes in material types, regional slopes, and the erosive capabilities of the underlying bedrock as well as surface soils. Figure 5 depicts the drainage that was mapped for the northern half of the Study Area. In addition to the geologic indicators provided by drainage mapping, the efforts helped delineate wetlands and gave an indication of the number and location of stream crossings for any given route. Both of these latter factors would have direct bearing on the general environmental problems that would be faced in siting the route later.

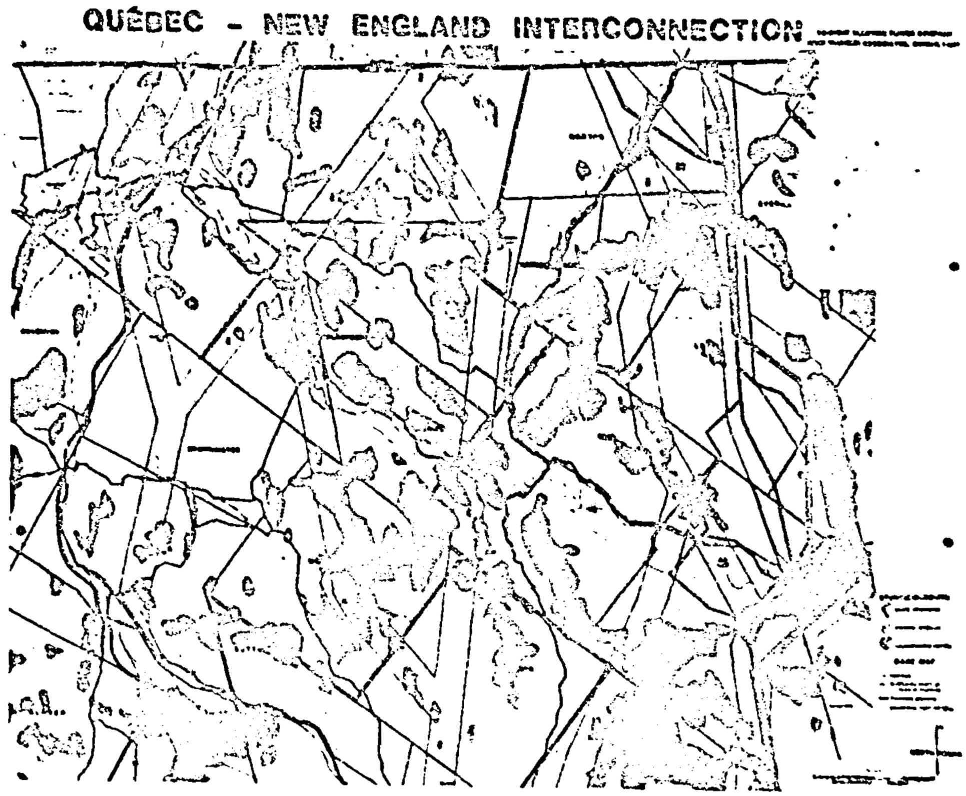

Figure 6. Reduced Scale - Geologic Feature Map of
the Northern Half of the Study Area.

Another group of factors mapped from the airphotos were those related to geology (Figure 6). As a result of State-wide environmental concern in earlier years, Vermont agencies have identified geologic features deemed unique or important to the State, such as eskers and specific mineral locations. These factors were noted from existing State lists and their locations determined from the aerial photographs. Photographic interpretation was used to locate and delineate large areas of coarse grained soil materials which serve as aquifers in the region and to find and delineate those areas with less than five feet of soil cover over bedrock. This latter parameter was useful in determining those areas in which blasting would be required to provide sufficient foundations for the poles.

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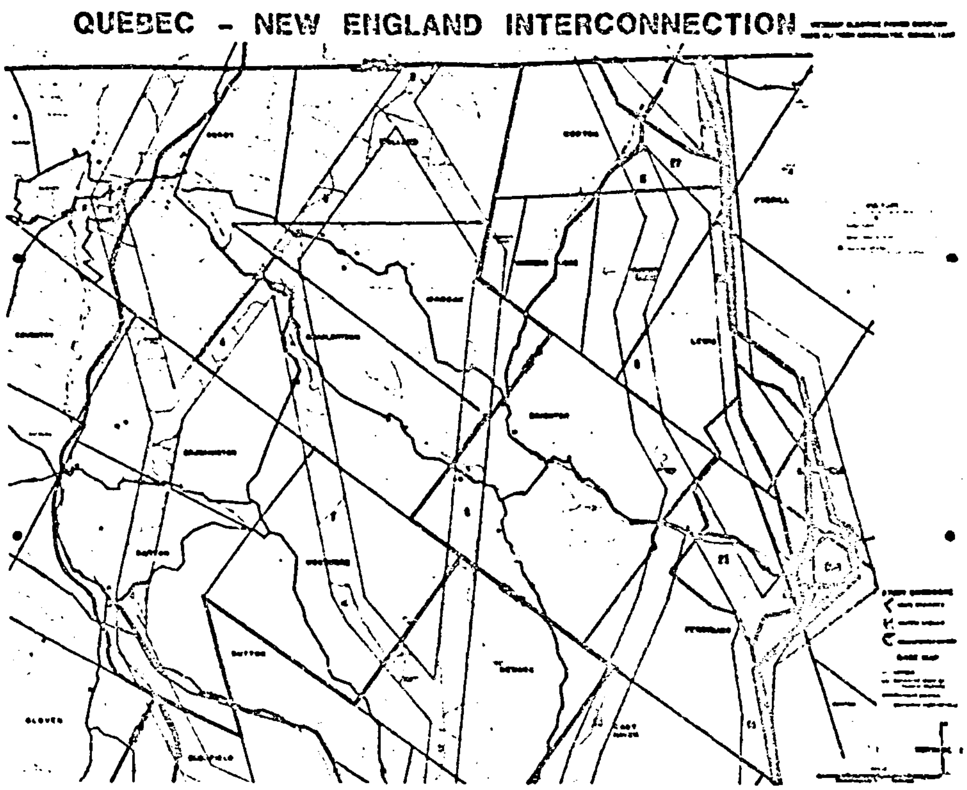

Figure 7. Reduced Scale - Culture Map of the Northern Half of the Study Area.

Existing access to a potential powerline right-of-way is of particular concern in assessing the environmental impact of a facility through relatively wilderness areas. The more new construction or reconstruction of roads that is requires, the more potential impact of the project. Because much of the Northeast Kingdom is held in large tracts, the aerial photographs were invaluable in delineating the myriad private roads that have been built but do not appear on state maps. Figure 7 depicts these roads as well as the locations of the many historic sites which appear on local, State and federal registers and which must be avoided by any powerline through the area. While seemingly unrelated, these two factors are quite compatible on this map as each factor falls into the broad general category of cultural features. Were there any known archaeological sites, or any suspected ones, in the Northeast Kingdom, these, too, would have been included in this figure.

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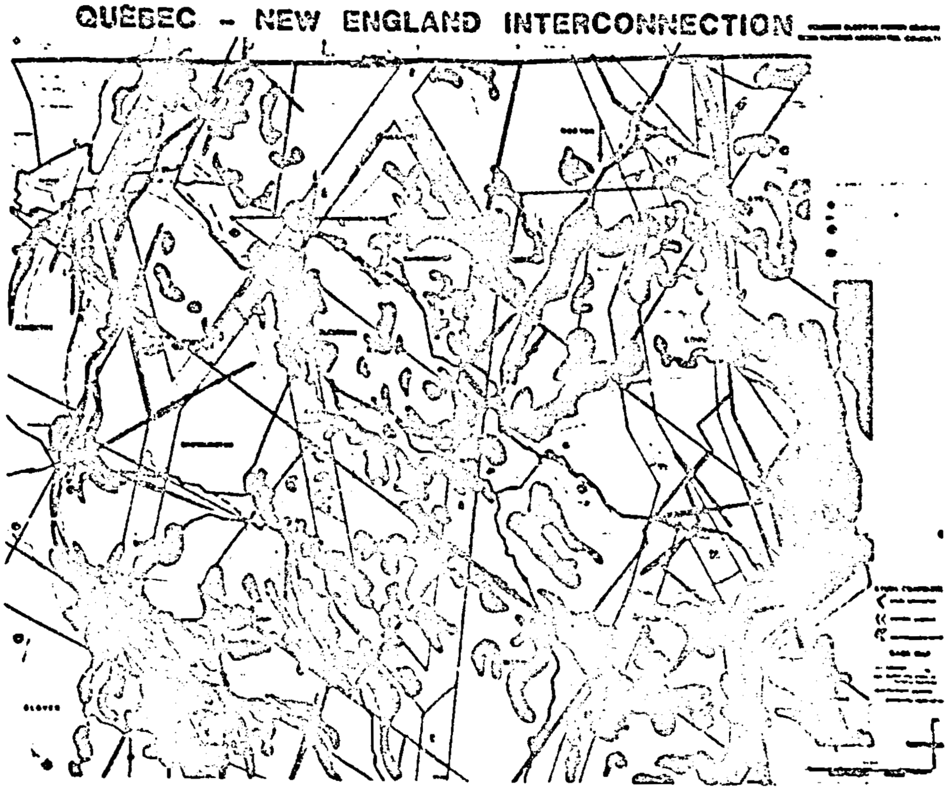

Figure 8. Reduced Scale - Scenery Classification Map of the Northern Half of the Study Area.

Visual analysis is difficult to quantify and more difficult to portray on a map because of the subjective nature of the factor compounded by transitory elements of changing viewing points and seasonal changes. For this study, a combination of ideas was used to determine those areas of the Northeast Kingdom which had high scenic values and which should be avoided, if possible. Figure 8 shows the final product which resulted from joining data from topographic maps, previous studies, slope maps, personal knowledge and airphoto interpretation.

Figures 3 through 8 illustrate the types of maps developed from these aerial photographs for inhouse study purposes and, later, public presentations in setting forth opportunities and limitations for locating the powerline corridor in the Northeast Kingdom.

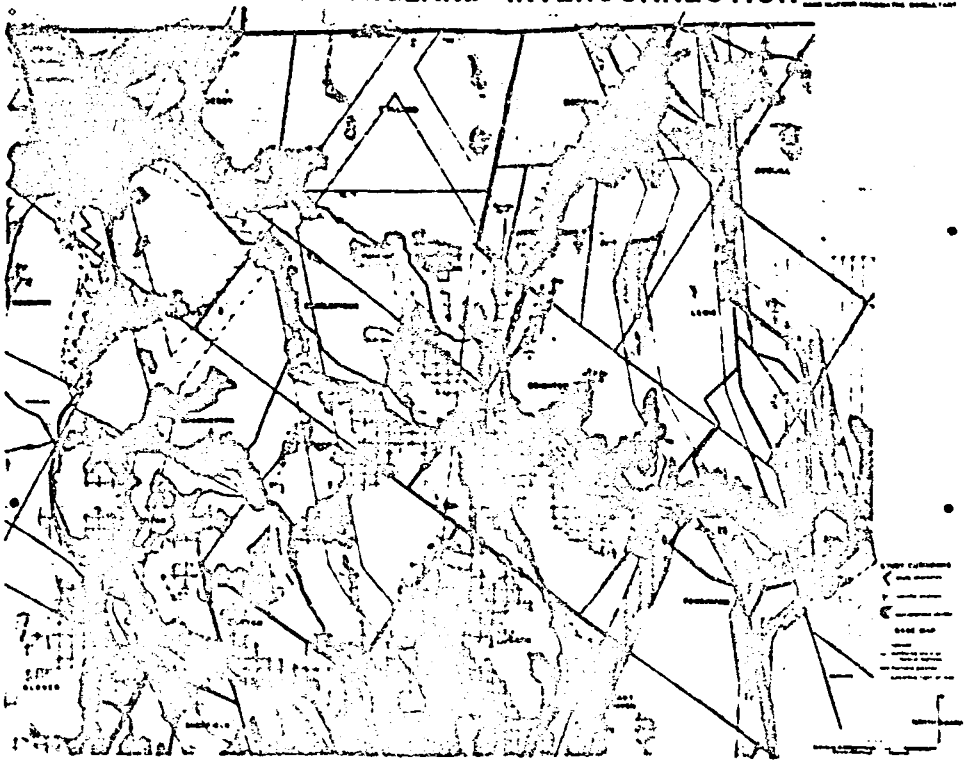

Figure 9. Reduced Scale - Limitations and Development Capability Map of the Northern Half of the Study Area.

These maps were used to develop a final map which indicated areas with no limitations, slight limitations, moderate and severe limitations to a powerline corridor and, conversely, elements that would be of impact upon a powerline corridor, such as steep slopes, inaccessibility, and other conditions creating techuical limitations to the building of a powerline (Figure 9).

Parenthetically, I would like to mention the final design, shown in Figure 10. We have recommended not a steel lattice-type structure, but a low-profile wood or Corten steel H-frame structure that renders a visually less obtrusive design. These structures will blend into the background with relatively little disturbance to the segments of large forest environment through which the line will ultimately pass. The structures will be between 85 to 95 feet above the ground with the cross arms 65 feet above the ground. The minimum conductor (wire) clearance will be 36 feet.

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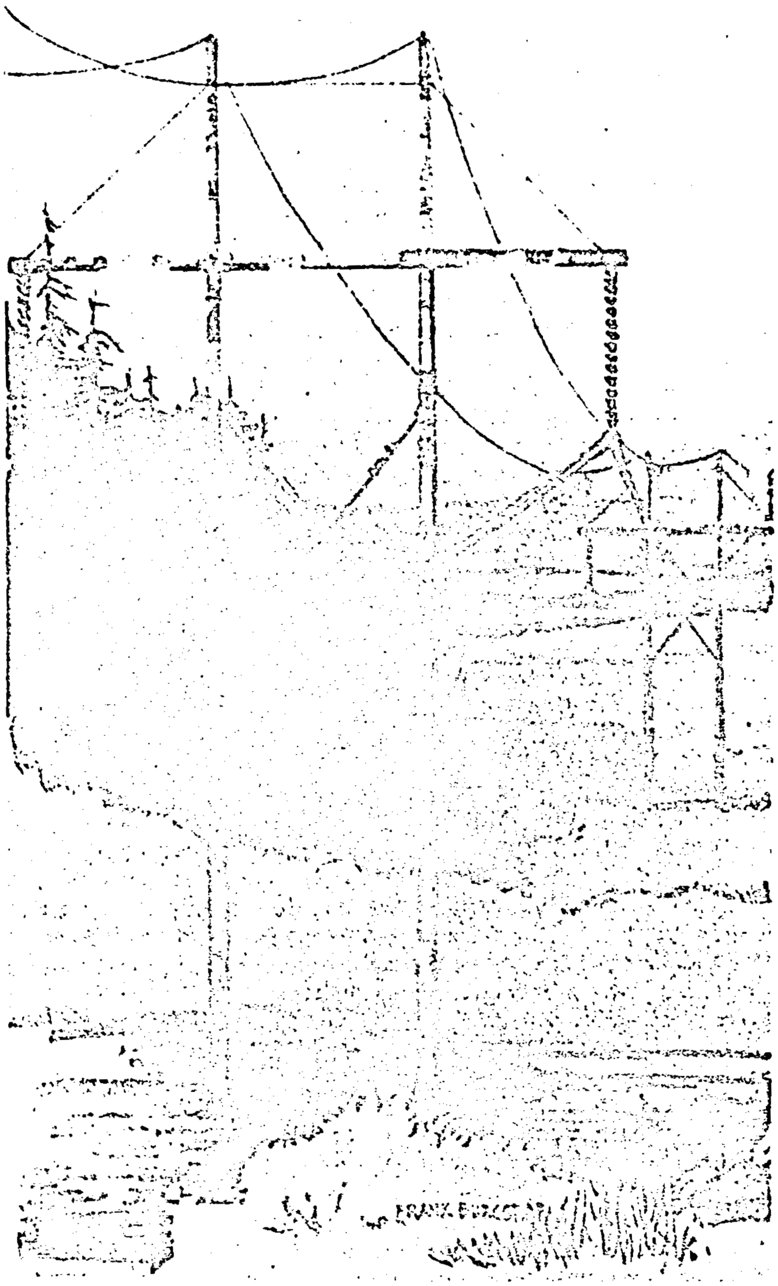

Figure 10. Artists Conception of H-Frame Structures

The first report to VELCO was a document setting forth 29 study segments. These segments were one mile in width and varied from 2 to 20 miles in length. They were interconnected in such a way that they could provide many paths from the Canadian border to either Comerford Dam or Moore Dam on the Connecticut River. The segments were established taking into consideration the constraints imposed by natural and manmade elements. Figure 12 shows these segments and the myriad paths a powerline might follow.

The result of this first phase was a regional overview and recommended preferred corridor alignment. This established the recommendation to VELCO that, based on information gathered in the first phase using regulatory, legislative, and VELCO's criteria, the Essex Mountains Corridor was the one that should be further investigated for location of the line.

The Essex Mountains Corridor provides for an alignment which will have the least effect on the environment and the people of the Northeast Kingdom. The recommended corridor avoids major settlements, unique geologic and biologic areas, large wetlands, deer yards, steep slopes and agricultural land. It is a corridor that is 52 miles in length and provides a link between the New England and Hydro-Quebec systems that is environmentally acceptable and yet proves cost effective because it avoids problems areas, is relatively straight and technically feasible.

After submitting this regional overview, VELCO authorized the second portion of the study which analyzed all of the individual corridor segments in general and the Essex Mountains Corridor in detail. Also, it allowed for the development of a combination of segments that would render the least adverse routing from an environmental standpoint. This phase would also recommend a study corridor that would be narrowed from one mile to a maximum width of 1500 feet and, where possible, more specific than 1500 feet. For the most part, the project route would eventually be 1500 feet wide so that actual field verification could be used for the final 200 foot right-of-way selection within the 1500 foot band.

Land acquisition considerations, construction considerations, suitable access for construction, and land ownership patterns were additional criteria in the determination of a final specific corridor recommendation. In order to develop information with greater specificity, larger scale (1:24,000) black and white photographs were flown. In addition, enlargements at a scale of 1:6,000 were acquired. This afforded sufficient detail to allow the development a 1500 foot wide corridor to be submitted to the Vermont Public Service Board by December 1.

At this time (mid-October), the 42 towns (townships) in the project area were informed of VELCO's intentions based on the initial studies. It was also pointed out that a preferred corridor had been chosen, though it had not be finalized, and would not be until December 1, the date VELCO expected to file for approval of a corridor. This meant that all municipalities in the Northeast Kingdom were put on notice for the project. Communities through which the preferred corridor passed were asked to meet

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with us in order to evaluate our preliminary findings and render their own input.

At this point the new black and white aerial photographs were used to identify detailed vegetative cover, locate individual structures, drainage ways, steep slopes, private and public roads, existing utilities, identifiable property lines, wetlands, and biologically and geologically sensitive areas (Figure 11). In addition, the towns' own plans, tax structures, the impact of the line on land use and the economy of the communities were incorporated with photographic interpretation to select a 52.7 mile long corridor. This corridor avoided, as much as possible, contact with conflicting land uses, year round and seasonal homes, natural constraints and other elements that might cause problems in locating a large powerline.

Land use and vegetative cover were mapped in detail for the entire mile-wide preferred corridor and for some distance to either side. The larger scale aerial photographs allowed the mapping resolution to be about one acre for factors such as wetlands. In addition to the increased details, the new mapping broke the forest land into age and composition categories so that softwood growth areas could be avoided.

Similarly, the other factors were mapped to greater detail, both in resolution and definition so that each could be closely scrutinized and evaluated. The other factors evaluated at this scale included population, drainage and geology.

On December 1, 1981, VELCO filed Plans to Construct with the Vermont Public Service Board. This document was the official notice to the State that VELCO intended to build the line and it asked the State for approval. The plans showed a 1500 foot wide corridor within which the final right-of-way would be selected.

Because of the soundness of this second phase, all eleven towns through which the corridor passes essentially approved the preferred corridor recommendations. Only at the Canadian border, in the Town of Norton, did the filing with the Public Service Board include an alternate as part of the filing (Figure 12). This alternate resulted not from any problem with the Town, but because of uncertainties in where the line would come in Quebec.

The third and final phase of the study began at this point and further detailed studies using airphoto analysis, additional literature survey, field investigations, and helicopter overflights were conducted to establish the exact location of the line. This had to take into consideration detailed topography, location of access roads, environmental constraints, such as wetland areas, vegetative cover, drainage, and soil and subsoil conditions.

While these detailed studies were being undertaken, the State of Vermont assigned the responsibility of evaluating VELCO's recommendations to its Department of Public Service. They were also to develop their own

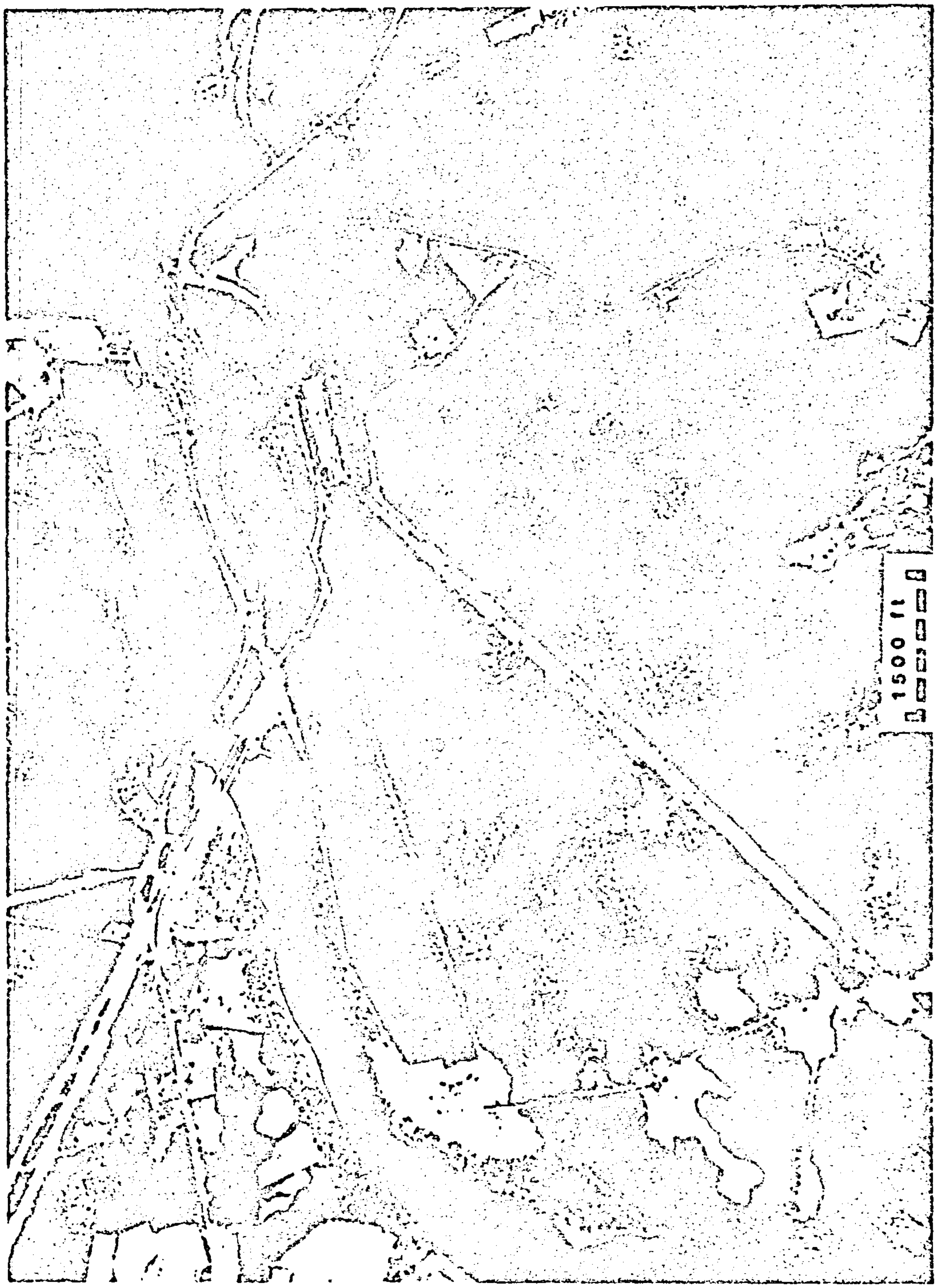

Figure 11. Portion of a Black and White Aerial Photography Depicting Moore Dame and the Site of the Connecticut River Crossing

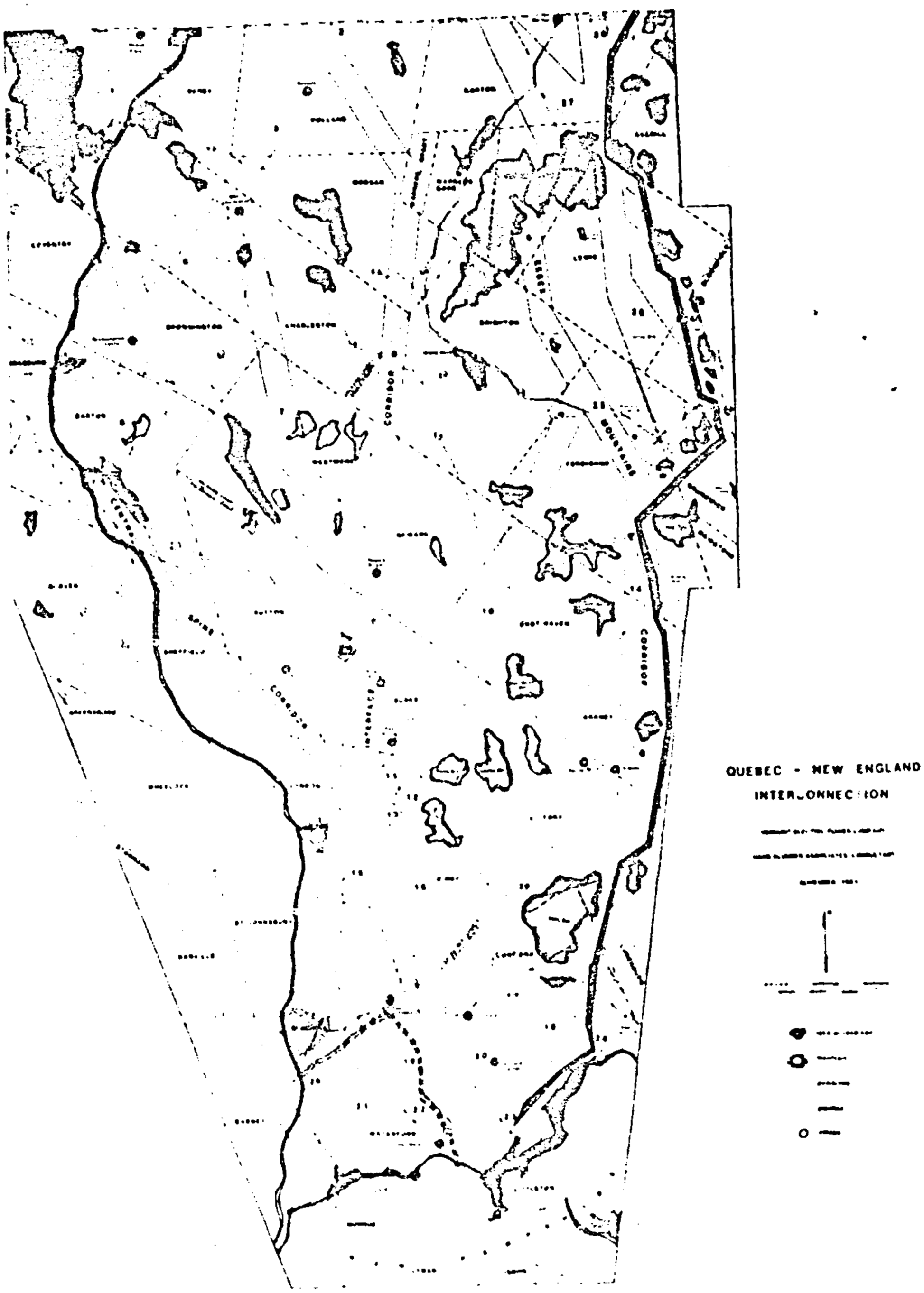

Figure 12. Recommended Corridor (Heavy Black Line) for Powerline Right-of-Way

recommendations for locating the powerline corridor. It was here that the thorough and sound information developed as part of our inventory proved itself. It showed that the State's evaluation could only confirm our findings. Only in two locations did the State suggest changes in our filed corridor. One of these locations concerned differing opinions of the the visual exposure in the Town of Granby, somewhere near the center of the 52 mile line. The second concerned a deeryard at the southern extremity of the corridor which could not be substantiated by the Fish and Game Department. So, when it came to the public hearings, the State's own findings were in support of our corridor selection.

It was encouraging to see that the two professional approaches conducted largely independently, resulted in quite similar routes. By June of 1982, the snow had left the study area and the project team, accompanied by representatives of the Vermont Agency of Environmental Conservation, the Department of Public Service, and the Department of Agriculture, proceeded to walk the entire corridor. This phase of the project further documented the soundness of airphoto interpretation during the earlier phase. As we walked the 52.7 miles, it became increasing evident that the location selected for the powerline corridor was extremely appropriate

To summarize, within the framework of the project parameters established by VELCO and the constraints by legislation regulation, a technique was devised to quickly focus attention to those geographic areas which would warrant further consideration for locating a high voltage powerline. Existing color infrared aerial photographs were obtained at a scale of 1:42,000. Interpretation of the aerial photographs quickly provided data on land use, wetlands, slopes, geology, population distribution and the transportation network. Maps and the literature augmented these data with information concerning historic sites, pronounced elevations, biologically or geologically sensitive areas, planning and zoning.

Through this process, twenty-nine corridor segments, one mile wide and varying in length from two miles to twenty-four miles, were identified for more detailed study. These segments were based on assumptions concerning entry and exit points from the study area and formed an intricate network of paths which avoided the major problem areas.

Further aerial photographic interpretation and literature research, along with consultation with the affected communities, led to the selection of a 1500 foot wide study corridor which has the support of the State and local people and which is presently being reviewed by the Vermont Public Service Board.

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POTENTIAL ROLE OF LAND USE AND LAND COVER INFORMATION IN POWERPLANT SITING: EXAMPLE OF THREE MILE ISLAND

James R. Wray
U.S. Geological Survey
Reston, Virginia 22092

Selecting a site for a nuclear powerplant can be helped by digitizing land use and land cover data, population data, and other pertinent data sets, and then placing them in a geographic information system. Such a system begins with a set of standardized maps for location reference and then provides for retrieval and analysis of spatial data keyed to the maps. This makes possible thematic mapping by computer, or interactive visual display for decisionmaking. It also permits correlating land use area measurements with census and other data (such as fallout dosages), and the updating of all data sets. The system is thus a tool for dealing with resource management problems and for analyzing the interaction between people and their environment. Besides powerplant siting and selection of powerline right-of-way, it can also help the planning of wastewater treatment facilities, assessing the impact of natural or man-made hazards, and preparing for emergencies.

Under present practice, selection of a powerplant site begins with a proposal and application by an existing utility company. This is nearly always for a site within that company's present area of operation. In late March 1979 a nuclear accident occurred at the Three Mile Island site on the Susquehanna River, 10 miles southeast of Pennsylvania's State capital at Harrisburg. The accident raises questions about where such plant are located and what areas are affected. A current land use and land cover map of the plant site and vicinity that is keyed to political units and census statistical areas is one tool that the interested layman can understand and that the politician, planner, and utility company can use in decisionmaking. An example of such a map is provided and described. Prepared by computer from a USGS digital data base, this map illustrates, after the fact, a rationale for the site chosen if only a land use criterion is considered. (Other relevant criteria include ground water hydrology, geological structure, and seismic activity.)

The accident at Three Mile Island serves as a catalyst for examining not only the spatial data sets and information system used in site selection, but also the prospective role of that system in hazard mitigation and emergency response. The land use and census areas information used in the Three Mile Island example was extracted from a statewide digital

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data base completed in 1978 as a cooperative effort between the State of Pennsylvania's Department of Environmental Resources and the U.S. Department of the Interior's Geological Survey. By 1986, land use and land cover maps are expected to be available for the entire country. Coverage in digital tape form--from which the Three Mile Island map was made--will follow. The land use maps are compiled largely from remotely sensed data. When interpretations from similar data for a later time are placed in the same geographic information system they can be used in routine map revision and update, or in emergency detection of change and assessment of damage.

United States Department of the Interior

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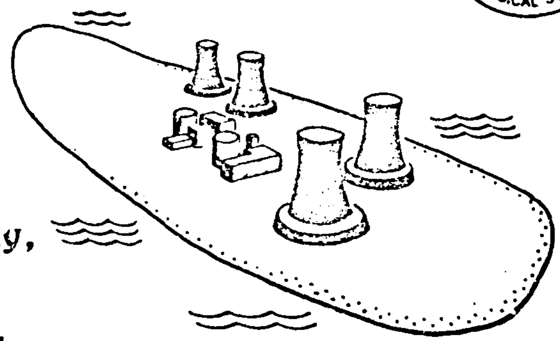


Computer-Plotted Map of Land Use and Land Cover, Three Mile Island and Vicinity, With Census Tracts

Explanation of a map illustrating the availability of digitized land use and land cover information, and one timely application.

A nuclear accident occurred in late March 1979 at the Three Mile Island powerplant on the Susquehanna River, 10 miles southeast of Pennsylvania's state capital at Harrisburg. The accident raises questions about where such plants are located and what areas are affected.

Using river water to cool the turbines and the nuclear reactor, the Three Mile Island thermal nuclear powerplant occupies an insular location in an area of relatively low population density. Even so, it is at the center of a triangle formed by populous electricity-consuming metropolitan centers at Harrisburg (10 miles away), York (13 miles), and Lancaster (23 miles). Small residential areas do lie nearby, but extensive open water, agricultural land, and forest land dominate the immediate vicinity. Suburban Middletown, however, lies less than 5 miles north. Off to the southeast—and usually downwind—lies industrial Lancaster in the heart of a rich agricultural area.

A current land use and land cover map of the plant site and vicinity that is keyed to political units and census statistical areas is one tool which the curious layman can understand and which the politician, planner, and utility company can use in decisionmaking. The accompanying figure is a reduced reproduction of such a map. An unannotated version was drawn in one evening's time by a U.S. Geological Survey computer-driven mapping plotter. At one scale, it overlies a USGS topographic base map which provides other essential information, such as roads, mountains, and drainage lines. A separate legend, also prepared by computer, identifies by color and shading pattern 19 categories of Level II land use or land cover. In general, the smaller land use polygons in darker tones are urban and built-up areas. The larger polygons in lighter tones are agricultural and forested areas, or water bodies. The rings spaced at an interval of 5 miles are used in analysis, planning, and assessment of impact. The grid lines spaced at an interval of 10 km are in the Universal Transverse Mercator (UTM) rectangular coordinate system. They are used for location control in mapping and analysis by computer, but locations can also be expressed in geographic coordinates.

The land use/land cover and census areas information is reconstructed from a statewide digital data base completed in 1978 as a cooperative effort between the State of Pennsylvania's Department of Environmental Resources and the U.S. Department of the Interior's Geological Survey. The corresponding overlays of associated maps for the Harrisburg and Baltimore 1° x 2° topographic map quads have been open filed at a scale of 1:250,000. These show census county subdivisions, political units, hydrologic units, and Federal land ownership. By 1982 similar map coverages will be available for the entire country. Coverage in digital tape form—from which this map is made—will follow. The land use maps are compiled largely from remotely sensed data, which are also to be used in map revision and update.

The USGS Geographic Information Retrieval and Analysis System (GIRAS) geographic information system makes possible not only the mapping by computer, but also the correlating of land use area measurements with census and other data, the updating of all data sets, and the retrieving and analyzing of data. The system is thus a tool for dealing with such resource management problems as powerplant and powerline site selection, planning of wastewater treatment facilities by drainage basin, assessing the impact of natural or man-made hazards, and preparing for emergencies. The map of Three Mile Island not only graphically dramatizes these needs but also the capability to meet them.

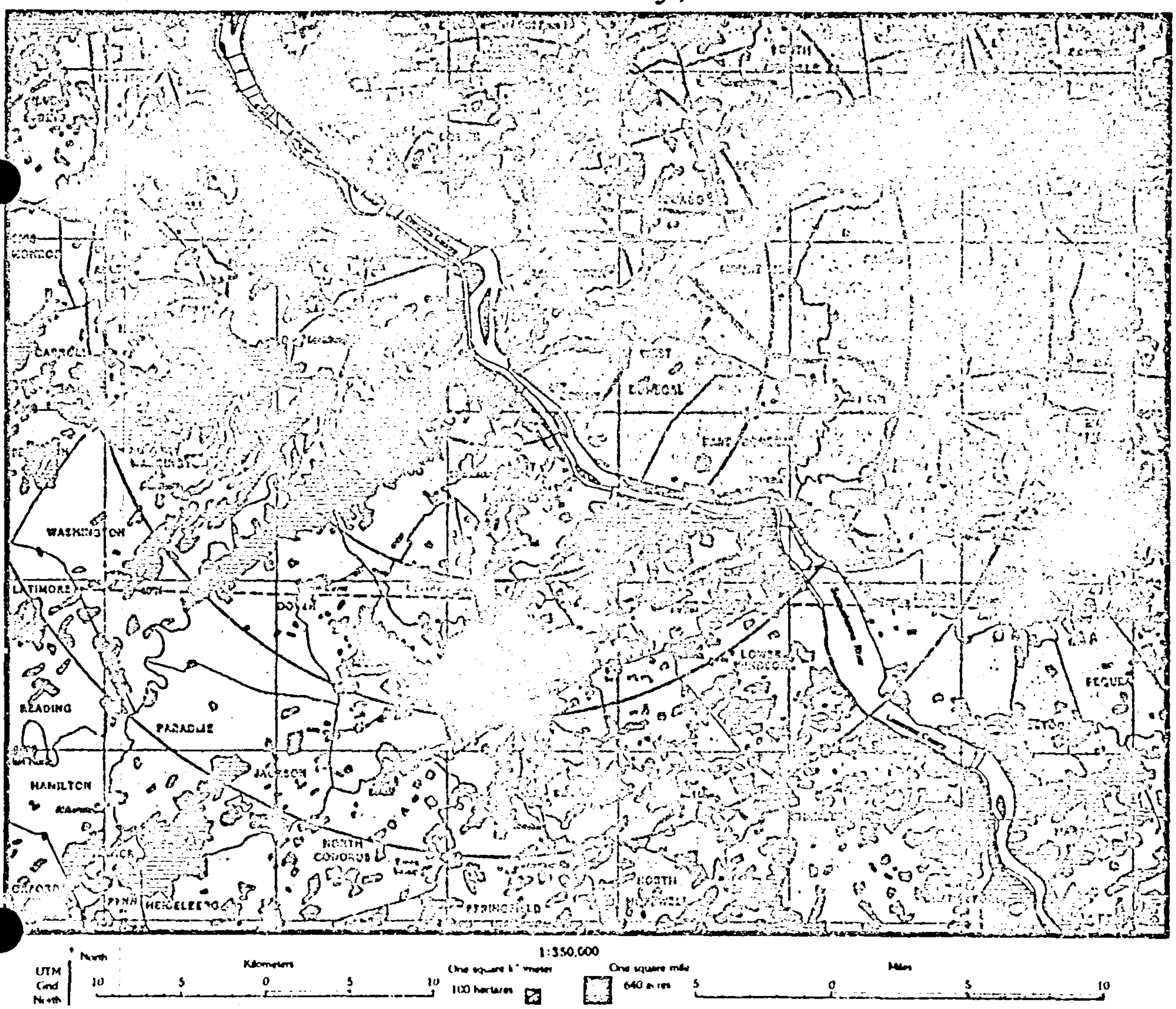
Although data are filed by such mapping units as the Harrisburg and Baltimore 1° x 2° topographic map quads, the USGS GIRAS geoinformation system can also recall data centered on other areas, such as Three Mile Island and vicinity, which lies in more than one quad. At the user's direction, it can also portray data in different combinations and at different scales. Except for the census tracts and some place names—for which the computer file presently uses numerical codes—the accompanying figure is in the style of a multicolor, computer-drafted and -shaded pen plot. Other graphic output modes are also possible, including video display.

Availability of maps and data.—Besides the maps, digital tapes and selected statistical summaries are becoming available for selected areas throughout the United States. From the tapes, a great variety of maps and tables can be made by other users, as well as by USGS. For information, contact National Cartographic Information Centers at USGS offices in Reston, Va., Rolla, Mo., Denver, Colo., and Menlo Park, Calif., or contact:

Geography Program
U.S. Geological Survey
710 National Center
Reston, VA 22092
Telephone: (703) 860-6256

For information about a full size, 46 x 58 inch land use map exhibit of Three Mile Island and vicinity call James R. Wray at USGS (703-860-~~6345~~), or Germain LaRoche at the U.S. Nuclear Regulatory Commission (301-492-8269). 7796

Computer-Plotted Map of Land Use and Land Cover, Three Mile Island and Vicinity, With Census Tracts



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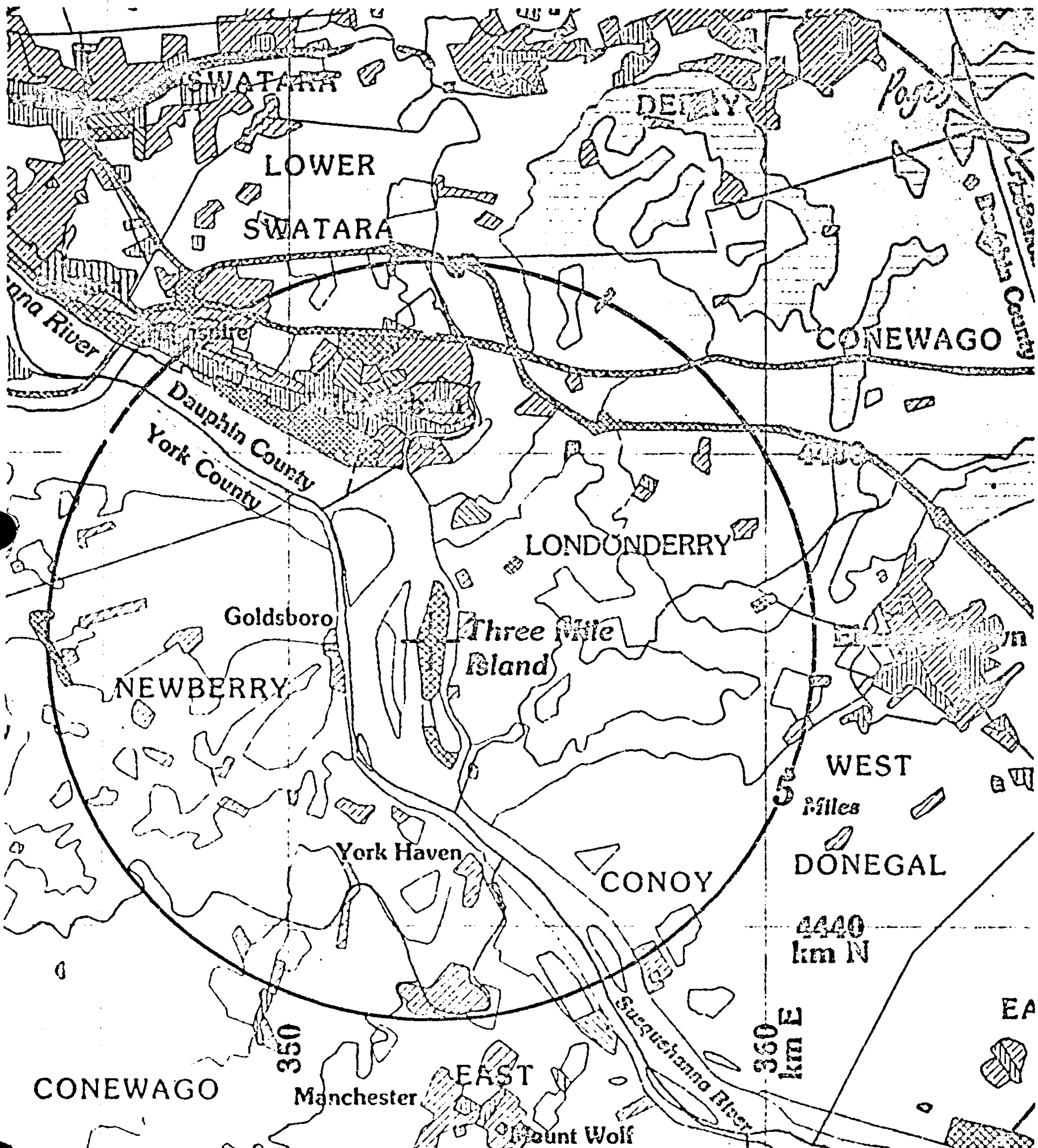

Portion of computer plotted polygon-style map of land use and land cover for Three Mile Island and vicinity, with census tracts, scale 1:100,000. Following the March 1979 nuclear accident at Three Mile Island, a basic unannotated map of the area was prepared. Because of the use of digital techniques, preparation of the map required only one evening's time.

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COMPUTER-AIDED SITING OF COAL CONVERSION FACILITIES

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1. INTRODUCTION

Today's precarious energy situation in the United States has focused much attention on the question of coal conversion. The principle of coal conversion is the transformation of coal into more usable forms -- namely, synthetic gas and various types of liquid fuel. Much of the excitement that synfuels generated among energy planners only a few years ago has faded. The main problem with synfuels today is an economic one: petroleum prices have not increased at projected levels and synthetic fuels simply cannot compete in today's energy market. In fact, one study has shown that even in an economy of rapidly rising oil prices, the projected costs of producing synfuels from a proposed facility increase commensurately [1]. Because a typical synfuels plant might today cost between 1.5 and 3 billion dollars to construct, the apparent rewards of commercial development do not match the risk.

Given the marginal nature of synfuels economics, plant site location can be a major determinant in overall project feasibility. Furthermore, because plant location may largely determine the severity of environmental and cultural impacts, proper siting can be "the key to public acceptance of a coal facility" [2] and, cumulatively, to the technology in general. The challenge in siting conversion plants rests in optimizing transportation costs in the larger context of a regulated and sensitive environment. Energy planners must simultaneously address issues which often conflict with each other. Also, a highly changeable economic climate demands that almost total flexibility be built into site selection methodology. This flexibility should allow for changes in transportation rates, market and mine locations, and as government priorities dictate, changes in regulatory conditions.

These challenges are being met quite successfully through the active use of geographic information systems.

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2. CASE STUDY DESCRIPTION

Dames & Moore has conducted a number of site studies for synfuels conversion plants in the Midwest. In the course of these studies, the firm has developed a methodology for simultaneously addressing several siting criteria. The methodology and results from these collective studies have been borrowed for this paper to demonstrate how a typical siting problem might be solved. The following discussion, therefore, will be treated as a single "case study."

A study area centered on the lower Ohio River Valley (Figure 1) has been selected for illustration. This is a typical synfuels siting region due to its proximity to Midwestern coal sources, synfuels markets, and the Ohio River transportation corridor.

Dames & Moore's Geographic Information Management System (GIMS©) was selected as a tool for the manipulation and display of project data. GIMS is a fully integrated system

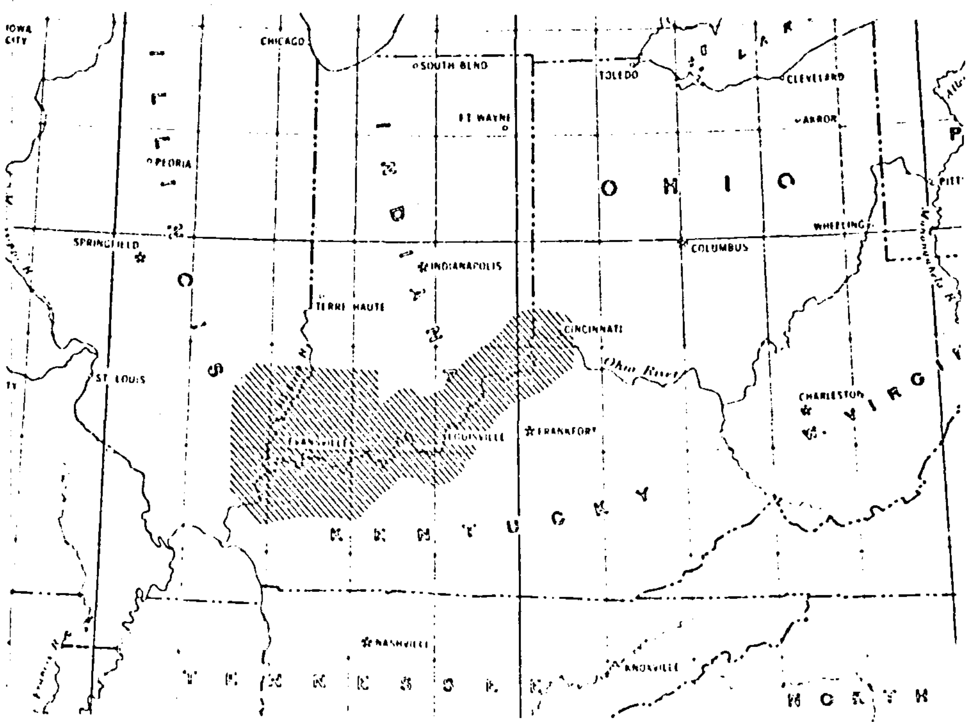

Figure 1
Study Area Location

developed by Dames and Moore to provide planners with a tool for entering, storing, analyzing, and displaying large amounts of geographic information. GIMS has been employed successfully on a variety of past projects relating to industrial site and route selection, resource assessment, and environmental impact.

2.1. Analysis Strategy

The initial step in the analysis concerned the identification of the salient issues which bear upon the siting decision for a coal conversion plant. The planning team decided upon three basic issues of concern; these issues are identical to those traditionally evaluated in the siting of any power plant or other major industrial facility.

First, because of the strict air quality standards imposed upon many regions in and near the Ohio Valley and the several areas of ecological distinction, environmental suitability emerged as a primary siting issue. The study region is also characterized by varying densities of population and complex patterns of urban and rural land use; therefore, cultural suitability became the second main issue.

In the construction and operation of a coal conversion plant, the owner incurs many costs which cannot be avoided or optimized by reason of geographic location. However, other costs such as those incurred in transporting the coal from mine to plant and costs of moving the product to market can vary considerably with site. For this reason, the third issue addressed consisted of site-dependent capital and operating costs.

2.2. Data Base Creation

For each of the three siting issues, a strategy was developed to allow for the transformation of available "source data" into a map representing the suitability across the study region for the issue in question. Once these strategies were outlined, it was determined which source information had to be collected for input into the models. Most of the data were obtained from published sources and then were transcribed onto standard USGS base maps for consistency in digitizing. Source maps were input into GIMS in two ways. For most maps, polygons representing various features (for example, air quality zones or state parks) were digitized directly from physically mapped data. Other data were obtained in already digital form and only had to be converted into a GIMS-readable format. These files included surface topography, which was obtained from the USGS, and population density, which was derived from a U.S. census file of enumeration districts. All source data were abstracted into matrix files of grid cells, with each grid cell representing a land area 1.5 kilometers on a side.

2.3. Primary Screen

In most regional siting studies, there exists a number of features which preclude development *a priori*; these features include legal and quasi-legal restrictions such as national and state parks and federal air quality non-attainment zones. Other "fatal flaws" include environmental restrictions such as fault traces, subsidence zones, and wetlands. The methodology used in this study consisted of a two step process. The first step, a primary screen, excluded offhand the areas possessing any legal or environmental restrictions. These areas were physically mapped and digitized as one of the map files in the data base. The second step in the analysis evaluated the suitability of those areas which survived application of the primary screen, based on the three major issues of concern. For purposes of illustration within this paper, the primary screen has been removed from all but the final site suitability map.

3. DERIVATION OF SITING ISSUES

3.1. Environmental Suitability

The first siting issue addressed was environmental suitability. Figure 2 shows a data structure diagram for the derivation of this issue. The diagram shows that environmental suitability is a combination of two sub-issues: air quality suitability and distance to ecological areas. The air quality suitability map in turn consists of two components: first, the distance of sites to federally-designated TSP, PSD Class 1, and SO_2 non-attainment zones, and second, a measure of plume dispersion capability, based on surrounding topography.

The ecological suitability map reflects distances of potential sites to areas of ecological concern, including parks, recreation areas, wildlife habitats, and game preserves.

Together, the air quality and ecological suitability maps were combined in the computer to yield a single environmental issue map (Figure 3); lighter shades on the map represent areas of higher environmental suitability for plant location.

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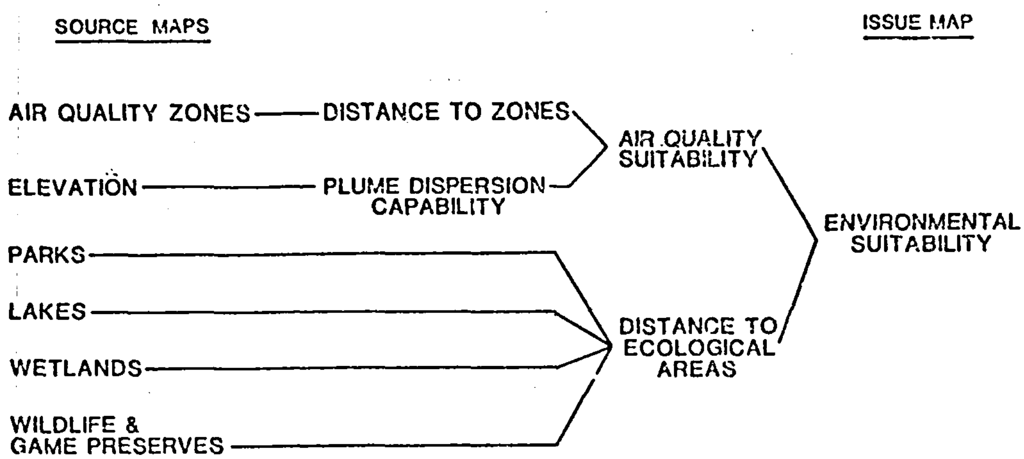


SITING ISSUE 1

ENVIRONMENTAL SUITABILITY

Figure 2

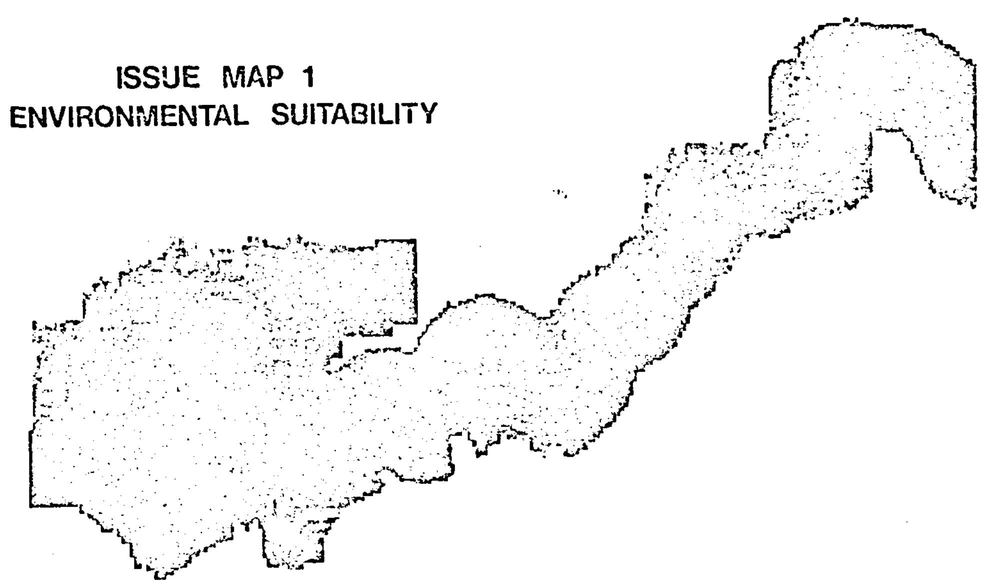
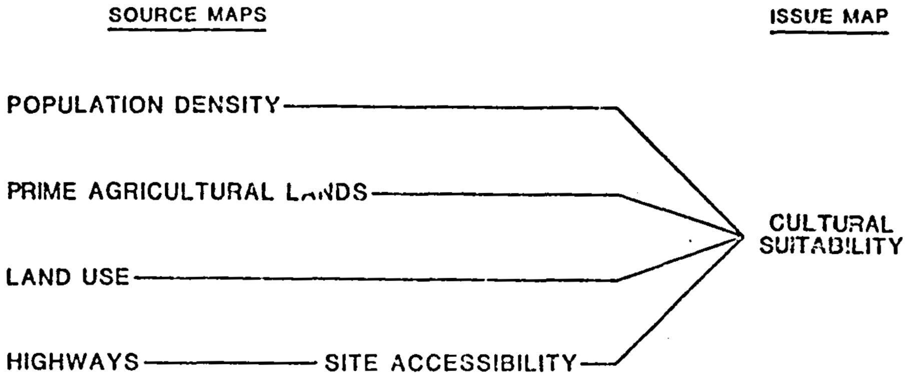


Figure 3

3.2. Cultural Suitability

The cultural suitability issue (Figure 4) sought to avoid areas of high population density and culturally sensitive land uses. Zones of industrial uses or other environmentally disturbed lands were given a favorable suitability rating. Urban areas, prime agricultural lands, and regions of poor highway accessibility were given lower ratings. The suitability map (Figure 5) shows better siting areas as lighter grey shades.



SITING ISSUE 2
CULTURAL SUITABILITY

Figure 4

ISSUE MAP 2
CULTURAL SUITABILITY

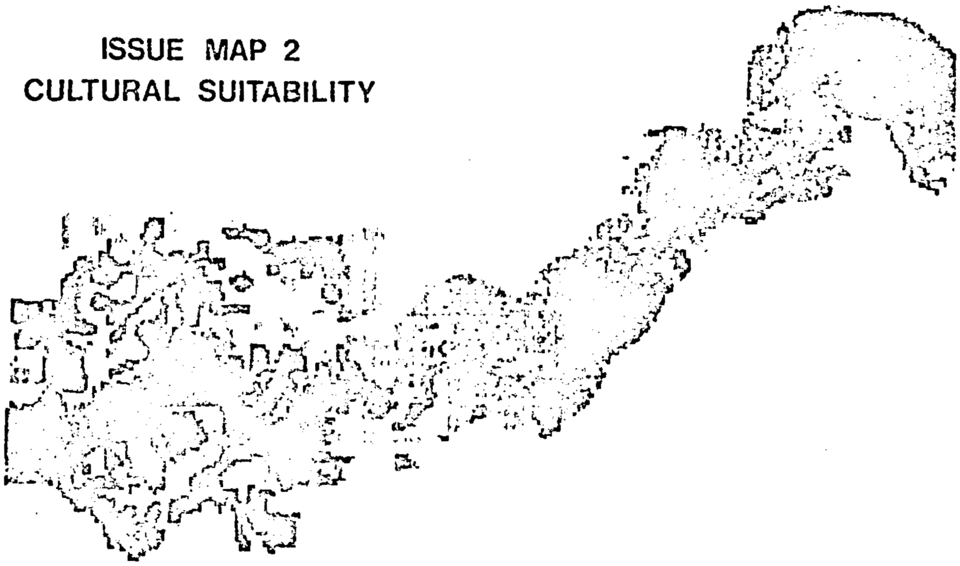


Figure 5

3.3. Capital and Operating Costs

The issue of plant cost centered on those capital and operating costs which could be expected to vary across the region of interest (Figure 6). The general form of the model used in this analysis is:

$$C_{(i,j)} = (a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + a_5 x_5)$$

where: $C_{(i,j)}$ = total site-variable plant cost in annualized dollars at location (grid cell) i,j

a_n = number of cost units of factor X_n at location i,j

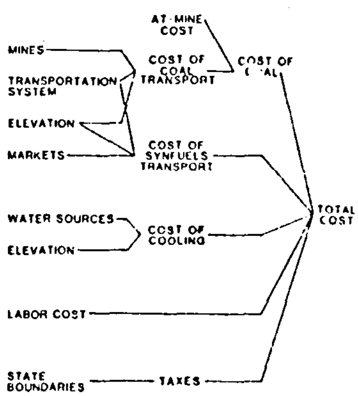
x_1 = cost of delivered coal at plant

x_2 = cost of synfuels transport to market

x_3 = capital, operating, and maintenance cost of obtaining cooling and processing water

x_4 = labor cost

x_5 = state taxes



SITING ISSUE 3

CAPITAL / OPERATING COST

Figure 6

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Although other minor site-variable costs could have been added to the model, their potential contributions to the cost issue were considered to be insignificant. For each possible site, or grid cell, within the study region, the cost of every component of the model was computed by GIMS on an annualized dollar per year basis. Component costs of coal and synfuels transport and plant cooling were broken into two further categories: capital cost and operating-maintenance cost.

After the five component cost surfaces were created and stored in the computer data base, they were summed to produce a single total cost map. A discussion of each cost component follows.

Cost of delivered coal. The cost of delivered coal is a function of the annual cost of the coal at its source, shipping charges along the existing transport system, and any construction and operating expenses required to connect the coal source and plant with the existing transport system. The regional transportation system consisting of highways, railroads, and navigable rivers (Figure 7) and coal source locations were entered into the data base.

Several steps were required to perform the coal transportation analysis. First, the cost of connecting the coal source to the nearest transportation facility was computed.

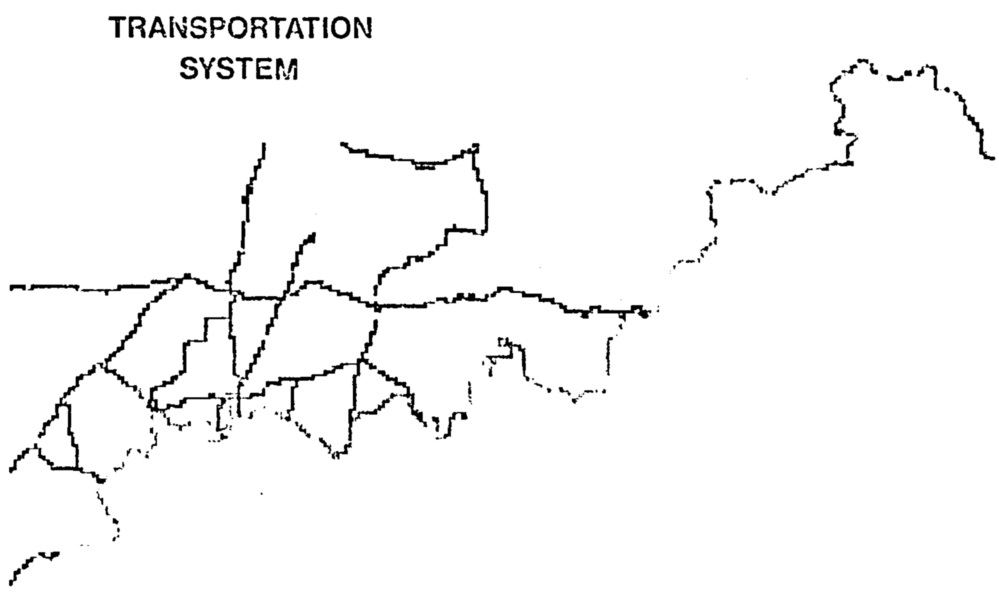

Figure 7

This connection was made either by rail spur or by conveyor, whichever was determined by GIMS to be more economical. Once the model brought the coal from its source to the closest highway, rail, and river, the costs were allowed to accumulate along these facilities, incrementing different unit costs along each transport mode. Transfer from one mode to another invoked an appropriate loading and unloading penalty.

After the minimum coal cost was derived for all potential sites along the main transportation system, it was necessary to compute costs to sites off the digitized routes. GIMS calculated the length of new spur construction from existing rail lines to all sites in the region. This length was determined in conjunction with a topographic data file (Figure 8) which depicted the elevation change from one cell to the next. In steep grades, additional spur length was incurred to reduce the grade to a maximum of 3 percent. The analysis showed higher rail spur construction costs in areas of varying terrain.

All of the above steps were performed for each coal source considered in the analysis. The resulting maps were compared to yield a single map representing the minimum cost of delivered coal, optimized by coal source and mode of transportation (Figure 9).

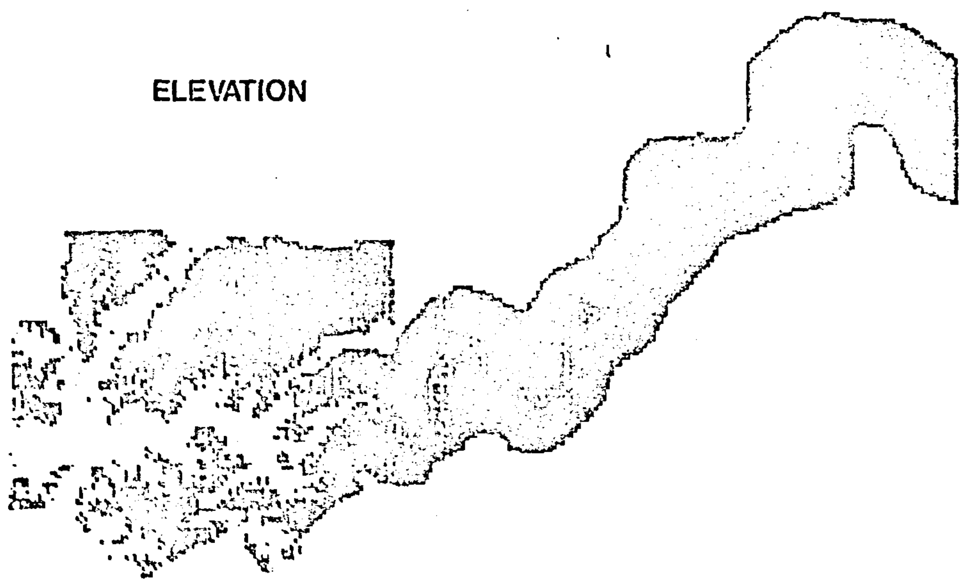

Figure 8

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COST OF COAL

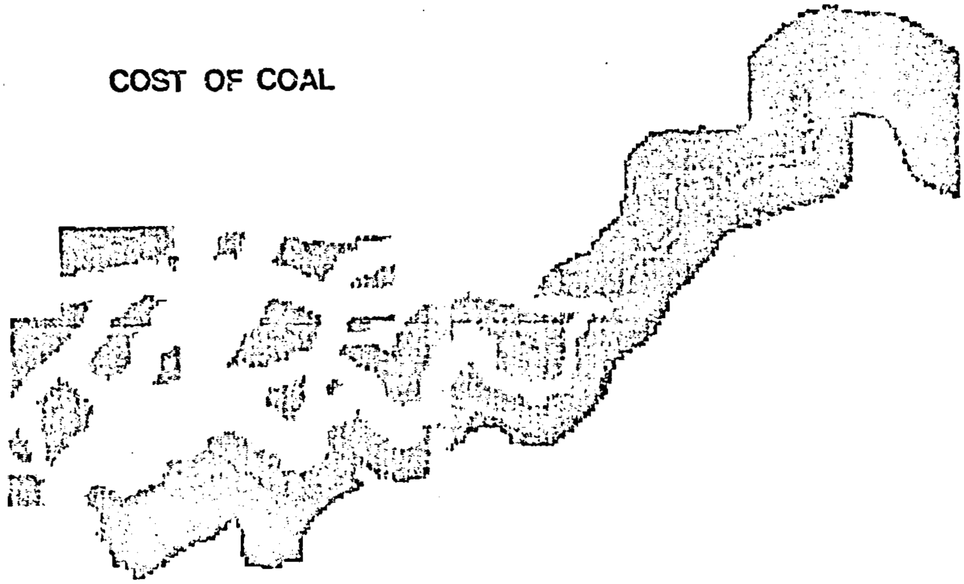

Figure 9

Cost of product transport. Costs for transporting synfuels produced at the plant to a mix of predesignated markets (Figure 10) were derived in a manner similar to the coal transportation model. The analysis assumed that a constant quantity of synfuels would be produced and transported each year by an optimized combination of rail, barge, and pipeline modes. It was also assumed that the price obtained from product sales would not vary with market. To accommodate uncertainties in the definition of the synfuels markets, alternate scenarios for product distribution were developed. The results of these scenarios were compared within the computer to achieve an optimized marketing strategy based on the distribution of synfuels to several regional markets.

Cost of plant cooling. The cost of supplying cooling and processing water to the synfuels plant is based on the distance from a suitable source of water and the elevation differentials between the source and the plant site. First, GIMS computed the capital costs of installing pipelines from digitized rivers and streams to all potential sites in the region. Added to this cost surface were the operating expenses of pumping water over uneven terrain to the sites.

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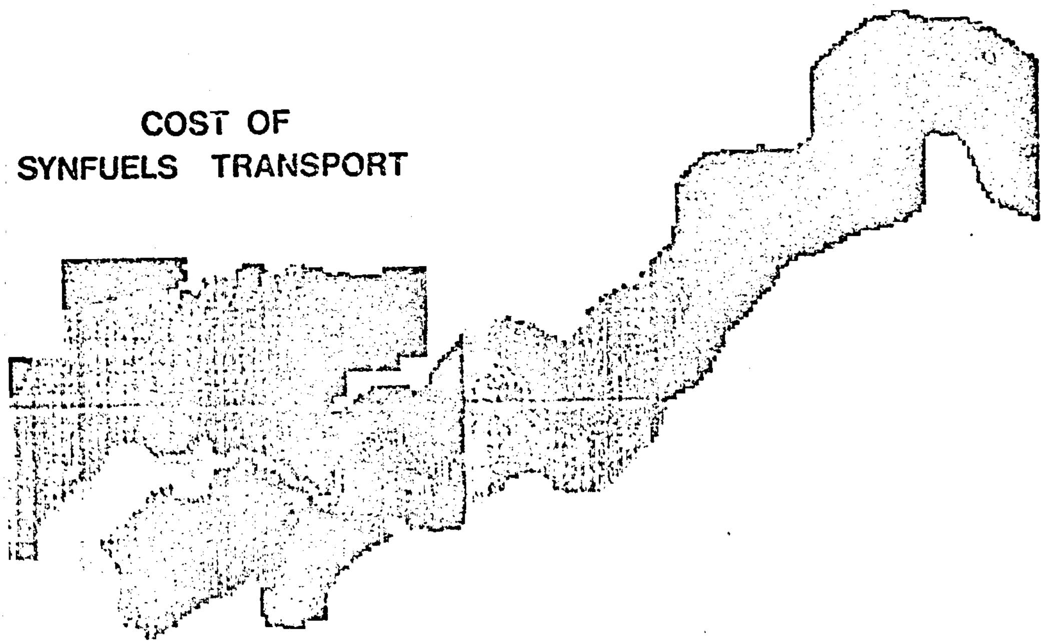


Figure 10

Labor and taxes. The cost of labor was calculated through the use of regional labor rates applied to the estimated number of man-hours required to construct and operate the plant. In addition, digitized state boundaries were used in order to add state income, property, and franchise taxes.

Composite cost. The composite cost issue for the region of interest (Figure 11) is a summation of the five component costs described above. Sites closest to the Ohio River and existing railroads generally fared best in the cost analysis.

3.4 Composite Site Suitability

The three siting issue maps (environmental suitability, cultural suitability, and capital/operating costs) contained different units used in measuring suitability. The first two issues were classified on a 1 to 5 ordinal rating scale, while plant cost was expressed in millions of dollars per year. To combine three maps which contained incompatible scales of measurement required the employment of an issue weighting scheme and a map overlay technique (Figure 12).

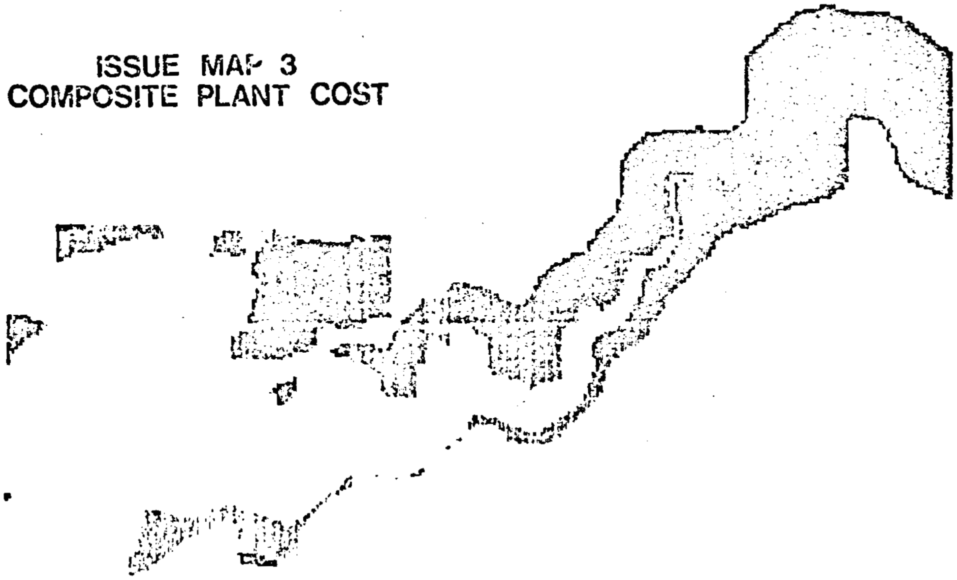
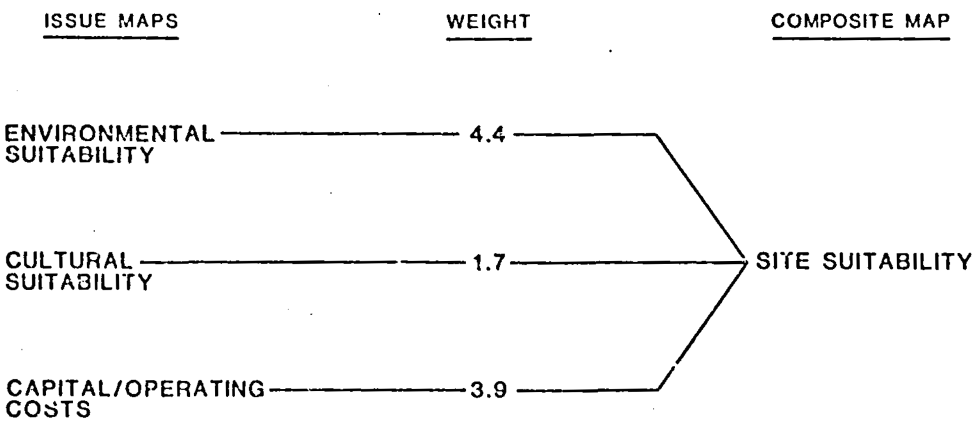


Figure 11



COMPOSITE SITE SUITABILITY

Figure 12

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The analysis strategy dictated that each issue of concern would be assigned a weight reflecting that issue's relative importance in the overall siting decision. This is often the least objective part of any siting study and demands special care, since application of such weights can significantly affect the final siting solution. The Delphi technique has proved to be a structured and rational approach to criteria value-setting [3]. A typical Delphi session brings together a group of individuals who possess either specific or general expertise in the type of siting problem under consideration. Through a detailed exploration of the siting objectives, the group seeks to achieve a general concensus regarding the relative importance of the siting issues.

A Delphi session conducted as part of the conversion plant siting study yielded the following weights:

Environmental suitability	4.4
Cultural suitability	1.7
Capital/operating costs	3.9

The overlay function of GIMS normalizes the individual scales of issue maps, applies weights and sums the weighted maps together. The result of the overlay (Figure 13) is a final site suitability surface from which promising siting areas may be selected and analyzed in further detail. Lighter shades indicate those areas most suitable for plant location.

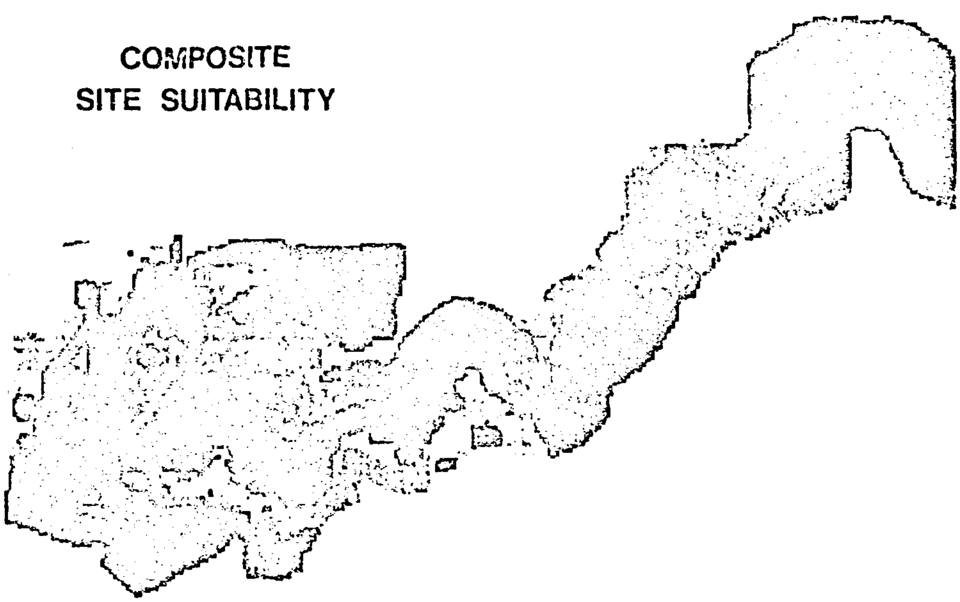

Figure 13

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4. SUMMARY AND CONCLUSIONS

Based on the issue maps and the final suitability surface created in this study, the client was able to make a rational and informed selection of promising siting areas for its proposed coal conversion plant. These siting areas are currently the object of detailed field investigations which will further narrow down the final siting decision.

This case study illustrates the value of geographic information management systems in finding acceptable sites for synfuels plants and other industrial facilities. The use of GIMS in this analysis provided several obvious advantages over traditional manual site selection methods. Among these advantages were:

1. The storage and efficient management of large amounts of data.

2. A verifiable and fully documented analysis strategy (especially important when responding to federal, state, and local environmental standards).

3. The ability to conduct a multi-objective analysis which accommodated several independent and often conflicting siting criteria.

4. Flexibility to change cost assumptions, market or coal source locations, and issue weights in response to changes in economic or regulatory conditions.

5. Quantitative and realistic cost estimates which not only assist in site selection, but give the client the capacity to evaluate financial requirements of a project and compare alternate modes of transport and technology.

6. The ability to optimize marketing strategies by changing the locations of assumed synfuels markets and varying the prices obtained for the product at each market.

In order for synfuels conversion plants to become economically feasible and therefore regain a prominent place in U.S. energy policy, sites will have to be chosen with extreme care. The enormous investments required from both government and private industry will demand the type of decision tools that computer-based geographic management systems can provide.

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Part 3

USES OF REMOTE SENSING FOR RECLAMATION AND SURFACE MINING

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MINING OPERATIONS AND REMOTE SENSING

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The primary goal of the Office of Surface Mining (OSM) is to "create a nationwide program to protect the environment and society from the adverse effects of surface coal mining operations, while ensuring an adequate supply of coal to meet the Nation's energy needs." In this regard, the OSM directs its efforts toward two major programs; the enforcement of environmental rules for active surface coal mining and reclamation operations, and the implementation of a major abandoned mine land reclamation program.

Major objectives of the OSM program include establishing minimum national standards for regulating the surface effects of coal mining, assisting the States in developing and implementing their regulatory programs, and promoting the reclamation of abandoned mine areas. Remote sensing and special studies play an important combined role in these responsibilities. Also, the ability to inventory, monitor, and quantify present mining activity and abandoned coal surface mine problems are being evaluated through the use of various remote sensing techniques and platforms.

The special studies or applied research program at OSM is divided into four categories: geotechnical compliance with the law and the rules, reclamation of affected lands, ecological investigations, and environmental monitoring. The objectives of the projects under this program are to: provide the research direction,identify the OSM needs, support the rules, and improve mining methods and techniques.

The environmental monitoring area includes the use of remote sensing and supplementary data to assist OSM in its mission. Throughout this effort, remote sensing data are being evaluated as OSM is involved with projects such as: (1) Low altitude aerial photo reconnaissance coverage to assist inspection and enforcement through the examination of mine related features for permit compliance with the interim rules in the Appalachian States, (2) Yearly color aerial photography for evaluation of alluvial valley floor assessment, mining impact, and mine plan review for over 200 Western U.S. mine sites, (3) Imagery evaluation and digital thermal data related to abandoned deep mine fires and waste bank fire problems in Pennsylvania and Wyoming, (4) Low-altitude photo interpretation manual of surface mining operations for State and Federal inspectors, and, (5) Development of mine monitoring capability utilizing high altitude aircraft and Landsat data on western mine sites. Also being studied are the naturally occurring incidents which endanger public health, safety, general welfare and property from the adverse effects of surface and previous underground coal mining practices. Results and conclusions from these studies have shown both the limitations and usefulness of aerial, thermal infrared, digital and Landsat data to produce needed information to assist OSM in its mission through applied research studies and analysis from various multistage platform imagery.

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REMOTE SENSING APPLICATIONS TO THE PENNSYLVANIA ABANDONED MINE RECLAMATION PROGRAM

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ABSTRACT

The recently completed Pennsylvania Abandoned Mine Land Inventory demonstrated the effective use of remote sensing techniques within the context of the Surface Mining Control and Reclamation Act of 1977. The inventory combined data from field work, a literature search, and photointerpretation to fulfill both State and Federal requirements. A primary project objective was to accurately identify and map all surface features and disturbances from abandoned surface and underground mining. Black-and-white aerial photographs were used to record pits, contour benches, highwalls, spoil material, graded and recontoured areas, impounded water, and serious erosion and slide prone areas. In addition, vegetation cover estimates and surrounding land uses were noted. The inventory data base provides Pennsylvania with a valuable resource management tool that should be systematically updated. The utilization of remotely sensed data from SPOT or Landsat-D satellites may prove valuable in the anticipated updating and monitoring of the Pennsylvania AML Inventory over the next several years.

INTRODUCTION

Coal has been mined in Pennsylvania since about 1760, with peak production of both anthracite and bituminous coal occurring during World War I. Although production has tapered since that time, Pennsylvania still ranks as the fourth largest individual state producer. One result of two centuries of mining activity is environmental degradation on nearly 200,000 acres of land. Historically, coal mines in Pennsylvania were not subject to strict environmental regulations. As in other states, it was common practice to simply abandon a mine complex when extraction was no longer profitable. In many instances, these abandoned mine lands (AML), have seriously degraded the surrounding environment or created health and safety hazards for nearby residents. These environmental and safety problems include, but are not restricted to open shafts and portals, surface and underground fires, subsidence, abandoned facilities, acid drainage, erosion and sedimentation, highwalls, and flooded pits.

The first comprehensive inventory of these problems and features in Pennsylvania is scheduled for completion in 1982. This project, possibly the largest to date in the United States, was authorized by the Surface Mine Control and Reclamation Act of 1977 (P.L. 95-87) [1] and designed for consistency with the Pennsylvania Reclamation Program [2] that has been ongoing since 1968. The objectives of this inventory are discussed within the context of both the federal and state program goals, with particular emphasis directed toward data collection methods relative to those goals. In addition, the potential utility of data from SPOT and Landsat-4 satellites in the anticipated data base revision procedures is considered.

INVENTORY OBJECTIVES

Title IV of P.L. 95-87 established a national program, administered by the Office of Surface Mining (OSM), to promote the reclamation of lands mined prior to August of 1977. Lands to be considered in the program are those that were inadequately reclaimed and continue to "substantially degrade the quality of the environment, prevent or damage the beneficial use of land or water resources, or endanger the health or safety of the public." A systematic, standardized national inventory of AML problems was the obvious first step for OSM in carrying out this program.

The OSM inventory and ensuing program are clearly oriented to the identification and restoration of specifically defined AML health and safety problems. This orientation is consistent with the first two Reclamation Fund priorities as specified in Title IV. These include problems that 1) are extremely dangerous, and 2) adversely affect public health, safety, and welfare. It was recognized by OSM that funds were not available to identify every surface disturbance from past mining. Consequently, problems of lesser importance were not actively sought by the OSM National Inventory. Oak Ridge National Laboratory (ORNL) was contracted by OSM to develop a standardized methodology for the national inventory. From this effort, a labor intensive field survey of AML problems that adversely affect the health, safety, and welfare of local populations was deemed to be the most appropriate mode of data collection. Remote sensing applications to the national inventory were evaluated and dismissed, since feature identification was not an objective [3].

However, the identification and documentation of all AML features is consistent with the objectives of the Pennsylvania Reclamation Program. One reason for this is the keen public awareness in Pennsylvania of all types of AML problems. This awareness is responsible for several State laws, all predating P.L. 95-87, which authorize State agencies to fund four specific categories of reclamation/abatement projects. These included: abatement of mine dranage; extinguishment of burning refuse banks within public ownership; extinguishment/control of deep mine fires; and control of surface subsidence.

The difference in State and Federal objectives is significant when the objectives of the inventory are translated into methodology and scope. OSM felt that the inventory should target AML problems which were specifically responsible for adverse effects to the health, safety, and general welfare of local populations. Since limited federal monies were available, only the most serious problems were to be documented and prioritized for reclamation funding consideration. The State likewise felt that hazardous problems should be given high reclamation priority, but also felt that non-hazardous AML-related environmental problems should also be identified. The State determined that the most cost-effective mode of data collection to meet that objective was an intensive aerial survey. That determination is consistent with the findings of Mroczynski and Weismiller [4] that aerial photo analysis is a cost-effective tool in the operation of a state reclamation program.

A compromise methodology was eventually agreed upon that incorporated key elements of both programs. In January 1981, Earth Satellite Corporation (EarthSat) along with SMC-Martin as principal subcontractor, was contracted by the Pennsylvania Department of Environmental Resources (DER) to develop an AML inventory of Pennsylvania for incorporation into the National Program. The specific objectives of the inventory were to: 1) survey the overall environmental effects of past mining operations; and 2) generate an information base from which future accomplishments can be measured for OSM, and also for use in programs initiated by DER. EarthSat performed three separate data collection tasks to meet the objectives, including field, aerial, and literature surveys. In combination, these data sets effectively merged the ongoing DER program into the more recent and narrowly defined OSM program.

METHODOLOGY AND RESULTS

The three data collection tasks were accomplished systematically in a two-part program. Part A was a documentation of existing technical information compiled under the auspices of DER, while Part B consisted primarily of concurrent field and aerial surveys with limited input from literature reviews. Together, the three data sources satisfied both human and environmental concerns of the Federal and State governments, respectively.

Throughout all phases of the project, AML data was recorded on Problem Area Data Forms (PADAFO's). These two-part forms were designed by EarthSat to specifically address the data requirments of both OSM and DER. Each form includes a "keyword" list of health, safety, and welfare problems developed by OSM to meet the national program objectives, in addition to a DER "Problem Code" list of all AML features. The keyword list is comprised of 16 problems that denote an element of public impact, while the 13 component Problem Code list allows for the identification and physical assessment of all AML features, regardless of public impact at the time of the inventory.

Part A of the Pennsylvania Abandoned Mine Lands Inventory involved an extensive literature search. Data compiled by the Commonwealth's Division of Mine Reclamation provided a wealth of information in the form of files and reports. Investigators were able to identify potential health, safety, and welfare problems from a collection of approximately 1,500 public complaint reports, known as inquiry files, as well as environmental data from a series of engineering studies entitled Scarlift Reports.

The inquiry file system was a major data source in the initial effort to locate hazardous AML problems. Each file contained the complaint report and a site assessment, with reclamation or abatement alternatives recommended where appropriate, from a DER District Mine Inspector. Information extracted from these files in Part A was recorded for use during the field survey in Part B. Scarlift Reports are a collection of sixty-seven watershed and sub-watershed studies covering nearly all coal producing areas within the State. The reports, completed between 1969 and 1978 by various consulting engineers, were the primary sources of acid mine discharge information recorded into the data base during Part A.

Part B was conducted in two phases in consideration of Commonwealth and Federal requirements. Concurrent twelve-month field and photo interpretation efforts identified health, safety, and environment degradation problems. The field effort was conducted according to the standarized OSM methodology. Working in three, five-person teams, field personnel were able to locate, identify, and review health, safety, and general welfare problems throughout Pennsylvania. Problems not identified in the literature search turned up in conversations with state, county, and local officials knowledgeable of mine land problems. These officials included DER mine inspectors, SCS personnel, county health and tax officials, and township planners, supervisors, and mayors. Firemen, rescue workers, and "old timers" also proved to be valuable sources. Site investigators explored the nature of reported problems and an appropriate cause-and-effect impact analysis was recorded on the PADAFO if a hazardous situation was present. These problems were delineated on 1:24,000 scale topographic field maps and corresponded to descriptions on the data form. In many instances, the site investigators determined that no written impact assessment was called for; the nature of the problem did not appear to pose a threat to the health, safety, and general welfare of the surrounding population. In these cases, the physical characteristics of the site were recorded on the map to be used as collateral data in the airphoto interpretation effort. In addition to impact assessments, field investigators also conducted ground truth visits to an estimated 80% of the mine sites in Pennsylvania. Features which could be identified on the ground were delineated on the paper topographic field map. Investigators recorded percent and type of vegetative cover, height, length and condition of highwall, soil development, and mine water discharge parameters. The delineations of these AML features were later incorporated into PADAFOS and maps during the airphoto interpretation segment of Part B.

The aerial survey effort was the final phase of Part B data collection. This application of fundamental airphoto interpretation techniques to identify and delineate AML surface features resulted in several important benefits to both the data base and the Commonwealth. These included: 1) identification of nearly all of the surface expressions of past mining activities that were abandoned prior to August 1977; 2) accurate map delineation of these features plus those problems identified during the field survey; and 3) significant inventory cost savings.

It was estimated by EarthSat and other sources that the cost of assembling the current data base while using the field survey as the sole approach, would have increased the inventory contract value by as much as eight fold. That estimate was based on a comparison of the cost per PADAFO ratio of several Appalachian region inventories that utilized no aerial survey with the cost per PADAFO ratio of the Pennsylvania Inventory.

Airphoto coverage of most of Pennsylvania's coal regions was available through the U.S. Geological Survey. This photography, obtained in 1977 and 1978, was optimal since the project was initiated to identify lands abandoned prior to P.L. 95-87 (August 1977). Two areas which lacked suitable photo coverage were flown as part of the program. The black-and-white 1:80,000 scale photography proved adequate to delineate accurately most of the surface mine features defined by the State problem codes. The necessary quality control was assured by field observations. Acreage, highwall length and height, and volumetric estimates were computed during this phase and recorded in tabular form on the PADAFO. Additional descriptive information regarding highwall condition, vegetation cover, and relation to other surface features was also recorded.

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As written descriptions were recorded on PADAFO's, corresponding site feature delineations were made on stable-base map overlays. To ensure the accuracy of the completed draft product, a sandwich of quad-centered photo enlargement, stable-base topographic map, and overlay material was made. The overlay was attached to the quad and the two were locally registered to the photo base. Features identified using the corresponding stereo aerial photographs were thus easily and accurately drafted onto the base map overlay via the intermediary photo enlargement.

The statewide results of the inventory have been tabulated by Problem Code with appropriate acreage or number figures, and are presented on Table 1. The magnitude of the inventory is indicated by the total numbers of PADAFO's, keyword problems, features, and disturbed acreage that were recorded and mapped. More detailed subdivisions of the preliminary data are not presented here because the draft data base is under review by both OSM and DER at the time of publication.

TABLE 1. Preliminary Data Results

PROBLEM CODE	ACREAGE	NUMBER
1. Abandoned Strip mine (Dry)	71906	
2. Abandoned Strip Mine (Flooded)	5932	
3. Open Shafts or Entries		3181
4. Abandoned Refuse Piles (Burning)	556	
5. Abandoned Refuse Piles (Not Burning)	98028	
6. Underground Mine Fires	1791	
7. Underground Mine (Eliminated from Inventory)	-	-
8. Subsidence Prone Areas (Known)	5633	
9. Subsidence Prone Areas (Suspected)	13295	
10. Abandoned Coal Processing Settling Basins	1035	
11. Abandoned Structures		162
12. Erosion Prone Areas (Due to AML)	1371	
13. Slide Areas (Due to AML)	45	
14. Reported AMD Discharges		4593
Total Disturbed Acreage	199792	
Total Number of Health, Safety, and Welfare Keyword Problems	2236	
Total Number of AML Features	24977	
Total Number of PADAFOS	5274	

Cartographic, photographic, and data processing technicians made final deliverable products from original draft overlays and data forms. Working with the draft map overlay, cartographers produced inked and labeled camera-ready products to be reproduced as seven clearfilm overlay copies to each of 452 quad sheets. In addition, one inventory overlay composited with its screened topobase will be produced for each quad. Problem Area Data Forms were transcribed to computer tape by data processing personnel. From this file, AML data can be accessed in a variety of formats which, when used in conjunction with the maps, provides an operational data base for AML reclamation decisions.

REMOTE SENSING APPLICATIONS FOR DATA BASE UPDATING

Under a third part of the contract, EarthSat will develop a total data management system by which the State can update its data base. Initially the State will be provided with the data obtained and recorded on computer tape in Part B. The tapes will be delivered in a form compatible with the existing computer system currently being used by the State. An updating procedure will be developed to provide necessary instructions and guidance to the State regarding the input of additional information. At the completion of the project, DER will be self-sufficient operators of the data management system.

The specific mix of revision procedures is likely to be a modified extension of those incorporated in the inventory methodology. A key to the system will be flexibility, since it is anticipated that several types of revisions will be necessary. These will include, but may not be restricted to: 1) newly discovered or reported AML hazards and environmental problems requiring additions to the data base; 2) funded reclamation/abatement projects that once completed shall necessitate deletion of the original problems from the data; 3) the elimination of AML problems through current mining activity that will require the deletion of data; and 4) literature source data, such as acid water discharge information, that was unverified in Parts A or B that may require revision or deletion from the data base.

Each of these types of revisions will require the collection of both accurate and timely data, as well as an appropriate method of transferring this information to the data base. New high resolution satellite systems such as SPOT or Landsat-4 may prove to be valuable tools in the revision methodology. The use of satellite aquired data may facilitate selected and narrowly defined aspects of data collection and transfer, to include: 1) identification of current mining and reclamation activities; 2) accurate data transfer to the existing map base; and 3) reclamation project monitoring.

Several investigations have determined that Landsat-1, 2, and 3 were of marginal value for detailed surface mine inventory and reclamation monitoring purposes. Russell (1977) concluded that MSS data was of little use in the implementation and enforcement of the Pennsylvania Surface Mining Conservation and Reclamation Act because of poor resolution, data acquisition time delays, and costs [5]. Mamula, Jr. (1978), concluded that MSS imagery was valuable for the identification of surface mine features only when closely monitored and verified by ground truth and aerial photography [6]. The overall conclusion from these investigations is that the limitations of the Landsat-1, 2, and 3 imagery were exceeded in attempts to perform the detailed surface mine feature monitoring that is relavent to current state and federal regulations.

However, imagery from the new and advanced SPOT or Landsat-4 satellite systems may be well suited for specifically defined needs of the AML inventory updating procedures. The data requirements, such as the need for an accurate means of map data transfer, are not likely to exceed the upgraded capabilities of either the SPOT High Resolution Visible (HRV) instrument or the Landsat-4 Thematic Mapper. The 10 and 30 metre spatial resolution of the HRV SPOT and the Thematic Mapper, coupled with the availability of this data on an on-demand or as needed basis make these systems appear to be desirable components of the AML inventory updating [7,8]. Both systems are scheduled for full operational status by early 1985 at which time the imagery will become available commercially.

CONCLUSION

The Pennsylvania AML Inventory, authorized by Title IV of P.L. 95-87, is scheduled for completion in 1982. Differences in State and Federal reclamation program objectives resulted in a compromise inventory methodology that included literature, field, and aerial surveys. The incorporation of fundamental aerial survey techniques in the methodology proved to be an efficient and cost-effective approach to help satisfy the total AML data needs of Pennsylvania. Benefits to the State resulting from the application of remote sensing techniques include:

- A more accurate and uniform map base
- A nearly complete AML data base
- Significant inventory cost savings

Future applications of high resolution satellite imagery from SPOT or Landsat-4, if used appropriately, are expected to aid the State in maintaining the data base in a similar cost effective manner.

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A TEMPORAL APPROACH TO MONITOR SURFACE MINE RECLAMATION PROGRESS VIA LANDSAT

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1. ABSTRACT

The demand for increased energy production in this country has prompted a greater dependence upon surface mining for coal to meet the growing needs. Surface or strip mining is a common method of mineral extraction particularly popular in Central and Southeastern Ohio. If appropriate measures are not taken to condition the land for revegetation, the effects of strip mining can be extremely devastating to the environment. An effective monitoring system is essential to observe the progress of the reclamation process.

Using LANDSAT satellite imagery, the reclamation process can be studied on a temporal and continuing basis. Not only can the progress of reclamation be readily monitored, but also a breakdown in the mining reclamation process can be detected.

In viewing reclamation, it is important to monitor the mined site well past initial revegetation stages. With present mining laws and bonding procedures, fast revegetational growth is encouraged, often leading to poor soil fertilizing and inappropriate stabilizing species. As a result, the initial reclamation may exhibit good qualities for one or two years but then may experience vegetational deterioration after the state has relinquished the mining company from it's responsibility. It is this small-scale breakdown in the reclamation process that was detected using an unsupervised classification technique with eight-year temporal LANDSAT imagery coverage.

2. INTRODUCTION

With the ever rising demand for energy in the United States, the increased exploitation of retrievable coal resources has become a major objective. Energy consumption continues to grow each year by large measures as more demands are placed upon energy resources.

Coal represents a valuable energy reserve for which current technological advances have boosted its availability. Present mining techniques emphasize the most efficient and cost effective methods of mineral extraction which, in the Eastern United States, is that of surface mining. Approximately one million hectares of land have been disturbed by strip mining for coal, with pronounced devastation to the environment unless concerned efforts are taken to restore the land.

Reclamation of surface mined lands entails several facets such as grading, revegetation, sedimentation and erosion control, and abatement of acid mine drainage. Although each is an important aspect of the reclamation process as a whole, the stage involving revegetation was the constituent examined in this study for determining reclamation effectiveness.

Since monitoring reclamation of surface mined lands can be both an expensive and time consuming task, LANDSAT data as a monitoring tool can play an important role in determining reclamation efficiency. The use of LANDSAT for surface mine monitoring has been demonstrated by numerous researchers (Anderson et al., 1977; Bloemer et al., 1981; Wier et al., 1973).

The literature provides sufficient evidence that LANDSAT can be an effective tool in monitoring mining and the reclamation process. One of the major benefits of LANDSAT data is the availability of temporal coverage. To take advantage of this aspect, this study addresses itself to the feasibility of assessing those areas which have been previously reclaimed and may have exhibited some decline in the revegetation sequence. This will lead to an evaluation of those areas which are in need of further reclamation efforts after the bonds have been returned to the appropriate companies - releasing them from further responsibilities.

3. THE STUDY AREA

The reclamation efforts undertaken in Belmont County, Ohio were chosen for this study. The region including East-central Ohio has been a significant producer of bituminous coal since the 1800's. Belmont County has been a major contributor to this production since strip mining was initiated in the county around 1918. Several layers of coal are present throughout the county, some of which are extracted by deep mining. Most of the coal however, is surface mined using the contour method. In contour mining, a bench is cut to expose the coal seam that crops out along a valley. Removal of the overburden into and around the hill continues until the earth removal makes further mining economically unfeasible. The spoils, which cover the seam, are deposited 180 degrees from the bench, often filling in the adjacent valley. This method of earth removal produces rows of spoil material, contributing to the furrowed characteristics following reclamation.

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The unreclaimed area is characterized by a high wall, which marks the last bench cut into the hillside, adjacent spoil banks, and often small lakes and sedimentation ponds. This is the setting where reclamation must begin.

Before the reclamation process can begin, the mined land must first be conditioned in preparation for vegetation. Top soil is replaced and the terrain graded. Reseeding of the area is accomplished predominantly by using hydroseeders which are popular in the hilly Appalachian region for seeding slopes not easily accessible by other equipment. Hydroseeders distribute seed, fertilizer, and mulch which are mixed with water to form a slurry that can be applied in a single pass over the area to be reclaimed. Seed composition varies slightly with region and soil characteristics. Seeding mixtures recommended for erosion control contain one annual or short-lived perrenial species that quickly establishes initial ground cover, at least one perrenial legume, and one long-lived perrenial grass for permanent vegetation cover. The presence of perrenial legumes is especially important because legumes are nitrogen fixing species, and their establishment in the permanent cover vegetation eliminates the need for refertilization at later intervals.

4. DISCUSSION

4.1 Procedures

LANDSAT computer compatible tapes (CCTs) containing late summer scenes of 1973, 1976, 1979, and 1981 were obtained from NASA Goddard Space Flight Center and EROS Data Center. For each scene, the study area was subset to include Piedmont Lake and the surrounding strip mining activities adjacent to Interstate 70 in Belmont County, Ohio. These data subsets were then transferred to 8 inch floppy discs by the Earth Resources Data Analysis Systems (ERDAS) technicians in Atlanta, Georgia, for use in the ERDAS 400 image processing microcomputer system at the Remote Sensing Center of Ohio University.

4.2 Rectification

Each image was geometrically rectified to a Universal Transverse Mercator (UTM) coordinate system so points of a specific geographic area could be compared for all four images. To perform this correction, five ground control points, whose exact position could be located, were chosen and their UTM coordinates calculated from USGS 7.5 minute topographic maps. Using these five control points, the ERDAS 400 computed a linear transformation from the map coordinates to the pixel coordinates which were identified by a cursor. Each control point was entered one at a time, first with map coordinates (x,y), and then with the pixel coordinates corresponding to the map point. A final error tolerance of 2.00 was specified by the researcher but pixel correspondence registered to within an error of 1.05 or less for all four rectified images. Rectification proceeded using nearest neighbor calculations, producing a rectified output image with a 100 meter x 100 meter cell size.

4.3 Classification

An unsupervised classification was applied to the four geometrically rectified LANDSAT images involving an interactive clustering algorithm (CLUSTR: ERDAS, 1982). The data subsets were clustered with parameters set for 15 clusters for the 1973, 1976, and 1979 data and 20 clusters for the 1981 image; two standard deviations about each mean, and a minimum mean distance of separation of five. The category means and percentage indexes were saved and transferred to an IMGRID (geographic information system) file, and the resulting image was classified on the basis of ground truth information. Classification was performed on each individual cluster by displaying it on the monitor in a contrasting color before final assignment to a cover class.

Classification of categories for the 1973 and 1979 data was facilitated by high-altitude color infrared 1:130,000 scale aerial photographs. These were enlarged and optically registered to USGS 7.5 minute topographic quadrangles of the study area to a scale of 1:24,000 by the General Electric Photographic Laboratory in Beltsville, Maryland. Black and white 1:80,000 stereopairs were available for verification in classifying the 1976 image. Ground truth information for the 1981 scene was provided through extensive field observation. The 1981 data coincides within two days of the actual field observation for which numerous oblique photos detailing various cover categories were taken and their positions recorded on 1:24,000 USGS topographic maps.

The classification of categories can be defined as follows. Reclaimed land is any area which was surface mined and has since been revegetated. Active mining and barren lands combine two spectrally similar categories with barren areas depicting mined areas which have not been reclaimed. For the purpose of this study, all vegetated areas encompassing forest, cropland, and pasture were grouped into a common vegetation category. Water was categorized as having little or no sedimentation, and shallow and/or high sedimentation. A mixed category denoted those areas which exhibited spectral confusion. These were predominantly areas in a combination of swampland-forest-water, and those areas influenced by the effects of shadows and slopes.

Following classification of the four images, a comparative analysis of reclamation was initiated. The 1973 data was used as a baseline to identify those areas initially mined and under partial reclamation. The 1976 and 1979 classified images provided information on the extent of reclamation which had taken place since the

1973 date. Having the first three images form the data base exhibiting the reclaimed or revegetated areas, the 1981 data was then examined to detect any areas which were previously classified as reclaimed and has since experienced a breakdown in the revegetation process. It is this reclamation deterioration with which this study concerns itself.

5. RESULTS

The classified images for 1973, 1976, 1979, and 1981 displayed major classification differences which can be explained by the temporal nature of the data. While reclaimed areas were easily separated in the 1973 and 1976 data, it was found that much of the reclaimed land by 1981 had to be classified in the vegetation category as it had become spectrally quite similar to the surrounding areas of vegetation which had been undisturbed by the mining process. This phenomenon was not seen as a problem in the classification sequence and in fact should be expected when dealing with temporal data spanning 8 years. In this time, early reclamation had undergone at least 7 growing seasons and had attained vigor and density closely resembling the undisturbed vegetation. Thus, the land in vegetation for 1981 was 58 percent while 1979 displayed 43 percent vegetation (Table 1).

An additional observation for increased percentages of vegetation was that the area as a whole exhibited a return to a more homogeneous pattern with each subsequent data set. Mixed pixels make up 8 percent and 11 percent of the 1973 and 1976 data respectively while only 2 percent of the 1979 classification fell in the mixed category. The 1981 data, which contained 20 clusters to increase separability of barren areas (due to increased homogeneity), exhibited no unclassifiable pixels - a further indication that the reclamation process over the study area as a whole, was positive in nature and the reclaimed sites were showing vegetational stability over time.

Table 1

LAND COVER TYPE	1973 DATA	1976 DATA	1979 DATA	1981 DATA
WATER	1%	1%	1%	1%
WATER (SEDIMENTATION)	1%	0%	2%	1%
VEGETATION	52%	38%	43%	58%
RECLAIMED	28%	40%	47%	38%
BARREN	10%	10%	5%	2%
MIXED PIXELS	8%	11%	2%	0%

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The 1981 classification did reveal some areas which had experienced a breakdown of revegetation (classified as barren in an area previously in the reclaimed category). Although these areas were small and scattered in nature, this does arguably justify the use of LANDSAT data to monitor mining reclamation on a broad temporal basis. The effectiveness of locating such areas in need of further reclamation efforts will be greatly enhanced when the 30 meter resolution expected from LANDSAT-D becomes available.

6. SUMMARY OF CONCLUSIONS

1) Temporal changes in classification of reclaimed surface mined areas become more evident as the revegetation assumes characteristics which closely resemble vegetation undisturbed by the mining process.

2) In a broad temporal sequence, reclaimed areas, in time, develop more homogeneity with the surrounding vegetation resulting in greater spectral uniformity and consequently less spectral confusion.

3) LANDSAT can detect those areas in need of further revegetation at the current 70 meter resolution.

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based upon environmental and social criteria. Clearly the areas to be first reclaimed will be those lands and water that both threaten the public's well-being most severely and present the greatest likelihood for successful reclamation.

I and another colleague, John Simpson, were retained as consultants to the Division of Reclamation. We assisted in the development of the AML program and carried out a prototypical study of a highly impacted drainage basin. The intent was to establish a model guiding the preparation of data collection and analysis for the remaining drainage basins impacted by previous mining activities.

This paper will summarize Ohio's Abandoned Mine Land Process, the Wheeling Creek Study Process and the conclusion and future trends for proceeding with the reclamation process.

2. EVALUATION PROCESS

The Abandoned Mine Lands Evaluation Procedure is structured to achieve a set of goals. They were defined to generate the information required by the Division of Reclamation in identifying AML reclamation projects. They will be selected by criteria set forth by OSM and the overall characteristics of Ohio Surface Mining Program. The goals are as follows:

a. To identify lands and waters adversely affected by past mining practices that constitute either an emergency of extreme danger threat to the public's health, safety and general welfare;
b. To establish the means whereby reclamation of emergency or extreme danger situations from past mining may be initiated as rapidly as possible;
c. To establish the environmental conditions of all remaining abandoned mine lands;
d. To establish the degree to which these conditions threaten the public health, safety and general welfare;
e. To establish the opportunities for public and environmental benefit resulting from reclamation of these areas and the likelihood of successful reclamation;
f. To establish the means whereby certain of these areas will be reclaimed based upon an Annual Work Plan approved and funded by the Office of Surface Mining; and
g. To establish a procedure enabling the review of any administrative decision made by the Division of Reclamation in the implementation of this program that directly effects the individual(s) requesting the review.

To achieve these goals, the Division proposed an Abandoned Mined Land Evaluation Program that exceeds the technical program requirements established by the Office of Surface Mining and fulfills the intent of the Surface Mining Control and Reclamation Act. The program is based upon a hierarchial screening process that initially evaluates those AML sites posing the most

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OHIO'S ABANDONED MINE LANDS RECLAMATION PROGRAM: A STUDY OF DATA COLLECTION AND EVALUATION TECHNIQUES

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ABSTRACT

The intent of the study was to formulate the planning process for a statewide reclamation plan of Ohio abandoned minelands. The plan responded to the Federal Surface Mining Control and Reclamation Act of 1977. The study included the development of a screening and ranking methodology, the establishment of a statewide review of major watersheds affected by mining, the development of an immediate action process, and a prototypical study of a priority watershed demonstrating the data collection, analysis, display and evaluation to be used for the remaining state watersheds.

Historical methods for satisfying map information analysis and evaluation, as well as current methodologies being used were discussed. In addition, various computer mapping and analysis programs were examined for their usability in evaluating the priority reclamation sites. Hand methods were chosen over automated procedures; intuitive evaluation was the primary reason.

1. BACKGROUND

On August 3, 1977 President Carter signed into law the Surface Mining Control and Reclamation Act, PL 95-87. The act establishes minimum national standards governing the surface mining of coal. Title IV of the act establishes procedures for reclamation of such lands and waters, termed abandoned mine lands (AML). To find the reclamation of these areas, the act taxes all surface and deep mine coal production. The Federal Government returns 50% of the tax monies generated within the state for AML reclamation.

Ohio contains approximately 450,000 acres of surface mines, 600,000 acres of underground mines and 4,400 acres of gob piles, as well as 2,500 plus miles of streams and 2,700 acres of reservoirs degraded as a result of past mining practices that are eligible for reclamation funds. Given projected funding schedules, reclamation of these areas will require many decades. These lands vary greatly in their threat to the public's welfare. Priorities for use of the funds, set forth in Section CFR 874, of the Federal AML Regulations center first on the reclamation of areas that threatened the public health, safety and welfare. Remaining monies may be used ...

serious threats to the public and environmental well-being from those sites posing less serious threats. The sites will then be evaluated in descending order based upon the severity of their conditions. Therefore, the intent of the Evaluation Program is to evaluate the present information to the Division staff on the most critical AML sites first thus, enabling the initiation of necessary reclamation projects as quickly as possible. Areas of lesser concern will be evaluated and initiated when projects of higher concern are completed.

The AML Evaluation Program is comprised of five (5) components: (1) Immediate Action Process, (2) Initial Drainage Basin Screening, (3) Drainage Basin Reports, (4) Administrative Review Procedures, and (5) Annual Work Plan. Each is briefly outlined in this paper (see Figure 1).

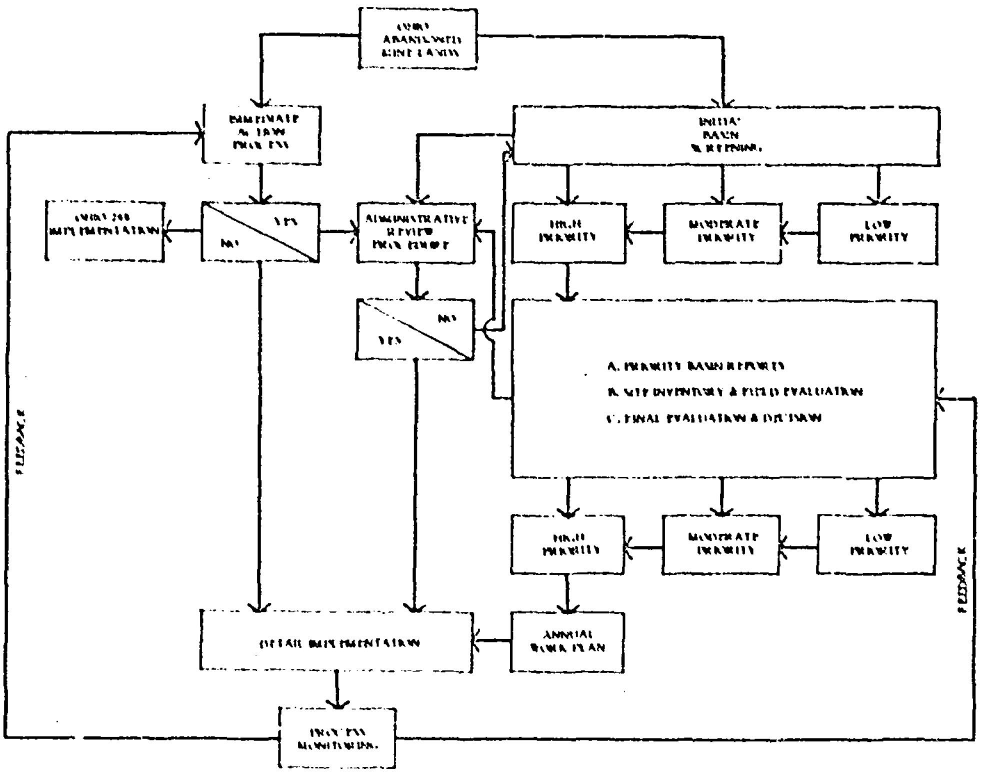

Figure 1. Ohio Abandoned Mine Land Evaluation Program

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2.1 Immediate Action Process

Lands and waters adversely affected by past mining practices that pose emergency or extreme hazard threats to the public's health, safety and welfare constitute the Program's greatest concern. These categories defined in the Federal AML Regulations in Section CFR 872.5(C) and (E), correspond to the regulations highest reclamation priorities established in Section CFR 874.13(A). The Immediate Action Process seeks to distinguish these areas from others posing less critical threats to the public and environmental well-being and to initiate the reclamation required to alleviate the threats as quickly as possible.

2.2 Initial Drainage Basin Screening

The majority of Ohio's abandoned mine lands are not emergency or extreme danger areas. Reclamation of areas of secondary concern will require decades. Therefore, the State must be able to differentiate within general areas (drainage basins), lands and waters of greater reclamation need and potential benefit from those of lesser concern. A hierarchial evalatuion process that distinguishes general areas (drainage basins) of greater concern from those of lesser concern prior to the detailed evaluation of each individual site is required due to the overwhelming amount of work necessary to initially evaluate all sites in detail.

In 1973, the Ohio Board of Unreclaimed Strip Mined Lands conducted a survey of the State's abandoned mine lands to identify drainage basins in most need of reclamation. Land Reborn, (Ohio Department of Natural Resources, 1974), has become a model for large scale evaluation of abandoned mine lands used by other states and the Federal Office of Surface Mining. The Division of Reclamation's proposed AML Evaluation Program will use Land Reborn as its first step in differentiating areas of greater reclamation concern from those of lesser concern.

The report divided the State's coal region into 79 drainage basins averaging approximately 175 square miles. Each drainage basin was evaluated and numeric scores assigned for its reclamation priority (see Table 1). Resultant scores indicated relative need for reclamation in each drainage basin and were used to sort the drainage basins into general reclamation priority categories.

Land Reborn provided an excellent initial screening of the State's abandoned mine lands. It quickly differentiates those areas of most obvious and serious threat to the public and environmental well-being from areas of lesser concern. The 25 high priority drainage basins classified by Land Reborn and 3 additional drainage basins added by the Division of Reclamation in this Plan comprise the 28 drainage basins of high priority to be first evaluated in the Detailed Basin Reports.

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Table 1. Criteria for Assignment of Rating Values
(Land Reborn)

	High(3)	Medium(2)	Low(1)	Negligible/ None (0)
Strip Mine Density & Total Area	3%	.85-3%	.85%	No abandoned mine land
Mine Drainage Pollution	High iron, sulfate and acid levels (Acidity 7,100ppm Fe 25ppm, SO_4 71,00ppm)	Moderate iron, sulfate and acid levels (acidity 100 ppm or Fe 10-25 ppm, SO_4 600 to 1,000 ppm)	No net acidity slightly elevated iron and sulfate levels (Fe 3-10ppm, SO_4 500-600ppm)	Net alkalinity and sulfate levels (Fe 3ppm, SO_4 500ppm)
Cost Effectiveness	$500/lb. of acid abated	$500-$1,000/lb	$1,000/lb	Without abandoned mine land
Development Demand	Based on presence of urban area, public access to affected basin, recreational resources, and airports.			
Economic Need	19% families below poverty level	12-19%	11%	Without abandoned mine land
Public Ownership	Abandoned mine land sites 67% publicly owned	33-67%	33%	Without abandoned mine land
Public Visibility	Abandoned mine land sites-near major highways/ large towns	Abandoned mine land sites-near small towns/ roads	Abandoned mine land sites-not readily visible	Without abandoned mine land
Visual Quality	Based on distribution and combination of land form and landscape pattern.			

2.3 Priority Basin Reports

Detailed Drainage Basin Reports utilizing the 79 Land Reborn basins will be prepared to provide information to assess environmental, social, and economic impacts of past mining on the basins. Necessary decisions about the feasibility of reclamation projects and priority action on abandoned mine land problems found in the basins can thus be incorporated into the Annual Work Plan. These reports will allow a uniform assessment of abandoned mine problems throughout the coal bearing region of the state.

The best available information gathered is being supplemented with new data where necessary and aggregated to sub-drainage basin units of approximately 10 square miles for interpretation, analysis and correlation to the Federal reclamation criteria. All information will be recorded at a compatible map scale of 1:24,000 for maximum flexibility.

The intent of the data base is to enable a reasonable understanding of the relationship between the effects of past mining practices and the present environmental and socio-economic conditions of the area. Only data suggesting a significant relationship between past mining practices and present conditions will be recorded.

In addition, sites identified through the National AML Inventory will be mapped and described. The National Inventory relies upon local input and extensive investigation to identify potential problem areas. It provides an excellent means of verifying the spatial data base and generating a comprehensive record of present conditions.

All information will be mapped, tabulated and displayed in report format. The basin report presents detailed description of the basin's present environmental and socio-economic conditions and correlates those conditions to the effects of past mining practices. Summary recommendations compare the basin's conditions to the federal evaluation criteria and present final opportunities and constraints affecting potential reclamation. The reports will be used by the Division staff as one method in identifying future reclamation projects for inclusion in Annual Work Plans

2.4 Annual Work Plan

To obtain funding for reclamation other than emergency and extreme danger projects, the Division must develop and submit to OSM an Annual Work Plan as specified in Section CFR 886.14 of the Federal AML Regulations. The Plan outlines all proposed reclamation and result to be conducted under Federal funding for the following year.

The Work Plan is formulated by the Mined Land Reclamation Section (MLR) within the Division of Reclamation. Candidate projects are identified using information generated by the AML evalaution program and local input. Final project selection is based upon criteria set forth by the Federal AML Regulations.

2.5 Administrative Review Procedure

Central to Ohio's Abandoned Mine Land Evaluation Program is a review procedure whereby any group or individual may request the reconsideration of an administrative decision that directly affects the individual(s) in the implementation of the program. The review procedure is intended to promote objectivity, fairness and comprehensiveness in the evaluation of abandoned mine lands and the selection of reclamation projects.

3. WHEELING CREEK DRAINAGE BASIN

The Wheeling Creek basin in Belmont County represents one of the most severely affected basins in this group and contains a wide variety of

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environmental and socio-economic conditions and therefore, it was selected as the basin to develp the prototype Detailed Basin Report which will be used as a model for the other 78 basins.

3.1 Setting

The Wheeling Creek drainage basin is located on the eastern border of Ohio, opposite Wheeling, West Virginia (Figure 2). The study area is centrally located along the eastern margin of Ohio's portion of the Appalachian Coal Field. The coal basin is mainly in Belmont County with small portions in Harrison and Jefferson Coutnies along its northern borders (Figure 3).

Interstate Highway 70 is located on the southern border. It is the major east-west highway for midwestern cities to Washington and other eastern shore cities. U.S. 40 is a historic road. It follows along Zane's Trace path. Later this path was widened to create the National Road.

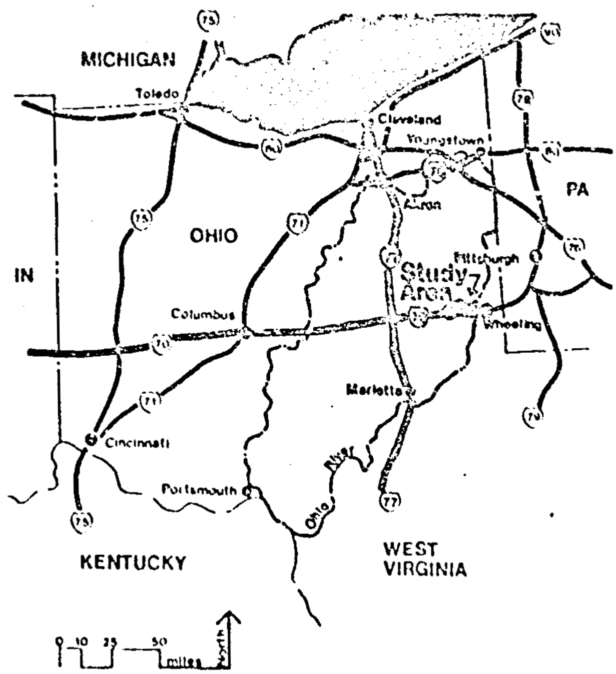

Figure 2. The Study Area and the Ohio Coal Region

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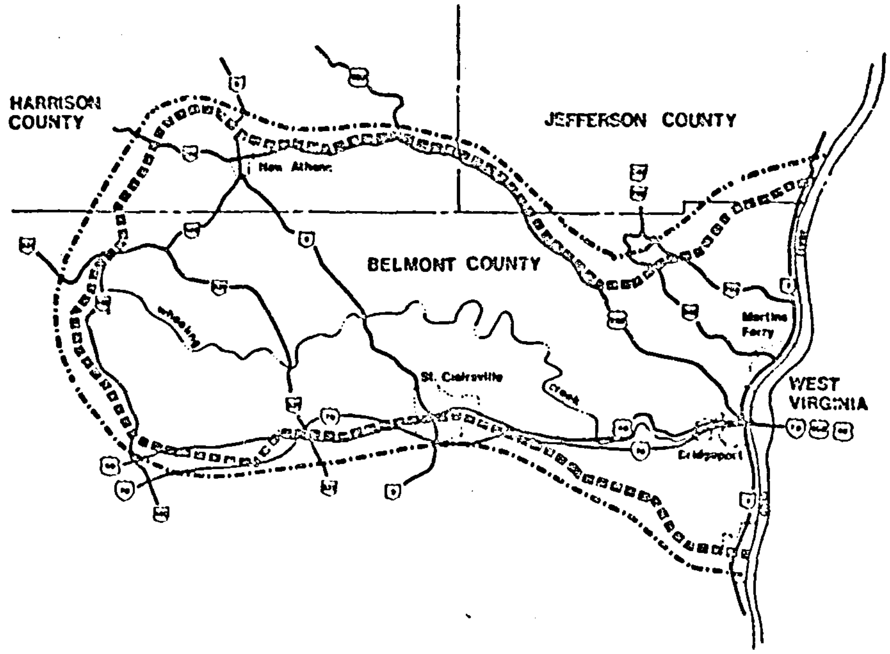

Figure 3. Wheeling Creek Drainage Basin

The eastern boundary of the drainage basin is the Ohio River. The major stream in the watershed is Wheeling Creek. Wheeling Creek drains 107.7 square miles. The Wheeling Creek Watershed encompasses 137 square miles. The drainage basin is somewhat rectilinear in shape, narrowing near the western portion of the eastern 1/3 and is about twice as long as wide.

3.2 Study Process

The process diagrammed in Figure 4 included research, data collection and mapping of environmental factors of the Study Area. The Study Area boundary was defined as the entire drainage basin of Wheeling Creek plus a half mile buffer that was extended in some points to include an entire town boundary.

The data requirement were based on one major objective. The survey was to provide a reasonable data for portraying the physical, biological and socio-economic factors that need to be considered for "political decisions." The cost of reclaiming Ohio's abandoned mine land is expected to cost over $4 billion. Obviously the present law does not supply enough funds. Also OSM criteria for selecting a site is flexible. These points reinforce a political decision. Our role was to supply enough information that was cost effective and documented in an understandable format. The data collected

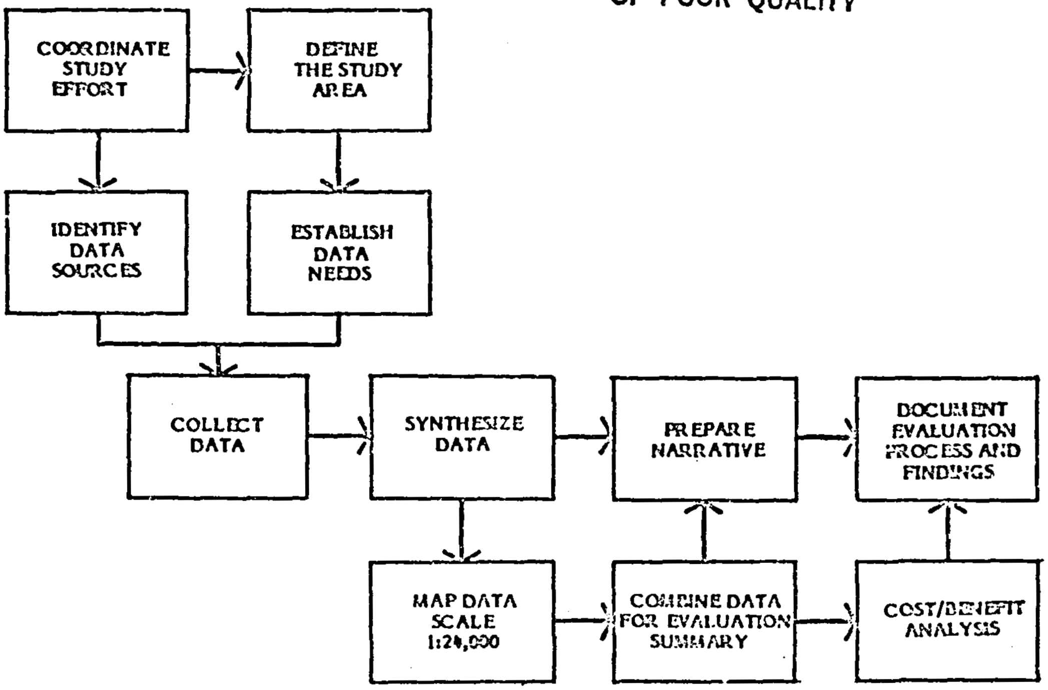

Figure 4. Wheeling Creek Study Process

was based on the best available information. OSM did not want to fund studies to produce new data unless it is essential to the process. Also, our initial effort was to resist recording everything that was available on Wheeling Creek area. Finding available information was easy. The hard task was to limit the data recorded.

3.3 Drainage Basin Screening

The Wheeling Creek Basin Report includes detailed examination of the following conditions:

- Land Environment:
    - Abandoned Surface Mines
    - Abandoned Underground Mines
    - Existing Land Cover
    - Transportation and Utilities
    - Historic and Cultural Features
    - Physical Features
    - Coal Resources
    - Problem Areas
- Hydrologic Environment:
    - Surface Hydrology

Subsurface Hydrology
Socio-Economic Considerations:
Population and Demograpy
Employment
Income and Welfare
County Revenues and Expenditures
Housing and Building Activity
Land Values

Determining the method of recording the information was our most important task. There was much discussion about using the computer. Several consulting firms had approached the Divison with "canned" programs. Our decision as to use only hand-drawn maps. The reason was based on the fact that actual site selection must be based upon visual observation. Maps are necessary only to see pattern relationships. This precluded the major advantges of the computer. That is the ability to weight data and to combine the information in complex combinations. It was more important to see the information associated with the cultural features and topography of a base map. The U.S.G.S. maps at 1:24,000 were selected for the base maps.

Another reason for not using the computer was that the existing graphic outputs were not legible for most public and political presentations.

Costs and new advances in computer mapping since the start of the project have now compelled us to reevaluate our techniques for future basin reports. These points are discussed further in the next section.

Some flexibility was necessary in the recording of the information. So the data was drawn with ink on mylar and pin registered. The spearation of data was influenced by the need to have the maps produced in color in the final report. The data was combined in different ways by Division personnel and ourselves. Four environmental summaries were used in the analysis. Up to five mylar separates were combined for one map. On a light table, information is understandable, but blackline prints become fuzzy and color was necessary for any group presentation. The labor costs of coloring the maps, again, have made up question the process for the other 27 reports.

The data maps were reduced to 25% of their original size for inclusion in the report at 1:96,000.

4. SUMMARY OF FINDING

The prototype study has touched on two important aspects of land use planning: the type of information necessary for "political decisions" by public administrators and ability to record data that can be used in an efficient and cost effective manner. The study attempted to give some dimension to the dynamics of specific study techniques towards the more effecive transfer of information and ideas among professionals and public officials and to the public. Following are the principle observations and suggestions emerging from this study:

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A. The estimated cost of reclaiming Ohio abandoned mine lands is over $4 billion. Consequently, the actual decision of reclamation will be political. This means the information collection must be clear, understandable and flexible. This resulted in less information being collected. The major tendency was to collect more. In fact, the vast majority of monies will be decided from "on-site" inspection and not planning assumptions of collected information.

B. The information collected serves as a record of the accumulation and analysis of information describing the basic environmental and socio-economic conditions, the product of this evaluation is the understanding of the information necessary to identify project sites. There is the analysis of the interrelationships of the data and means of recording it, which is the body of the study. Some key points to this statement are:

1) The information was recorded at 1:24,000 which is the most understandable scale for Division personnel, administrators and the public. (See Figure 5.A.) The scale 1:250,000, requested by O.S.M., was too coarse to be useful as a decision tool.
2) All information was drawn with ink on mylar and registered by pins to a base sheet. This allowed for reasonable flexibility in combining different data sets. Blackline prints could be run off different combinations. The maximum number of sheets that could be run at once are 5 sheets. Anything more and the information is blurred. To understand this number of combined overlays, the maps had to be colored. (See Figures 5.B-F.)
3) The limit of 5 sheets was not a significant restraint to our work but the need to apply color was an expensive procedure not anticipated in the early stages of the study. Other means may be used in the future. "Color-key" overlays can be combined up to 40 sheets and still have reasonable clarity of all information (EDAW, 1976). (See Figures 6.A&B.) The computer can combine even more, but unlike the mylar or color key methods, cannot show all the patterns of each element at once. The resultant combination must be shown separately to allow the viewer to dissect what made up the actual composite. (See Figure 6.C.)

C. The cost for collection and drafting of the information for the study was reasonable but to do this for 27 more reports will be quite costly. Especially when cost for report printing is considered, there are several consideration:

1) The maps produced in the first report could have been produced for 70% less if the color art work had been computer scanned for 4 color separates.
2) With the advent of reasonably priced micro-computers, good quality color data maps are possible, thereby significantly reducing the cost of hand coloring maps. Unfortunately there is the trade-off of losing cultural features and topo that are on hand-drawn maps.

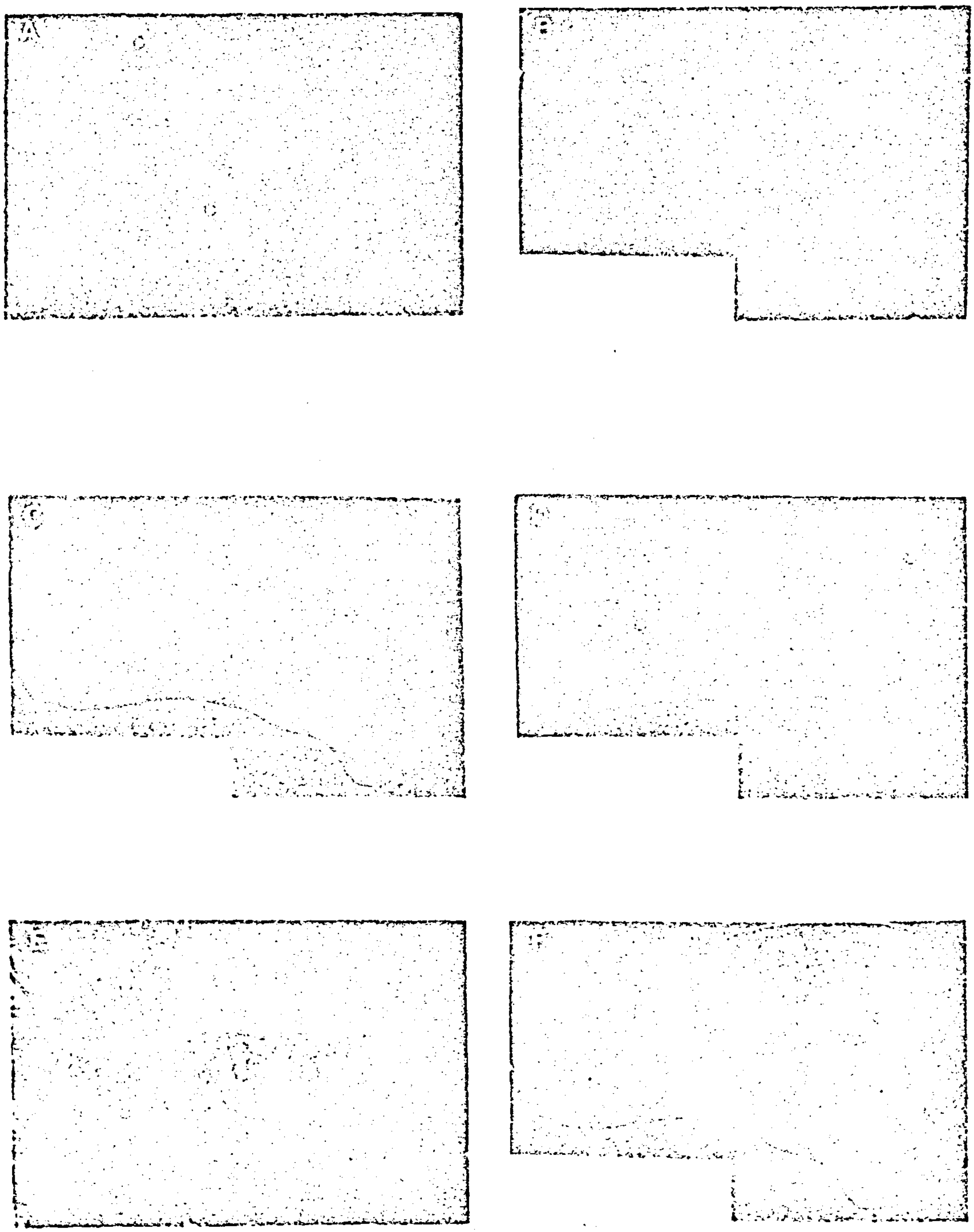

Figure 5. Some Typical Hand Drawn Data Maps and Composite Evaluation Map for the Wheeling Creek Basin Study

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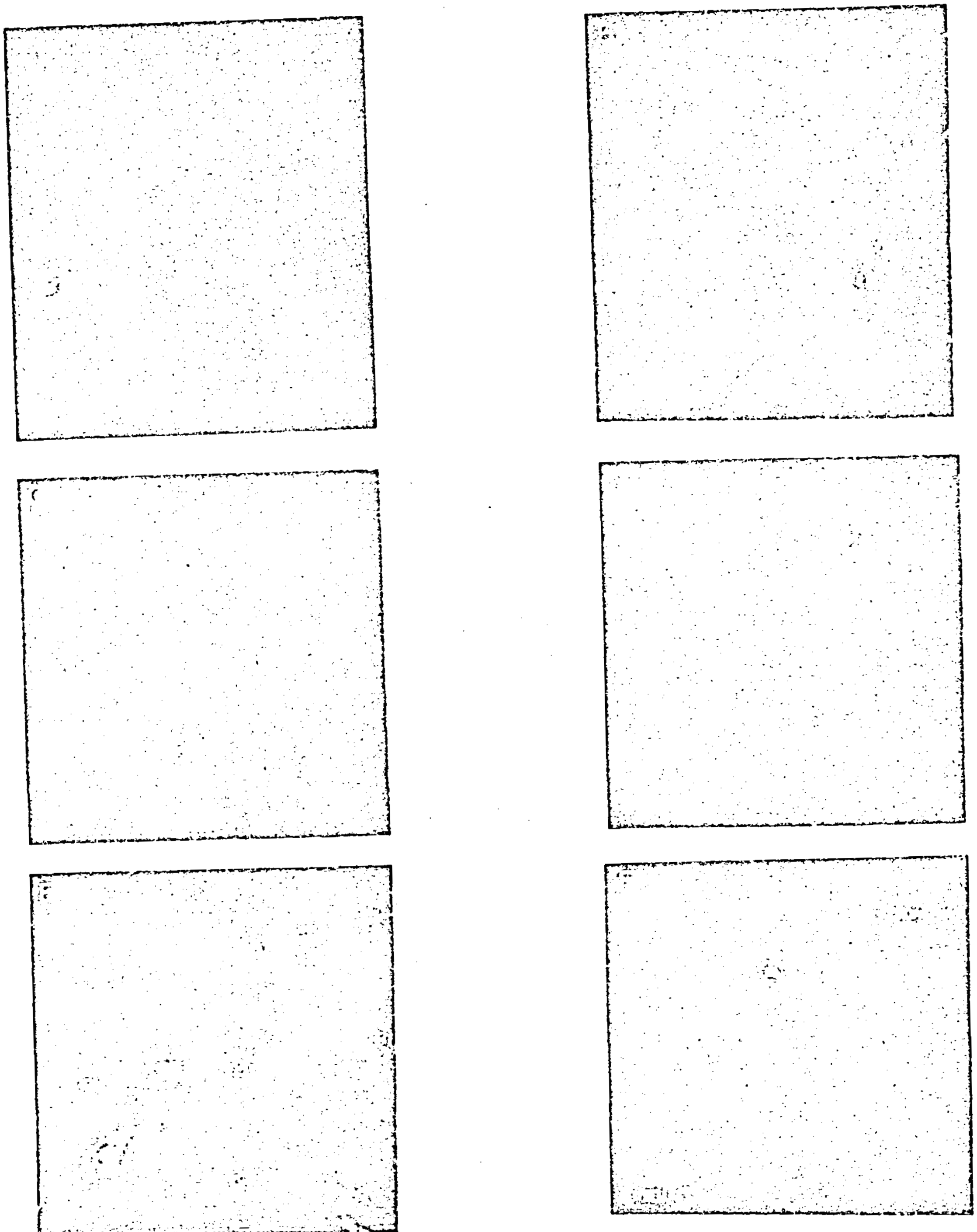

Figure [illegible]. [illegible] Corridor Analysis and Computer Display Graphics

3) There now exist hard copy devices that produce quality color copies of computer maps. (See Figure 6.D.)
4) Color is necessary for interpretation and understanding of data by public officials and the public.

D. There is a significant need for using remote sensing techniques for acquiring data for the remaining 27 reports. The existing visual reconnaissance of abandoned mine locations was only moderately accurate. The National AML Inventory found many mines classified as abandoned in the Wheeling Creek Study Area to be actually still active, thereby eliminating them from consideration under the law.

Land cover data interpreted from 1:80,000 air photos was very costly and time consuming. The reliability of the data is questionable. Field checking found several inaccuracies. The usefulness of the information for the Environmental Summaries was limited. Urban settlements were really the only major classification used. Lower altitude air photos would be better but expensive to fly.

The probability of using LANDSAT to acquire data on eligible abandoned mines and land cover (Spisz, 1979) still exists. Low cost micro-computers with image enhancement capabilities can significantly reduce the cost and enhance the accuracy and speed of classifying the data.

E. Important characteristics of hand-drawn maps versus computer-drawn maps are as follows:

1) Reasons for using hand-drawn maps:
   - o clarity of information on U.S.G.S. base maps
   - o ease of recording information by hand
   - o the perceived reliance on visual, on-site inspection for the final decision
   - o lack of need for major quantitative modeling
2) Reasons for possibly switching to computer-drawn maps:
   - o the cost of storing the information
   - o limited overlay capabilities of mylar
   - o need for color for undestanding combined information.

With the advent of large federal cutbacks, the abandoned mine lands program has changed emphasis from planning and cata collection to an immediate action program. There are enough projects to establish and annual work program for several years. When the program shifts to the next project level, the basin reports will be completed. At that time, the advances in computer data handling and graphic display should be able to merge the advantages of hand graphics and computer graphics. Figures 6.E and 6.F are computer graphics examples generated by the Harris Corporation and ERDAS, Inc. These vertical and oblique, three-dimensional views are examples of the next generation of computer graphics. When they are commonly used, planners will be able to have cost effective and easily understood information.

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Part 4

REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS FOR RESOURCE MANAGEMENT: AN INTERNATIONAL PERSPECTIVE

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REMOTE SENSING--AN INTERNATIONAL PERSPECTIVE

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The first decade of satellites for environmental monitoring has been dominated by the Government of the United States. Satellites have been launched to observe land, weather, water--many different aspects of our environment. Although receiving stations to read and process the data from these satellites are located in many different parts of the world, the majority of satellites have been developed by the United States Government.

However, now the picture is changing. As the United States contemplates its future role in the launching and maintenance of satellites, other countries and organizations are coming forward with their own plans to enter the field.

The following descriptions of those who are launching environmental satellites in the next 5-10 years will give the reader an insight into the purpose for the sateliite.

Descriptions of the satellites and sensors are in the appended tables.

The importance of these satellites to the user of such data can be appreciated when one realizes that the United States Government is not planning the continuation of the Landsat program beyond the anticipated date of 1988. These other sources of data will ensure a continuity of information to the resource manager.

AEROSPACE - AEROS-A AND B

The American Science and Technology Corporation, Bethesda, Maryland, USA, is developing the Advanced Earth Resources Observations System (AEROS). A sister corporation, AEROS Data Corporation, is implementing a complementary data acquisition system, resource management information system, and renewable resources management program. Taken together, the AEROSpace and AEROSdata systems form the first integrated earth observations information management system. The Combined Environmental Data Information System (CEDIS) is designed for comprehensive natural resources management applications, providing resource managers with physical, climatic, and biological information in maps and tables. These are updated frequently as inputs to resource system status models and operational management models (see Figure 1).

The AEROS integrated system also produced information for allocating resources, especially land, soil, and water resources, to production sectors in accordance with priorities established by resource managers and planners. Mineral exploration information is produced, in addition, such that satellite data is fully integrated with field data and other existing information.

The AEROS system is a private sector program, privately funded and operated on a commercial basis. As such, it must operate to provide an adequate return on investment. The integration of the space components with the information processing and resource management programs provides investors with balanced and multiple profit centers and clients with a comprehensive service.

EUROPEAN SPACE AGENCY (ESA) - ERS-1

In order to consolidate the complete range of space activities which had formerly been scattered throughout several organizations, the following countries joined in 1975 to create the European Space Agency: Austria, Belgium, Denmark, France, Germany, Ireland, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. The Agency goals are:

(1) To provide for and promote, exclusively for peaceful purposes, cooperation between European states in the fields of space research, technology, and applications.

(2) To elaborate and implement a long-term European space policy and a European space program.

ESA has been very active in communications and weather satellites, and is planning to launch its first ocean-oriented environmental satellite in 1987. ERS data used alone, or more commonly used in conjunction with complementary data from buoys, radiosondes, research vessels, other near-surface platforms and other satellites in prearranged global or regional experiments, will enable significant advances to be made in physical oceanography, glaciology, and climatology.

This is of importance in view of the increasing development of coastal and offshore activities and the adoption by countries of the 200 nautical mile economic zone. In addition, monitoring of sea-ice and icebergs will be of importance for industrial activities performed at high latitudes.

FRANCE - SPOT

The SPOT system, conceived and designed by the French Centre National d'Etudes Spatiales (CNES) is being built by French industry working in association with European partners (Belgium and Sweden); it consists essentially of an earth observation satellite and of earth stations for data reception.

The first SPOT satellite will observe in three spectral bands (in the visible and near infrared portions of the spectum) with a ground resolution of the order of 20 meters, and in a broader spectral band (panchromatic black and white) with a ground resolution of the order of 10 meters.

One of the key features of the SPOT instrument package is the provision for off-nadir viewing (i.e., the instrument can "look" to one side or the other of the satellite ground track). Among the possibilities introduced by this feature is that of increased revisit coverage at intervals ranging from one to several days, which should be particularly useful for monitoring localized phenomena evolving on a relatively short timescale. Another is the recording, during successive satellite passes, of stereoscopic pairs of images of a given area.

The following are among the main applications for the images returned by the first SPOT mission:

- Land use studies.
- Assessment of renewable resources (agriculture, forestry).
- Aid to exploration of mineral and oil resources.
- Cartographic work at medium scales such as 1/100,000, development of new types of maps, and frequent updating of maps at scales about 1/50,000.

JAPAN - MOS-1

As Japan is surrounded by seas, marine resources and the state of the seas are of great concern. Also, Japan's dense population and highly advanced state of industrialization make an acute demand for the effective management of land and its resources. Earth observation satellites offer a very useful means for collecting such information systematically.

Japan's first earth observation satellite, MOS-1, is an experimental satellite to collect information on earth surface (color and temperature of sea surface, land use, etc.) and to establish the fundamental technologies which are common to both marine and land observation satellites.

The conceptional design and the preliminary design of MOS-1 were completed in 1978 and 1979, respectively. The satellite is now under the basic design phase.

Relating with the design of the satellite, the system design of the ground facilities are being conducted, and the critical design and construction of the ground facilities in Japan were initiated in 1981.

CANADA - RADARSAT

In response to a Canadian initiative, the U.S. National Aeronautics and Space Administration (NASA) and the Canadian Division of Energy, Mines and Resources (DEMR) agreed on November 26, 1980, to conduct a bilateral study of the mission requirements for a future satellite which would have as its primary sensor a synthetic aperture radar. The agreement was signed by Anthony J. Calio for NASA and John D. Keyes for DEMR. At that time, Dr. Calio was Associate Administrator for Space and Terrestrial Applications at NASA and Dr. Keyes, Assistant Deputy Minister for DEMR. The American effort was given the name FIREX (Free-flying Imaging Radar Experiment), and the Canadian program, RADARSAT.

Apart from the bilateral sharing and discussion of future plans, the major activity undertaken in response to this agreement has been to determine the scientific and, to some extent, operational requirements for the proposed satellite. To do this, each country empanelled a science working group in each of four areas--ice, oceans, renewable resources, and non-renewable resources.

During the study process, some facts have become clearer about the status of SAR technology and its uses. It now appears that the best current understanding of SAR usefulness is in the ice area. Here, a SAR of sufficient swath width offers the unique possibility of enabling studies of the dynamics of the ice pack. SAR also can be used to guide ships and others operating in polar waters by revealing those areas with leads or thin ice. The land resource teams have determined that SAR data will be of considerable use in mapping, geology, and crop studies. Currently, the details of how the observations will be used are not as well specified as they are for ice observations, but there is a considerable desire in this area for multiple look angles, frequencies, and polarizations on a SAR instrument. These capabilities would represent a significant advance in technology over those SARs flown to date. Understanding of how to use SAR data in the oceans area is the least mature at present. The range of oceanographic problems which may be addressed is quite broad and the future promise of the technique is felt to be considerable.

Future plans for the eventual deployment of a SAR satellite are still being developed and remain uncertain.

INDIA

India built its first experimental earth observation satellite (SEO-1) which was placed in a circular orbit at a height of 525 km by a Soviet launcher on 7 June 1979. The satellite is equipped with a visible-light and near-infrared television camera with a 1 km IFOV, and also with a microwave radiometer. The television camera and the radiometer are transmitting meteorological and oceanographic data.

A second Indian remote sensing satellite (IRS-1) is to be launched in 1985. Its instruments for obtaining images will operate on a number of spectral bands and will have variable swath widths and resolutions. An Indian-built experimental satellite was launched in July 1980 using an indigenously built launcher.

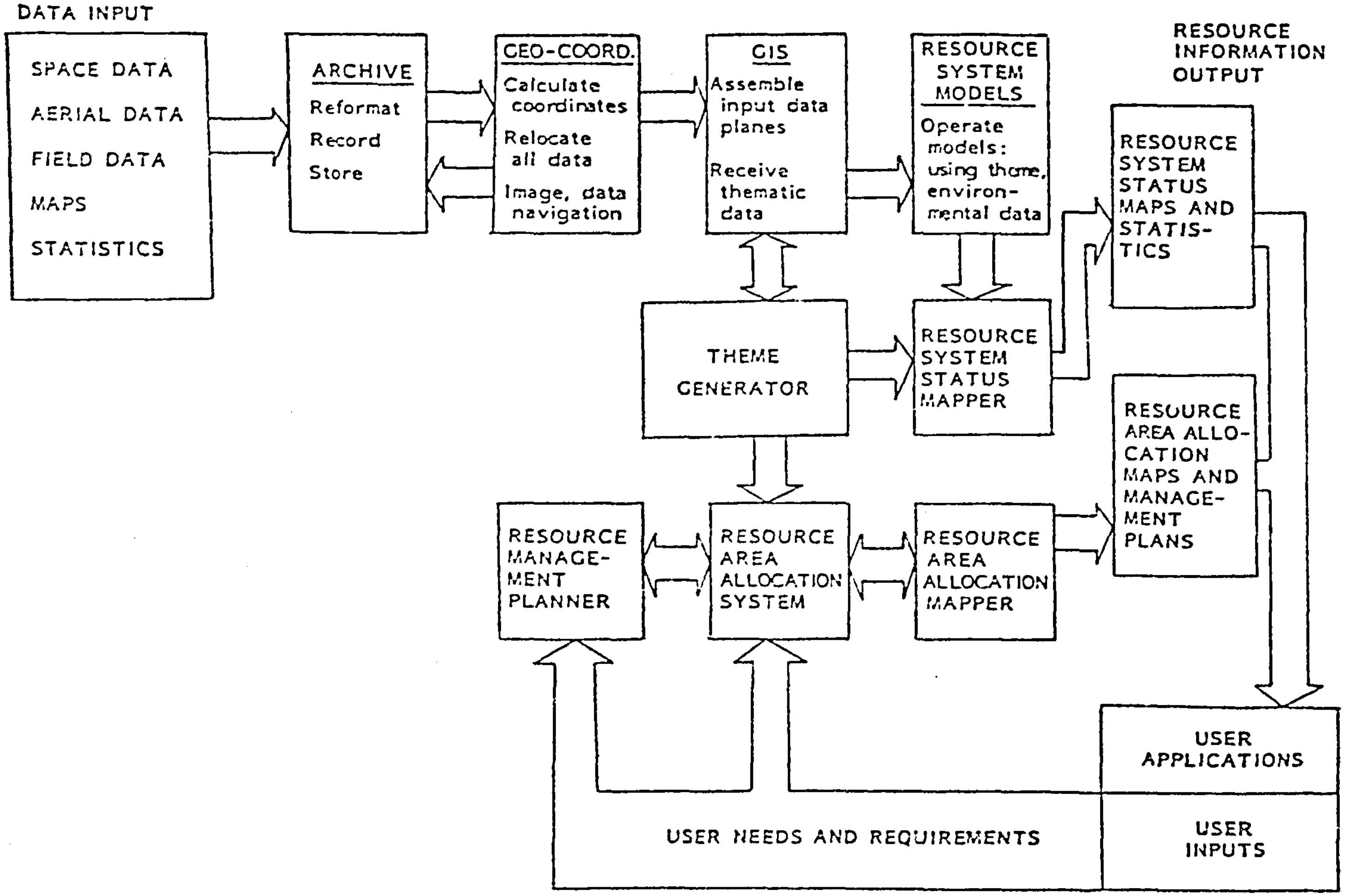

Figure 1. AEROS Data Corporation - Combined Environmental Data Information System (CEDIS)

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	AEROSPACE	ESA	FRANCE	JAPAN
SATELLITE NAME	AEROS-A, B	ERS-1	SPOT	MOS-1
EXPECTED LAUNCH DATES	1985, 1987	1987	1984	1986
DESIGN LIFE OF SATELLITE	5 YEARS	3 YEARS	3 YEARS	2 YEARS
PRIMARY SENSOR NAMES	MULTISPECTRAL SCANNER MILLISENSOR	ACTIVE MICROWAVE INSTRUMENTATION (AMI) RADAR ALTIMETER (RA) ALONG-TRACK SCANNING RADIOMETER WITH MICROWAVE SOUNDER (ATSR-M) -- FUNDED BY UNITED KINGDOM AND FRANCE PRECISE RANGE AND RANGE RATE EXPERIMENT (PRARE) -- FUNDED BY GERMANY	HIGH RESOLUTION VISIBLE (HRV) INSTRUMENTS	MULTISPECTRAL ELECTRONIC SELF-SCANNING RADIOMETER (MESSR) VISIBLE AND THERMAL-INFRARED RADIOMETER (VTIR) MICROWAVE SCANNING RADIOMETER (MSR)
ORBIT	SUN-SYNCHRONOUS	SUN-SYNCHRONOUS	SUN-SYNCHRONOUS	SUN-SYNCHRONOUS
ORBITAL INCLINATION	81°	98.52°	98.7°	99.1°
ALTITUDE	917 KM	777 KM	832 KM	909 KM
RECURRENT PERIOD--GLOBAL COVERAGE	18 DAYS	N/A	26 DAYS	17 DAYS
LOCAL HOUR OF DESCENDING NODE AT EQUATOR	9:30 AM	10:30 AM ± 15 MIN.	10:30 AM	10:00-11:00 AM
REVOLUTIONS/DAY	14	$14\frac{1}{3}$	$14 + \frac{5}{26}$	14
MISSION OBJECTIVES	(a) TRANSMIT EARTH RESOURCES OBSERVATIONS BY DIRECT DOWNLINK FROM LOW-COST, HIGH-TECHNOLOGY SATELLITES TO GROUND STATION OPERATORS AT BOTH HOME AND ABROAD.	(a) DEVELOP AND PROMOTE ECONOMIC/COMMERCIAL APPLICATIONS RELATED TO A BETTER KNOWLEDGE OF OCEAN PARAMETERS AND SEA-STATE CONDITIONS. (b) INCREASE THE SCIENTIFIC UNDERSTANDING OF OCEAN PROCESSES WHICH, TOGETHER WITH THE MONITORING OF POLAR REGIONS, WILL PROVIDE A MAJOR CONTRIBUTION TO THE WORLD CLIMATE RESEARCH PROGRAM.	(a) EXPERIMENT ON DESIRABLE CHARACTERISTICS OF FUTURE (OPERATIONAL) REMOTE SENSING SYSTEMS. (b) BUILD AN ARCHIVE AND MAKE AVAILABLE A WORLDWIDE DATA BASE FOR CARTOGRAPHIC AND EARTH RESOURCE EXPLORATION PURPOSES. (c) EXPERIMENT ON IMPROVING VEGETATIVE SPECIES DISCRIMINATION AND PRODUCTION FORECASTING. (d) BUILD UP A [illegible]	(a) ESTABLISH FUNDAMENTAL TECHNOLOGIES WHICH ARE COMMON TO BOTH MARINE AND LAND OBSERVATION SATELLITES. (b) OBSERVE THE STATE OF SEA-SURFACE AND ATMOSPHERE USING VISIBLE, INFRARED, AND MICROWAVE RADIOMETERS AND VERIFY THE PERFORMANCE OF THESE SENSORS.

	AEROSPACE (AEROS)	AEROSPACE (AEROS)	ESA (ERS-1)	ESA (ERS-1)	ESA (ERS-1)	ESA (ERS-1)	ESA (ERS-1)	FRANCE (SPOT)	JAPAN (MOS-1)	JAPAN (MOS-1)	JAPAN (MOS-1)
	MULTISPECTRAL SENSOR	MILLISENSOR	AMI IMAGING MODE (SAR)	AMI WAVE MODE	AMI WIND MODE	RA	ATSR-M	HRV	MESSR	VTIR	MSR
J-	80 M, POSSIBLY 40 M	4 KM	100 M or 30 M	STEP SIZE (SEE SPECTRAL SAMPLES)	50 KM		1 KM	20 M OR 10 M	50 M	90 M / 2.7 KM	32 KM 23 KM
	S OR X BAND	S OR X BAND	C BAND	C BAND	C BAND						
	.45-.52 .5-.6 .6-.7, .7-.8 .8-1.1, 2.08-2.35	2 FREQUENCIES IN MILLIMETER WAVELENGTH					3.7 11 12	.50-.59 .51-.73 .61-.68 (PANCHRO- .79-.89 MATIC)	.51-.59 .61-.69 .72-.80 .80-1.1	.5 6-7 ~.7 10.5-11.5 11.5-12.5	
	195 KM ADJACENT	1546 KM	80 KM MINIMUM		400 KM ONE-SIDED (25° TO 55° INCIDENT)		500 KM	60 KM AT NADIR 950 KM TOTAL	100 KM X 2 OPTICAL ELEMENTS	1500 KM	320 KM
	18 DAYS	ONCE DAILY									
	CROP MONITORING AND FORECASTING, WATER RESOURCES MANAGEMENT, LAND USE PLANNING, POLLUTION DETECTION	SEA STATE, SOIL MOISTURE, VEGETATION TYPES, POLLUTION DETECTION, VEGETATION AND LARGE AREA CROP MONITORING, INTENSE RAINFALL AND SANDSTORMS, AND FOREST AND GRASS FIRE DETECTION		MEASURE WAVE IMAGE SPECTRUM TAKE ALL-WEATHER HIGH-RESOLUTION IMAGES OF COASTAL ZONES, OPEN OCEANS, AND ICE AREAS	OBSERVE WIND SPEED AND DIRECTION	DETERMINE SIGNIFICANT WAVE HEIGHTS, WIND SPEED, TAKE MEASUREMENTS OVER ICE AND MAJOR OCEAN CURRENTS	DETERMINE SEA-SURFACE TEMPERATURE AND TOTAL VERTICAL COLUMN WATER VAPOR AMOUNT	ACHIEVE A MULTI-SPECTRAL CAPABILITY WITH HIGH GROUND RESOLUTION AND STEREOSCOPIC COVERAGE	SEA-SURFACE COLOR	SEA-SURFACE TEMPERATURE	WATER CONTENT OF ATMOSPHERE
		DUAL (HV)			VV, 3-ANTENNA BEAMS						
	≈10 M BITS/SEC	≈5 M BITS/SEC	≈100 M BITS/SEC	≈600 K BITS/SEC	1 K BIT/SEC	8.5 K BITS/SEC	110 K BITS/SEC	25 M BITS/SEC X 2 INSTRUMENTS	8.78 M BITS/SEC	8.78 M BITS/SEC	2 K BITS/SEC
			1 dB for 100 M 2.5 dB for 30 M BOTH AT σ = -18 dB				.1° K		39 dB	55 dB .5 K	1 K 1 K
E			23° AT MID-SWATH	23° SIDE-LOOKING							
			5.3 GHz IN HH POLARIZATION	5.3 GHz IN HH POLARIZATION	5.3 GHz	13.5 GHz		5.3 GHz			23.8 GHz 31.4 GHz
			< 400 W	< 100 W							
			≈10 M X 1 M		3.6 M X 3 M, 2 OFF 2.5 M X 3 M, 1 OFF	1 MØ					
				<100 M TO 1600 M IN 12 LOG STEPS							
				20° SPECTRAL ENERGY DENSITY OF σ° SPECTRUM	2 M S^{-1} OR 10%		5° K OVER 50 KM^2 - 80% CLOUD COVER				
				OVER 180° IN AZIMUTH IN STEPS <30°							
				100 KM ALONG TRACK LOOKING AT 5 KM SQUARE							
I					4 TO 24 M S^{-1} <20° (1σ)						
						590 W	40 W + 20 W				
						300 MHz					
						≈10 CM					
						1-20 M ± 10%					
						± 1 dB					

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GEOGRAPHIC INFORMATION SYSTEM IN BOLIVIA:

A CASE STUDY FOR LATIN AMERICA *

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ABSTRACT

Bolivia's Geological Service (GEOBOL) is concluding a successful project designed to give the Department of Oruro the capability to evaluate its natural resources using data generated by three United States satellites.

The Oruro Project saw creation of a permanent integrated Geographic Information System (GIS) which will be used to prepare base maps of soil characteristics, land use, geomorphology, geology, water resources and hydrology.

The information compiled through the project was stored on magnetic disks and tapes to permit periodic updating, retrieval of data on specific aspects of development projects, and obtaining various data mixes to analyze aspects of prospective development projects. Participating in the project were the Inter-American Development Bank (IDB), scientists from the Laboratory for Applications of Remote Sensing (LARS) of Purdue University, the United States Jet Propulsion Laboratory (JPL) and GEOBOL.

A prime use of the new system will be in land use planning, particularly as regards agriculture. Oruro's most important economic activity is tin and tungsten mining, with agriculture limited to small areas. Further development of agriculture has been held back by problems associated with overgrazing, soil erosion, lack of water, salinity and poor land management.

Plans are now underway to extend a second phase of the project to Bolivia's Department of Potosi.

The Oruro project is the first digital information system developed in Latin America and the IDB has taken the leadership in financing projects involving utilization of data provided by earth resources satellites such as the LANDSAT series.

Key words: geographic information, data processing, digitize, projection, digital mosaic, pattern recognition, pixel.

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GEOGRAPHIC INFORMATION SYSTEM IN BOLIVIA: A CASE STUDY FOR LATIN AMERICA

GENERAL CONCEPT

The field of geographic data processing is beginning to acquire an identity of its own, with an increasing number of papers being presented at national and international symposia as well as research results published in scientific journals. Geographical data processing systems are perceived by potential users as a vehicle by which a broad range of practical applications and numerous diverse results can be achieved. These systems of data processing pertain to the compilation, storage, manipulation or transformation and display of information commonly represented on maps. Recent advances in image processing, pattern recognition and business data management have strenghtened the scope of versatility of geographic information systems (GIS). Detailed descriptions, categorizations and analysis of the principal constituents of this new field are amply described by Nagy and Wagle (1979).

PROJECT BACKGROUND

Bolivia is a South American nation which covers 1.098.581 Km^2 divided into nine departments, extending from 8°S to 24°S in latitude, and 58°W to 70°W in longitude.

The pioneer work of Dr. Carlos E. Brockmann a few months after NASA had launched Landsat-1 in 1972 led to the creation of the Programa ERTS (Earth Resources Technology Satellite Program) within Bolivia's Geological Bureau (GEOBOL). As the first director of the Programa ERTS, Dr. Brockmann achieved numerous practical remote sensing results of national and international magnitude. These achievements convinced the Government of Bolivia, a member country of the Inter-American Development Bank (IDB), of the need to request funding from the IDB to design a permanent integrated geographic information system (GIS).

Upon approval of funds by the Bank, a contract was awarded to the Laboratory for Applications of Remote Sensing (LARS) of Purdue University, West Lafayette, Indiana, to design the GIS for the Department of Oruro, northewestern Bolivia. LARS subcontracted the Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena, California to carry out specific tasks related to the use of Landsat data in the GIS.

Oruro's most important economic activity is tin and tungsten mining, with agriculture limited to small areas. Further development of agriculture has been held back by problems associated with overgrazing, soil erosion, lack of [illegible] land management. One of the prime uses of the GIS is

FUNDAMENTAL CHARACTERISTICS OF THE GIS

DATA STORAGE

Oruro is within range of the Brazilian Landsat ground receiving station and is covered by seven Landsat frames. The data base, composed of these geometrically corrected Landsat scenes, was structured as a digital mosaic. The mosaic was constructed by using Landsat computer compatible tapes (CCT's) and appropriately selected ground control points of known geographic locations provided by experts from the Programa-ERTS/GEOBOL.

LARS scientists designed the Bolivian geographic information system which consists basically of a four level-16 element grid cell structure. The grid cells were created by constructing a hypothetical plane of 1500 kilometers in the horizontal (E-W) direction and 1500 kilometers in the vertical (N-S) direction. Therefore, it became possible to place the entire Bolivian territory in a squared plane. Furthermore, the plane was horizontally and vertically subdivided into 30,000 equal parts thereby generating a total of 900 million cells which represent squared areas on the earth surface of 50 meters by 50 meters each. Each cell contains 16 elements or bytes of information. Among the 16 elements are included the four Landsat MSS (multispectral scanner system) bands 4, 5 and 7 and the remaining 13 are: cantons, departments and provinces, elevation, geology, hydrology (drainage network), land cover and land use, population, precipitation, relief amplitude or local relief, slope and aspects, soils, temperature and transportation. Bartolucci and Phillips (1980) provide an in depth discussion about the storage requirement and data management system inherent to the design of the digital information system.

MAP PROJECTION

The selection of the most suitable map projection for the Bolivian geographic information system was based on the following six criteria:

1. The map projection should be well known and easy to compute.

2. The selected projection should facilitate the production of a whole map derived from the fitting of separate sheets.

3. A single projection should cover an entire region to be mapped at scales ranging from 1:25,000 to 1:1.000.000.

4. Scale error should be kept at a minimum throughout the projection;

5. Maximum error of area must be zero to facilitate the computation of areal estimates of ground cover by using projection-independent algorithms.

6. Maximum error of azimuth should be minimized whenever possible.

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Taking into account the six selection requirements Bartolucci and Phillips (1980) reviewed the key characteristics of the most commonly used map projections (Table 1) and prepared the following selection matrix:

Projection	Requirements 1	2	3	4	5	6
1. UTM				X		X
2. POLYCONIC	X					
3. Lambert-Conf.	X	X	X			X
4. Lambert-Zen		X	X		X	X
5. Albers	X	X	X	X	X	X

The results of the selection matrix indicated that the Albers equal-area projection is the most suitable one for designing a natural resources information system for Bolivia.

LANDSAT DIGITAL MOSAIC

The Jet Propulsion Laboratory had the responsability to create a multi-frame Landsat MSS digital mosaic of Oruro using a software developed under the VICAR/IBIS (Video Image Communication and Retrieval/Image Based Information System). The digital mosaic of seven Landsat scenes was prepared in four spectral bands. The data were resampled to 50 meter by 50 meter pixels and map projected to the Albers equal area projection. Corrections were performed to eliminate the effect of atmospheric haze on each scene and between scenes. JPL used approximately a total of 175 ground control points or about 25 points per scene during the mosaic preparation.

STRUCTURAL DESIGN OF THE GIS

The basic structural design of the GIS appears in Figure 1 where five major subsystems (input, data base, management, modeling or analysis, and output) are presented as an integral part of the system. The data base subsystem is composed of an image plane data base and an attribute data base. Each of these systems performs separate functions which complement one another and strengthen the degree of versatility of the digital information system. For instance, the image plane data base stores digitized maps in the form of geo-coded or spatially referenced image planes (Figure 2) whereas the attribute data base contains records which describe information related to the image plane data base. The elaborate description of the interrelated functions and capabilities of the five major subsystems of the GIS is found in detail in Bartolucci and Phillips (1981).

PRACTICAL IMPLICATIONS OF THE GIS FOR LATIN AMERICA

Even though there exist some commercially available software and hardware such as the COMARC system which have been sold to a few developing countries, the Bolivian project is the first geographic information system which has been constructed with the participation of scientists from the country and implemented successfully in Latin America and anywhere in the Third World. It is also an excellent example of what can be achieved in the Third World through national and international efforts and scientific cooperation.

The need to disseminate the concept of digital information system and construct appropriate systems in Latin America is based partially on the following considerations:

1. Approximately 18% of South America is somehow covered by reliable topographic maps at scales ranging from 1:40,000 to 1:250.000; a digital Landsat mosaic would provide a rapid, efficient and economic method of updating such data and generate much needed information over regions that have never been mapped.

2. A GIS can handle a broad range of data, analyze them, and produce new information on natural resources.

3. Large volumes of data can be stored, retrieved and displayed so as to aid policy makers in making decisions about development projects.

4. Current research in the field of electro-optical imaging technology will significantly increase the process of converting large-format graphics to digital form. As Latin American countries and others adopt digital files of mapping, geophysical and other types of graphic data, the demand for highly sophisticated sensor, software and hardware will grow rapidly in order to provide efficiency in data storage and retrieval on a national and regional basis.

   These observations are only a few which demonstrate some of the practical applications of geographic information system in natural resources management programs. Clearly the connection exists between research in detecting, storing and extracting data on energy resources, geologic studies, and global management of such resources through a combination of remotely sensed data, geo-referenced information and the design of geographic information systems. Such examples of practical advantages have stimulated the interest on the part of policy decision makers in Latin America and elsewhere in GIS. The international funding agencies like the Inter-American Development Bank, the World Bank and others, also have sustained interest in financing projects in which GIS offers great advantages for assiting their member countries in meeting national and regional development needs.

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TABLE 1. SUMMARY OF MAP PROJECTION CHARACTERISTICS

Projection	Characteristics
1. UNIVERSAL TRANSVERSE MERCATOR (UTM)	Conformal projection used mainly in military mapping at scales of 1:50,000 or larger.
2. POLYCONIC	Standard for field map at scales 1:50,000 and larger; predominant use, 1:24,000 quadrangle maps.
3. LAMBERT CONFORMAL CONIC	A conformal conical projection with two standard parallels.
4. LAMBERT ZENITHAL equal-area	A stereographic projection with a standard meridian and standard parallel.
5. ALBERS equal-area	An equivalent conic projection with two standard parallels.

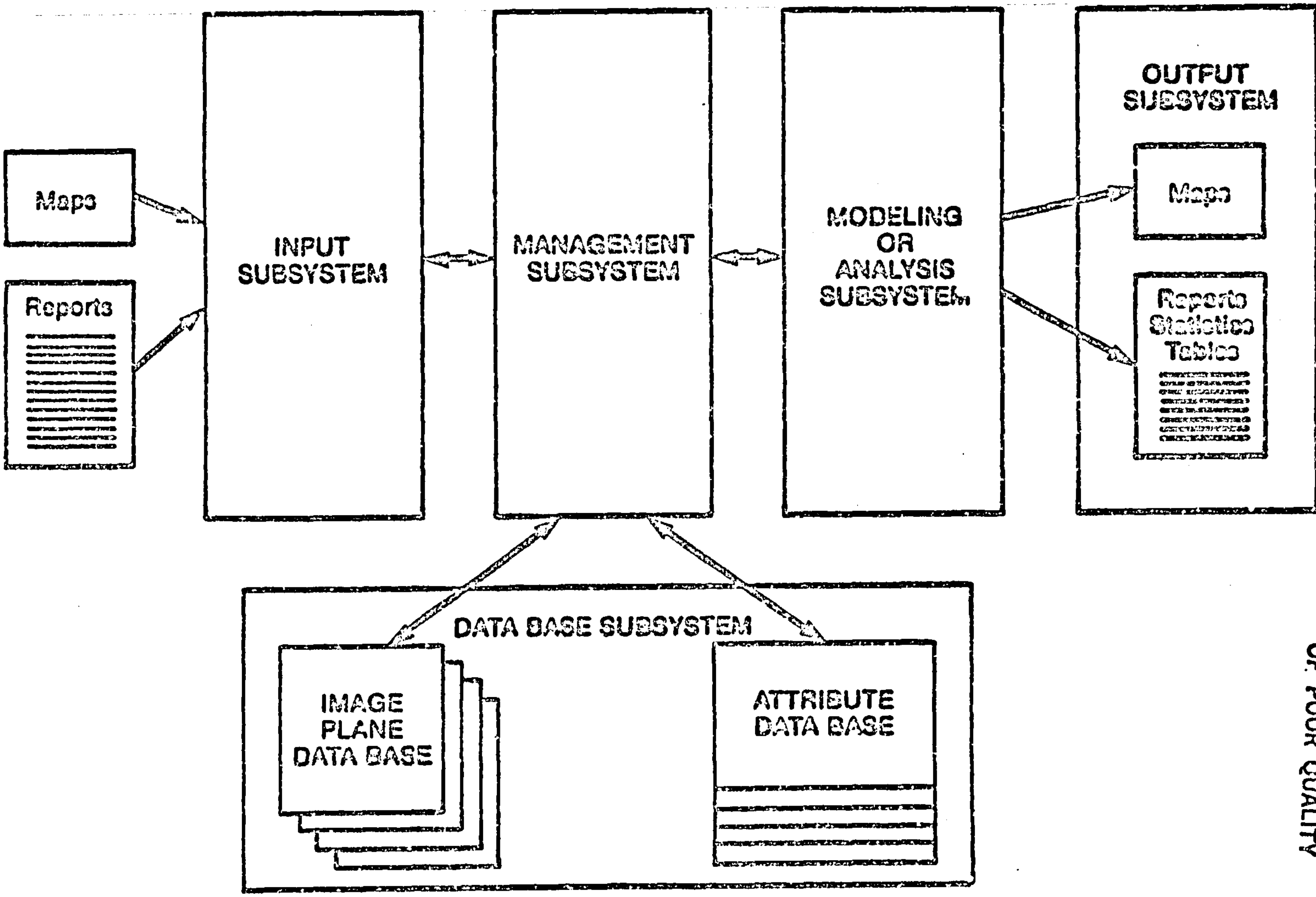

Figure. I. Basic components of a digital Geographic Information System.

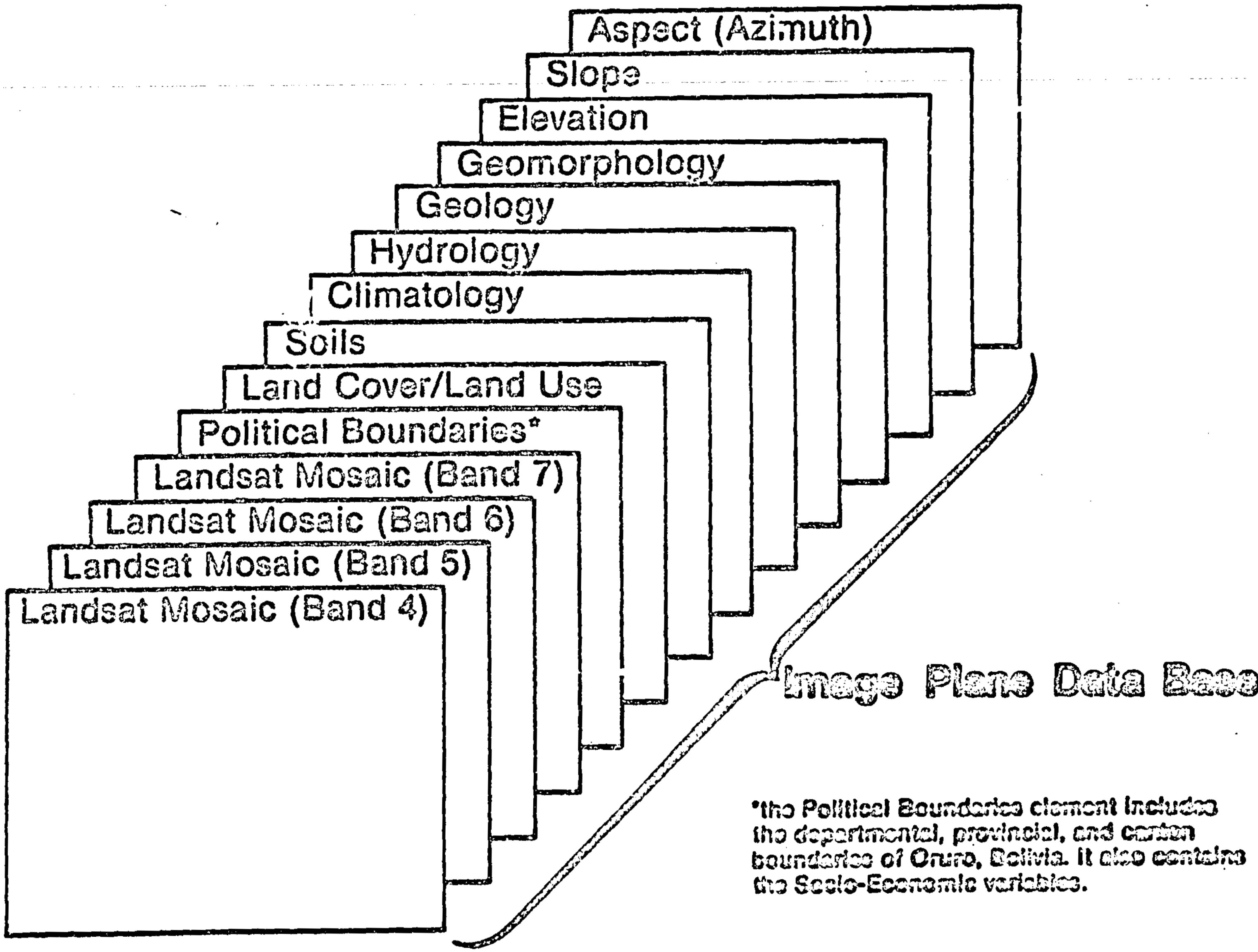

Figure 2 Image Plane Data Base for the Oruro Department GIS.

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FACTORS IN THE EFFECTIVE UTILIZATION OF A LANDSAT RELATED INVENTORY IN WEST AFRICA

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ABSTRACT

A comprehensive Landsat related resource inventory was performed in parts of three West African countries to determine resource development potential in areas freed of the disease onchocerciasis. The ultimate success of the project lies in the effective use of the data by host country personnel in resource development projects. This requires project follow-through, adequate training of regional counterparts, and integration of the data into an easily used framework. Present levels of support systems and technical expertise in West Africa indicate that an automated system for natural resource data is not currently appropriate. Suggestions for the greater implementation of such inventories are explored.

INTRODUCTION

The need for natural resource evaluation and management is especially important in fragile environments or where resources are relatively limited. These constraints exist in the developing nations of West Africa, particularly in the Sahelian zone. They have been the focus of numerous remote sensing resource inventories and development projects in recent years, sponsored by the U.S. Agency for International Development (USAID), the International Bank for Reconstruction and Development (IBRD), and other donor agencies and nations.

As of May 1982, there were twenty-seven (27) USAID financed projects ongoing in the Sahel in which resource inventory and mapping was a component. These represent an investment of forty million dollars and a projected investment of one hundred million dollars (Taylor, 1982). Resulting from these and other efforts is a wealth of information about the natural resources and development potential and constraints within the region. The ultimate success of the studies, however, depends on their integration in subsequent resource development programs. Such integration whereby the resource inventory products are effectively utilized is typically lacking, and appears to be contingent upon several complex factors, such as:

- Initial and sustained host country involvement and commitment to the inventories and their use;
- An organizational framework within the host country for planning, development and management of natural resource programs;
- Proper scale and intensity of inventory which matches the specific information needs of the most urgent problems to be solved;
- A requisite number of trained host country counterpart resource analysts and planners;
- Adequate counterpart training which provides concrete applications of product utilization as part of the training process;
- The inclusion of a vital period of follow-through or phase-out of continuing technical assistance and training after the inventory is completed (Taylor, 1982);
- A resource data base which is easily accessed and understood; and which both corresponds to and advances the technological status and training level in the host country.

To date, implementation of inventory results has been weakly linked to resource analysis programs in West Africa and elsewhere, and many inventory products are gathering dust on ministry shelves. This may be due to any or all of the above factors. This paper addresses reasons for this with regard to a resource evaluation project in the Volta River Basin and explores considerations in the choice of an effective system for resource data presentation and transfer.

PROJECT DESCRIPTION

Onchocerciasis is one of six major diseases targeted by the World Health Organization (WHO) for eventual eradication. The disease is caused by a parasitic worm (*Onchocerca volvulus*), vectored by a black fly (*Simulium damnosum*) which breeds in rivers and streams. The disease afflicts debilitation and blindness and, before the onset of the eradication program, was the priminary deterrent to human resettlement and economic development of many fertile valleys which had become uninhabited and unproductive.

The Regional Onchocerciasis-Free Area Planning (ROAP) project was designed to address resettlement problems in the onchocerciasis-free areas of Benin, Ghana, and Upper Volta. The ROAP project is the second stage in a three-stage program for disease control, settlement, and development of areas uninhabited because of the disease. The first stage is an onchocerciasis vector control program which was initiated in 1974 under the direction of the World Health Organization. The program has successfully controlled the disease in many valleys and will continue for twenty years. The second stage, funded by USAID and implemented by the African Development Bank, is the preparation of a data base containing a natural and cultural resource inventory and an assessment of resource development potentials. This task was undertaken by Tippetts-Abbett-McCarthy-Stratton (TAMS) and Earth Satellite Corporation in a joint venture, and was completed in 1981. The third stage will consist of capital investments necessary to implement development plans in selected areas (Brooner and Nichols, 1982). Within this framework, specific objectives of the resource inventory were:

- To elaborate and expand basic resource documentation for use in onchocerciasis control program areas in the three countries;

- To promote within a regional scale the development of all natural resources in these areas, such as minerals, agriculture and livestock, water resources, forestry, and fisheries; and most importantly,

- To train counterparts for effective day-to-day use of the resource data base in development planning and programs.

The information base included resources inventory and development potential maps and was derived largely from Landsat data, in a multilevel remote sensing approach with corroborative field work.

Specially processed and computer enhanced Landsat imagery was used for regional analysis of the 335,000 square kilometre study area. This was supplemented by larger scale black-and-white aerial photography in three subareas (2,000 square kilometres each) selected for more detailed study. In addition, field teams including host counterparts corroborated these data by ground checking specific sites and observing areas from low altitude light aircraft. Remote sensing methods proved to be efficient and cost-effective for the comprehensive coverage of the study area. The approach was especially useful in remote areas or over extensive regions of the developing countries where current data were unavailable.

Interpretation of the enhanced images supplemented by ground truthing resulted in detailed information on land use and land cover, geology and mineral resources, surface hydrology and groundwater resources, climate, and human resources (infrastructure). This was synthesized into the following categories of development potential: Agriculture, Livestock and Rangeland; Water Resources and Fisheries; Forest and Wildlife; Minerals; and Candidate Areas for Human Resettlement and/or Resource Development. The latter category was a fusion of the other classes intended to identify areas of relatively high development potential. Twenty-seven (27) such areas were selected as suitable for more detailed study.

DATA BASE PRESENTATION

The medium chosen to convey the information was a series of thematic map overlays registered to national topographic maps, at 1:200,000 scale for Benin and Upper Volta and 1:250,000 for Ghana. For resource management and development, map overlays can present substantial amounts of information in a simple and integrated manner. They are easily distributed to various administrative agencies responsible for diverse areas of resource management within each government. The overlays were designed to be used as unaccompanied resource tools or in conjunction with national topographic maps or the enhanced Landsat images. Landmark towns and roads on each overlay served as register points to

As an evaluation exercise, computer classification of a Landsat image was performed, using black-and-white aerial photography as "ground truth" to supervise the classification, as well as supplementary topographic and soils maps. Computer classification of imagery is useful in many situations, but in this case the results fell short of those acquired by manual interpretation. Since computer classification was based on spectral response only, important environmental considerations used in human interpretation were excluded, and overlap of spectral signatures in this complex environment resulted in significant classification inaccuracies. Manual interpretation of the enhanced images applied ecologic concepts of analysis which allowed detail surpassing that of the automated technique. In addition, accuracy would require that the classification supervision be performed separately for most of the twenty-five individual Landsat images used in the project, due to different acquisition dates and resulting variations in atmospheric and ground characteristics. Finally, computer classification would have provided only the land use/land cover data base, with the remaining inventory overlays still requiring manual interpretation.

For data presentation, an automated geographic information system was considered. In many ways, such a system would have been suitable for the data base. Automated manipulation provides ease of comparing several layers of information and has great advantages when many outputs may be required from the same data base (Calkins, 1977). Computer storage capabilities can assimilate the large quantities of inventory data and allow rapid retrieval for merging, analysis, presentation, or updating of data. However, the task of converting data from many sources to the same format in machine-readable form is a huge, cost-intensive one which requires extensive automated data manipulation and interpretation.

Critical considerations in an automated approach would be the effective transfer of this technology to West African counterparts, and the likelihood that the data base and supporting equipment would be adequately maintained. Installation of such a capability, even at the existing remote sensing center in Ouagadougou, Upper Volta, would involve large investments in sophisticated equipment by the host countries or the donor agency. This should be accompanied by additional operating systems in the other two countries.

Limiting factors other than initial cost and equipment prerequisites are system support and training requirements. In order for a computer system to be properly maintained, these minimum requirements are: an assured, continuous, non-surge power source; reliable, continuously air conditioned and humidity controlled buildings to house the facilities; and trained earth science and computer science technicians to perform digital analyses and service the system. At present, these prerequisites do not exist in the studied West African countries, and until this level of system support and expertise can be sustained, it is not recommended that computer-based facilities be installed there (Taylor, 1982).

DATA BASE UTILIZATION

For effective utilization, it is essential that any framework for using and maintaining a natural resource data base be realistically usable in the local environment (Poulton, 1982), especially given the extensive amount of counterpart training required for adequate technology transfer in any form.

The inventory overlays, development potential maps, and accompanying analyses planners. The importance of this consideration is recognized by the African Development Bank which has specified that the number of development projects initiated in each country will depend on the availability of local people trained in resource analysis and management. Thus, the training of host personnel in remote sensing techniques, field methods, overlay and legend interpretation, resource planning and management, and continued applications of resource data to planning is a crucial element in determining the ultimate utilization of inventory products.

During the ROAP project, the primary factors which impeded the maximum transfer of technical expertise to the counterparts and the application of results to development programs were: the scant availability of appropriately trained counterpart resource analysts; and the lack of an extended period of practial training and technical assistance after inventory completion, during which expatriate analysts could gradually withdraw as the host country personnel gained self-sufficiency in the implementation process. These are issues which can and should be accounted for in future resource inventories in Africa. They must be considered in the preliminary stages of project design by the funding agency and the host country, so that adequate time and resources for them are allocated (Poulton, 1982).

COUNTERPART TRAINING

Within the restrictions of project funding and design, the training program that the counterparts did undergo was carefully planned to emphasize practical applications while providing instruction in important inventory concepts and methods. The instruction team was a multidisciplinary group of scientists, planners, and engineers. Components of the training program found to be valuable were: an interdisciplinary orientation, extensive documentation on project issues, diversified training format, and maximum possible interaction between expatriate trainers and counterparts.

The three main elements of the training program were: a two-week course in the United States on remote sensing techniques and resource evaluation; on-the-job training in each country during which expatriate scientists and technicians worked with African counterparts on a day-to-day basis to study specific sites during two extended field trips; and a seminar in which counterparts participated at projects' end to present inventory methods and results to the administering agency and host country officials. This approach was designed to involve participants in inventory methods and familiarize them with the technology for eventual application in resource development projects.

In order for such a program to be successful, host countries should be prepared to commit individuals who have training in the earth sciences or natural resource management to full-time project participation, both during the inventory and after its completion. In most West African countries the supply of educated scientists and planners is extremely limited. The few specialists who do exist are often quickly cycled through government hierarchies and do not remain in positions where their project experience can be technically or managerially utilized. The shortage of scientists sometimes necessitates that government administraters be given assignments that would be more appropriately filled by people trained in the earth sciences. This was the case in the Volta Basin project where three of the seven counterparts were government administrators or work, they resumed their original duties and were unable to provide the necessary input and support for subsequent use of the resource data. A converse situation with a similar result may occur when the few available resource scientists attempt to integrate their newly found knowledge in ministry decision, and find that they do not have the required leverage which an administrator may enjoy.

PROJECT IMPLEMENTATION

Program success also requires the full commitment of scientifically trained counterparts for an extended period immediately following the inventory, during which resource development programs are initiated. The inclusion and funding of this extended implementation period is a critical element of any natural resource inventory. It is also one which has often been overlooked by sponsor agencies in project design. The result is that priorities are shifted, counterparts resume or are reassigned to other duties, and inventory products are shelved. Development projects may then continue on an ad hoc basis, without the benefit of the management resource.

The implementation program should be an uninterrupted extension of training begun during the inventory and should result in:

- A thorough understanding by counterparts and involved government officials of the methods employed in the project and how results and map products were derived;

- A practical knowledge of how the overlays can be manipulated to assess resources in an area;

- More detailed study of remote sensing techniques and their continued applicability to resource management and development planning; and

- Comprehensive education in resource management decisions.

Ideally, expatriate planners should work directly with counterparts in specific applications of inventory data to the planning process. Site visits to specific areas would illustrate the relationship between field observations and the resource map overlays. This information could then be used to rank and select additional areas with high resource development potential, and to identify projects to be implemented there.

An integral part of the implementation process should include presentation of methods for updating the data base in its current form, including the possible transfer of the information to a computer-based system, when practical in the future.

As counterparts become proficient at data interpretation and its use in resource management decision-making, expatriate personnel would be gradually phased out, so that at the end of the program each country has a relatively self-sufficient team of resource analysts. The scope and length of the implementation period should depend in part on inventory extent and detail, and available counterparts and development funds, but a minimum effective duration is probably six months to one year (Dodoo, 1982). The cost of the extended training period will also vary accordingly, and may comprise 10-25% of inventory costs. [1]

CONCLUSION

USAID is currently considering funding a follow-through program for an extensive land use inventory in Mali which was part of a five million dollar project. This resource evaluation was conducted by TAMS over the past three years and has recently been completed. As part of the project, a Malian team was trained in resource inventory and evaluation techniques. The proposed program continuation will cost approximately half a million dollars and is tentatively scheduled to last two years, so that Malian skills continue to develop towards greater self-sufficiency. Hopefully, the focus of the proposed follow-through program will be the establishment of a permanent Malian Unit of Natural Resource Inventory, Evaluation and Planning (Taylor, 1982).

It is only through efforts such as the proposed Mali follow-through implementation program that natural resource inventories in West Africa will have a greater chance of being ultimately successful. In order for the wealth of resource information to be fully utilized, there must be an extended period of technology transfer during which counterpart scientists and planners achieve greater independence in resource management.

The ease with which this is achieved is determined to a large degree by choice of inventory methodology and a data presentation system, and an effective counterpart training program. Adequate support for this approach requires high levels of involvement by host country officials and technicians, beginning with problem analysis in the preplanning stages and continuing through the inventory and its implementation in development programs. Close collaboration between the funding agency and host country government in terms of project goals and funding priorities is required (Poulton, 1982). Equally necessary is the commitment by the African government of educated scientists and technicians who can devote full time to the inventory and its implementation for an extended period of time.

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ACKNOWLEDGEMENTS

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NOTES

1. This percentage range is based on the cost of the proposed Mali training program and an estimation of projected costs for further technology transfer in the ROAP project. It is a preliminary estimate which is subject to revision pending more extensive planning of these types of programs.

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POTENTIAL APPLICATIONS OF LANDSAT DATA IN ENERGY RESOURCE MANAGEMENT ASSOCIATED WITH KENYA'S FORESTS

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ABSTRACT

The main sources of energy in Kenya are electricity, mineral fuels, and woodfuel. Electricity and mineral fuels are considered to be the major commercial sources of energy, whereas woodfuel (fuelwood and charcoal) are classified as non-commercial. Woodfuel is consumed by 90 percent of the rural population and the urban low income groups for cooking and heating purposes. The reasons for such high numbers of the population using fuelwood are: 1) the majority of the people are poor and practice a subsistence type economy; 2) fuelwood is inexpensive compared to electricity and mineral fuels; and 3) fuelwood is more readily available for most people. Despite the important role forests play in the energy sector in Kenya, they are being rapidly depleted because of population pressure, land shortage, and lack of proper management.

The major causes of forest depletion in Kenya include: conversion of forest land to agricultural land, harvesting of trees for lumber and building poles, and cutting of trees for fuelwood and charcoal production. Forests are a renewable resource that should be managed under the principle of sustained yield.

Forest resource management is essential for Kenya's economy and energy supply. Remote sensing data, particularly LANDSAT has been extensively applied to earth resource management including forestry in many developing countries. LANDSAT can be effectively used to monitor the extent and magnitude of forest cover change in Kenya in order to evaluate the potential for energy supply. Digital processing of LANDSAT data provides a reliable monitoring technique for forest resource management in Kenya. LANDSAT data analysis was used to illustrate that Kenya's forests are indeed diminishing. A model

$$FW = FR - C$$

FW = Tons of available fuelwood
FR = Annual forest regeneration
C = Annual consumption

was used to make projections for the availability of fuelwood as an energy source. The resulting figures imply that Kenya's forest will all but disappear around the end of the 20th century. LANDSAT data analysis for Mau East substantiates these alarming findings.

1. INTRODUCTION

Forest resources, particularly in the less developing countries (LDCs) such as Kenya, are declining at an alarming rate (Persson, 1977; Barney, 1980). The drastic changes in forest resource environments are attributed to high population growth

(Brown, 1978). The absence of adequate resource management programs has made ecological aspects of the man-forest relations as desperate as the economic issues in the LDCs. These countries have mainly labor-intensive agricultural systems. Increased food production to meet the demands of growing populations must come from raising the agricultural land base, which primarily implies clearing forests. In addition, natural cycles and processes are very rapid and forceful in the tropics and sub-tropical areas such that once the forests are cleared, chances for self regeneration are very slim. Therefore, since forests are a renewable resource that most LDCs depend upon for energy supply and other products such as lumber building materials and food, their management is vital for human survival.

2. MANAGEMENT OF KENYA'S FORESTS

Kenya is basically an agricultural country with a population of 15.8 million with an annual growth estimated at 4 percent, the highest in the world. Nearly 90 percent of the population is engaged in a subsistence economy geared toward acquisition of farmland at the cost of forest lands. Consequently, Kenya's forested land, estimated at just under 3 percent, is being cleared for agriculture.

Kenya's forests are under the management of the Forestry Department in the Minist of Environment and Natural Resources. As part of forest management, the Department of Forestry is concerned with prevention of soil erosion, establishment of green belts, nature reserves, and picnic sites (Progress Report, 1973-1978).

Since 1968 Kenya's forest policy has basically remained the same as stated in the Sessional Paper No. 1.[1] A section of the preamble of the policy statement is given below:

> The Forest Estate of Kenya ranks high as one of the country's most important national assets in its protective aspect of conservation of climate, water, and soil as the source of supply of forest produce for all uses by the inhabitants of Kenya; and as a revenue earner of high potential. The object of the government's forest policy is therefore to lay down basic principles which shall guide the development and control of forestry in Kenya for the greatest common good of all. These basic principles are described under 10 main heads - reservation of land for forest purposes; protection of the forest estate; management of the forest estate; industry; finance; employment; local authority forests; private forests and other forests not under ownership; public amenity; and research and education.

Under reservation of land for forest purposes, the policy states that the government is determined to reserve in perpetuity the existing forest and, wherever possible add to them so as to provide sufficient land in order to:

1. maintain and improve the climatic and physical conditions of the country;
2. conserve and regulate water supplies by protection of catchments and by any means necessary for the purpose, including the impounding of water in forest areas;
3. conserve the soil by prevention of dessiccation and soil movement caused by water and wind; and
4. provide for the needs of the country in timber and other forest produce adequate to meet the requirements of the community under a fully developed national economy and to provide the greatest possible surplus of those products for export markets.

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[1] Republic of Kenya, Sessional Paper No. 1 of 1968, A Forest Policy for Kenya, Government Printer, Nairobi, 1968.

Although there has been no major forest policy change since 1968, there has been a shift in emphasis by the government to encourage the establishment of privately owned woodlots and planting of trees by local farmers. At any rate where forests are under government ownership, a high squatter population has established itself.

It is interesting to note that the squatter system is used by the Forestry Department for creation of new plantations. The following procedure is followed.[2]

1. The area is clear-felled by a sawmiller of all millable timber.
2. The area, where possible, is exploited by contractors removing all remaining produce.
3. The forest squatter makes a shamba.[3]
4. The Forest Department plants trees on the third year after clearing.
5. The squatter cultivates the plantations until the trees are 18 months old.
6. The Department then takes over the trees and raises them to maturity.

The squatter movement into cleared forests is not without its own problems. Once the period of planting is over, squatters are supposed to move off of the forest by the Forest Department after harvesting what is considered sufficient crops to justify the work they put into clearing the plantations. The Forest Department does not have a program for resettling these people. As a result, land shortage and other problems force the squatters to remain at the plantation periphery or move to mountain slopes where they cultivate land illegally. The removal of vegetative cover on mountain slopes increases the risk of soil erosion and impoverishes other resources. Whereas this system helped the Forest Department to create new plantations faster and at low cost when population was low, it is no longer beneficial because there are no land management policies that can help resettle these people away from the forest.

2.1 Kenya's Forest Removal

Forest removal is not to be condemned *per se*. Legitimate, compelling social and economic reasons justify some tree removal and forest land conversion. The major factors of forest depletion in Kenya are: conversion of forest land for agriculture, lumber for industrial use and cutting of trees for woodfuel. Although human needs are primary in any development plan, both the short-term and long-term economic and social benefits obtained from Kenya's forest resources have to be considered before their removal. This includes their management as a renewable resource under the principle of sustained yield, and also the protection and maintenance of the environment that will be ultimately useful to future generations.

The future of Kenya's forests will be determined by decisions on rural development by the government that are not necessarily forestry related, such as food production, energy, land use policies, and population growth. Efforts must be intensified to address these fundamental influences as they affect Kenyan forest directly.

2.2 Kenya's Energy Sources

The main energy sources in Kenya are electricity, mineral fuels, and woodfuel. Electricity and mineral fuels are considered the major commercial sources of energy, whereas fuelwood and charcoal are classified non-commercial. Since the energy crisis of the 1970's, Kenya has been spending a high amount of her foreign exchange on imported energy which has caused great pressure on the balance of payments, accounting for 36 percent of imports in 1980 compared to 16 percent in 1978 (World Bank, 1982). At present, the government is trying to seek the development of other sources

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[2]This information was obtained from Londiani Forestry School as part of students' notes on forest management, 1980.

[3]Shamba is a Kiswahili word for cultivable land.

of energy such as geothermal power.

However, Kenya's resource management for energy production is essentia for the 90 percent of the population found in the rural areas where electricity and mineral fuels are not used for cooking and heating. In Kenya's Fourth Development Plan (1980) energy supplies for the rural population are considered as one major objective in improving the welfare of the rural population. In this regard it is clear that more emphasis in energy development and resource management must be placed on the areas where the majority of the country's population is found. In Kenya the rural population uses fuelwood and charcoal as their primary source of energy. Therefore, it is necessary that better resource management techniques are employed to ensure continuous supply of these products.

2.3 Woodfuel Consumption

A number of studies to evaluate the potential supply and demand of woodfuel for fuelwood and charcoal in Kenya have been done by Chlala, 1972; Uhart, 1975; Kabagambe, 1976; Western, et al., 1979; and Kamweti, 1980. Although these studies have assessed the importance of woodfuel supply for the rural population in Kenya there exists a large gap in our information on forest productivity, per capita consumption of fuelwood in the country and the rates of forest regeneration for continuous fuel supply.

According to Githinji (1978), greater dependence on locally produced energy sources will lessen Kenya's dependence on imported fuels, and will save on foreign exchange. Looking at Kenya's energy package (Table 1) one realizes that the only existing internal energy sources are fuelwood and charcoal forming the highest percentage while a small percentage is derived from electrical power. Since Kenya does not have any source of mineral fuels, to achieve self-sufficiency in energy, there is great need for proper forest management directly linked to energy supply.

Investigations on fuelwood supply and consumption indicate that fuelwood is highl in demand in Kenya. In 1979 a study done on rural energy consumption revealed that approximately 20 million metric tons of woodfuel are consumed annually in rural areas in Kenya (Western, et al., 1979). This study based on a sample of 4800 households taken from across the country indicated that the pattern of fuelwood consumption varie from one province to another. In another survey conducted by Akinga (1980), the total amount of fuelwood consumed in the country was approximately 22 million metric tons. Akinga's study went further to illustrate the quantity of woodfuel utilized by various sectors of Kenya's economy.

TABLE 1

Contribution of Various Energy Resources in Total Energy Package in Kenya 1976 (in percent)

	Energy Resources: As Percent of Total Commercial Energy	As Percent of Total Non-Commercial Energy	As Percent of Total Energy
1. Electrical Power			
(a) Thermal	4	--	2
(b) Hydro	7	--	4
Total	11	--	6
2. Mineral Fuels			
(a) Crude Oil	87	--	48
(b) Others (coal, coke,	2	--	1
etc. TOTAL	89	--	49
3. Others			
(a) Charcoal	--	4	2
(b) Fuelwood	--	96	43
TOTAL	--	100	45
GRAND TOTAL	100	100	100

Source: The Weekly Review, December 1, 1978, p. 14.

According to Akinga (1980) the amount of wood consumed for charcoal assumed a recovery of 25 percent. However, since charcoal making techniques are very wasteful a good estimate could be determined on the assumption that 11 kg. of wood would be required to produce 1 kg. of charcoal. This provides a recovery of nine percent (Kamweti, 1980). If this is the case then it takes 15, 534,035 tons of fuelwood to produce 1, 412,185 tons of charcoal. That means a total of 31,750,000 metric tons of wood consumed in the country in 1979. This figure obtained from the rural energy report conduced by Tuschak (1979) was used as one of the basic inputs in developing the model for potential of Kenya's forests for energy supply and making subsequent projections in the following section.

3. THE METHOD

In calculating the potential woodfuel supply for Kenya's forests, projections were made for the whole country based on the following data:

1. Population figures were projected to the year 2000 using the total population figure for 1979 of 15,427,000 with an annual growth rate of four percent (Central Bureau of Statistics, 1979); and
2. projections on the status of the forest were calculated using the total hectares classified as forest in Kenya (1,370,160) (Doute, et al., 1980).

To evaluate the issue of woodfuel in the country the following model was built and applied to make projections for the availability of fuelwood as an energy supply:

$$FW = FR - C$$

FW = Tons of available fuelwood
FR = Annual forest regeneration
C = Annual consumption

Tons of available fuelwood are derived by taking the total hectares of landcover classified as forest in 1979 and multiplied times 45 kg/m² or 450 tons per hectare (the mean biomass dry matter of tropical rain forest). (Lieth et al., 1975)

Annual forest regeneration figures are derived by multiplying the actual number of hectares classified as forest by 2,200 g/m²/yr. or 22 tons/ha/yr. (the mean annual net production of dry matter for tropical rain forest. (Lieth et al., 1975).

Annual consumption figures are determined by dividing the total population figure for 1979 (15,427,000) into the total tons of fuelwood consumed in 1979 (31,750,000). The resulting figure of 2.058 tons per person was kept constant while the consumption was assumed to increase with the projected population increase of four percent annually.

Table 2 shows the results of the calculations for each year from 1979 through the year 2000 including the percentage change of hectares of forested land. The projected figures actually include forested lands for potential fuelwood which are, in fact, off limits. The total forest figures comprise national parks and forest reserves which could not be separated from the other forests given the available data. Also, the four percent population increase is not likely to be a constant for the next twenty years in Kenya. However, a moderate variation is not going to have a major impact on the findings of this study.

4. LANDSAT DATA ANALYSIS

LANDSAT data for the Mau forest area was obtained for January 3, 1973 and December 31, 1978 (Path 181, Row 60). The data interval was considered important because of readily available data and experience by the authors in monitoring land reclamation

TABLE 2

Kenya - Forecast of Population Increase, Wood Availability, Tons Regenerated and Consumption per Year (in millions)

Year	Population Increase at 4%	Tons of Fuelwood Available	Tons Regenerated	Tons Consumed	Difference in Tons	Forest Hectares	Percent of 1979 Forest Hectares
1979	15,427	616,500,000	30,143,520	31,750,000	-1,606,480	1,370,160	100
1980	16,044	614,893,520	30,061,461	33,091,835	-2,958,374	1,366,430	99.7
1981	16,686	611,935,150	29,916,830	34,341,123	-4,424,293	1,359,856	99.2
1982	17,353	607,510,860	29,700,528	35,713,862	-6,013,334	1,350,024	98.5
1983	18,047	601,497,530	29,406,546	37,142,170	-7,735,624	1,336,661	97.5
1984	18,769	593,761,910	29,028,360	38,628,103	-9,599,743	1,319,470	96.3
1985	19,520	584,162,170	28,559,039	40,173,721	-11,614,682	1,298,138	94.7
1986	20,301	572,547,490	27,991,211	41,781,082	-13,135,204	1,272,327	92.8
1987	21,113	558,757,620	27,317,039	43,452,243	-16,135,204	1,241,683	90.6
1988	21,957	542,622,420	26,528,207	45,189,262	-18,661,055	1,205,827	88
1989	22,836	523,961,370	25,615,889	46,998,315	-21,382,426	1,164,358	84.9
1990	23,749	502,578,950	24,570,526	48,877,342	-24,306,816	1,116,842	81.5
1991	24,699	478,272,140	23,382,194	50,832,518	-27,450,324	1,062,827	77.5
1992	25,687	450,821,820	22,040,178	52,865,901	-30,825,723	1,001,826	73.1
1993	26,715	419,996,100	20,533,143	54,981,607	-34,448,464	933,324	68.1
1994	27,783	385,547,640	18,848,996	57,179,636	-38,330,640	856,772	62.5
1995	18,894	347,217,000	16,975,053	59,466,163	-42,491,110	771,593	56.3
1996	30,050	304,725,890	14,897,710	61,845,304	-46,947,594	677,168	49.4
1997	31,252	257,778,300	12,602,495	64,319,116	-51,716,621	572,840	41.8
1998	32,502	206,061,680	10,074,127	66,891,716	-56,817,589	457,914	33.4
1999	33,802	149,244,100	7,296,378	69,567,220	-62,270,842	331,653	24.2
2000	35,154	86,973,260	4,252,026	72,349,744	-68,097,718	193,274	14.1

done using the ERDAS 400 microcomputer system housed at Ohio University's Ohio Center for Remote Sensing.

Because of the inadequate ground truth data that directly correlated with LANDSAT data this study was limited to a cluster algorithim based on unsupervised classification procedure (Bloemer et al., 1981). Using cluster algorithim twenty seven (27) clusters were set for spectral groupings in the data (ERDAS 400, 1982). These groupings were determined and correlated with forest land cover information, then reduced to three distinctive land cover categories, namely water, forested and non-forested land.

In order to monitor the forest status and determine change over the time interval for each temporal data sets, pixel counts were established for each land cover category and converted to acreages (Pixel X1.1). A comparison of these data was done to determine change through visual inspection and compared with available ground truth (Short, 1982). The percentages were calculated by dividing acreage per category by total acreage for the whole subscene for Mau East.

The results for each land cover category, as noted in Table 3, show a decrease of over five percent in forest cover over a six-year period. Visual inspection implies that Mau East forest has undergone change both within and at the forest periphery.

5. RESULTS AND DISCUSSION

The major scenario in this study is that the total forest area under woodfuel exploitation, irrespective of other uses such as lumber production and building poles, will be completely destroyed by the turn of this century. Figure 1 indicates that while consumption rate is increasing every year, the ability of forests to regenerate is declining. This drop in forest productivity is a clear sign that, as population increases (Figure 2), consumption rates will accelerate as well. In that case, unless forests are well managed, it does not seem likely they will survive the great energy pressure.

From a national perspective the future woodfuel energy for Kenya is totally disastrous if present management practices prevail. In fact, the projections demonstrate that there will be no forest left by the year 2002 unless proper management and conservation techniques are begun immediately. The trends of future fuelwood availability are further reflected in Figure 3. Decline in fuelwood availability is bound to cause serious problems in all sectors of Kenya's economy.

TABLE 3
Cluster Analysis

Category	Pixel	Acreage	Percent
	MAUEAST 1973		
Water	4242	4666.2	6.90
Forest	16931	29624.1	43.83
Non-Forest	30269	33295.9	49.26
TOTAL	61442	67586.2	99.9
	MAUEAST 1978		
Water	6151	6766.1	9.40
Forest	25168	27684.8	38.48
Non-Forest	34082	37490.2	52.11
TOTAL	65401	71941.1	99.9

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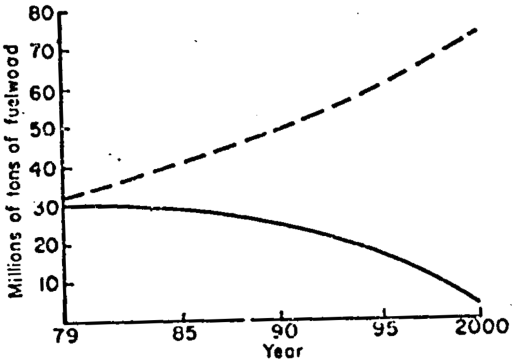

Figure 1:

—— Regenerated fuelwood
– – Consumed fuelwood

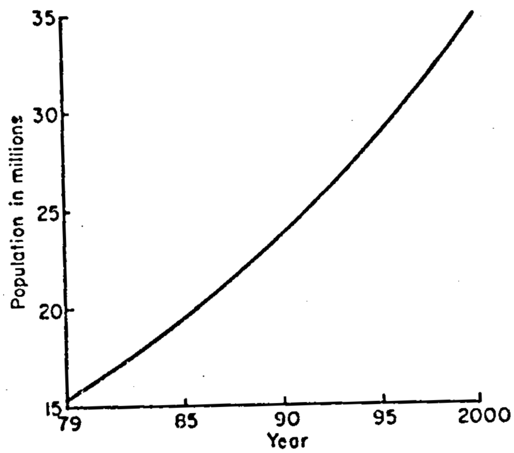

Figure 2: Annual population growth (4%)

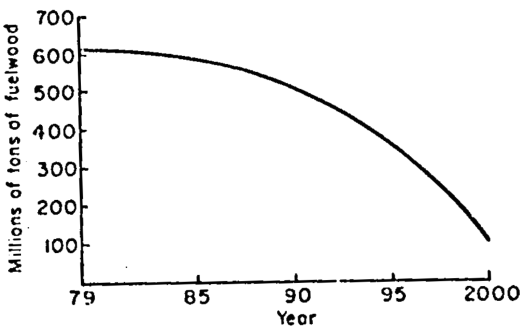

Figure 3: Available fuelwood

compares closely with the six percent decrease in forest cover over the same period as projected in Table 2. The use of LANDSAT data for forest management can enable Kenya to design reforestation programs both at regional and national levels.

The results of this study show that immediate action must be taken towards effective forest management in Kenya. The potential of forests for energy will be realized mainly through effective forest management. A number of procedures might contribute to alleviating the problems of forest conservation in Kenya.

1. Land conservation measures designed to reduce deforestation and erosion, increased reforestation with fast growing productive species to enhance economic returns should be taken more seriously. Research on various species that can be used for reforestation must be part of an integrated approach to forest management.

2. Improved land utilization practices and higher output on smaller plots would allow a sizeable population to be supported without high demand for additional land which often is obtained by clearing forests.

3. The techniques for forest management which exist in Kenya should be intensified and brought to greater use with additional inputs for regular forest monitoring and updating the data base.

4. The government should become actively involved in research programs dealing with forest management so that financial aid, allocated for resource conservation, can be used for that specific purpose and not diverged to other uses.

5. Local headmen and chiefs should be involved in management programs on the district and location level.

6. CONCLUSIONS

The measures of forest management advocated in this paper are of themselves unlikely to enable Kenya to arrest deforestation and create forests plantations to supply energy to support its growing population. What may be done is to reinforce an increase in woodlots for every farmer on individual farms for woodfuel supply. This might lead every household to assume responsibility for their energy requirements. National forests instead can be harvested to supply woodfuel in the urban areas. Illegal forest excision is most likely to continue as a strategy for coping with land shortage constraints. Strict reforestation measures may be the first step in alleviating the problem while seeking better plans for settlements. The absence of interventions to reduce the rate of decline in forest cover will result in pressure on Kenya's resources base in economic production particularly when Kenya is solely an agricultural country. The population will become increasingly impoverished as people continue to spend their meager income to meet fuel needs, and the wasteful use of resources will continue. A data base must be established by the Forest Department to ensure frequent monitoring of forest cover. There is a great need for more data on Kenyan forests before conclusive analogy on their potential for energy supply can be accurately assessed. Kenya must act fast and on a large scale if the inevitable, as projected by this model, is to be diverted.

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A METHOD FOR PEAT INVENTORY BASED ON LANDSAT DATA AND COMPUTERIZED MAPPING(*)

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ABSTRACT

Through its programs to map the wetland types of the Ontario portion of the Hudson Bay-James Bay Lowland and of the Canadian Shield region of the province, the Ontario Centre for Remote Sensing has developed an effective method based on LANDSAT data for the regional inventory of peat resources.

A preliminary delineation of wetlands is provided by a geometrically-corrected colour composite map printed from the digital LANDSAT data using a computerized colour plotting system. A digital classification is then performed to identify the location and extent of wetland types (e.g., open bog, types of treed fen and black spruce-alder swamp). A map is printed from the results of this classification using the computerized colour plotter. This colour-coded map, produced at several different scales, provides a basis for pre-selecting field sampling sites.

This paper reports the results of a trial application of the new peat inventory method over a 1700 km^2 area of Northern Ontario. Helicopter-aided spot sampling based on the LANDSAT-derived map was conducted over the entire area. Traditional transect sampling was carried out over a portion of the area, so that a comparison could be made between the two methods. This comparison indicates that spot sampling based on the LANDSAT-derived map produces results virtually identical to those produced by the transect sampling technique, in approximately one-fifteenth (1/15) of the time and with a proportionate reduction in cost.

(*) This paper was also presented at the Symposium on Peat and Peatlands, Shippagan, New Brunswick, Canada (September 12-15, 1982) and will be published in the Proceedings of that conference as well.

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INTRODUCTION

Attention has increasingly been paid to Canada's peat resources over the past few years, in light of their potential as a new energy source. The Province of Ontario is ostensibly one of the most promising locations for developing this new fuel, as it possesses some of the country's most extensive wetland areas. There is little information available, however, on the extent of actual peatland within the wetlands of Ontario, and even less information on the depth and quality of the peat deposits.

Two preliminary estimates of the extent of peatland in Ontario have been produced to date. Tibbetts (1980) estimates an area of 160,000 km^2, while Monenco Ontario Ltd. (1981) estimates 258,000 km^2. The magnitude of the figures and the large difference between them are evidence of a need for an accurate provincial peat survey.

The established peat inventory method consists in the delineation of peatland areas by airphoto interpretation and grid sampling of individual peat deposits. Although effective for the inventory of peat resources at the local level, a more rapid and less costly method is required for inventory on a regional scale.

A practical new regional peat inventory method has been developed at the Ontario Centre for Remote Sensing which is based on the following two techniques:

1. The mapping of individual wetland types and calculation of the total area coverage of each, by the digital analysis of LANDSAT data and computerized map production;

2. Spot sampling conducted on the basis of LANDSAT-derived maps.

This study presents the results of the application of this method to a test area in the Northern Clay Belt of Ontario, and demonstrates the effectiveness and economy of the method in comparison with the traditional survey techniques.

STUDY AREA

The study area extends over 1700 km^2 of Ontario's Northern Clay Belt, between latitudes 48°N and 49°N and between longitudes 81°30'W and 82°30'W. Within this area, numerous bogs and fens, varying in extent from less than 10 to over 2000 hectares, have a total area coverage of 290 km^2. The underlying mineral soil is primarily flat-lying lacustrine clay deposits. The area is only accessible by helicopter, although construction of logging roads has begun.

MAPPING OF WETLAND TYPES

A LANDSAT scene recorded on July 29, 1979, image number 21649-15384, was selected for digital analysis. This date was chosen to correspond with the season when the field sampling would be conducted, and to provide a good representation of vegetation types. Training sites were selected through the visual interpretation of the LANDSAT data, on the basis of the author's knowledge of the reflectance properties characteristic of various wetland types. A supervised classification of the study area was performed using the digital image analysis system of the Ontario Centre for Remote Sensing. The classification results were then geometrically corrected to the UTM grid of the National Topographic Series.

Two types of hard-copy maps were produced from the LANDSAT data by means of an Applicon Colour Plotter. This instrument is a computerized printer which plots lines, curves and polygons at any selected scale, on large sheets of ordinary paper stock fixed to a rotating drum. Through the use of three ink jets, each applying a single basic colour, 256 different shades can be produced. The OCRS has developed software which enables the Applicon system to print a standard map format, complete with latitude and longitude references, UTM grid lines, the annotation of features and a legend. It takes less than 15 minutes to print one map. Figure 1 is a colour-composite map of a portion of the study area produced directly from the original LANDSAT data, geometrically corrected to the UTM grid, on which bogs and fens, forest types and waterbodies can readily be identified. This format was used in the field for purposes of orientation and navigation, as topographic map sheets did not adequately identify individual wetlands and as aerial photographs were too cumbersome for this purpose. Figure 2 is a thematic map of the classification of wetland types for the same area. Twelve different themes were mapped, of which nine were wetland types. The identification of these wetland types, listed below, was based largely on the wetland classification system developed by Jeglum _et al._ (1974).

- Graminoid-rich open bog
- Open bog
- Treed bog
  - low-density (5-10% tree cover)
  - medium density (10-25% tree cover)
  - high density (25%+ tree cover)
- Poor (mesotrophic) treed fen (a transition type between bog and fen, where sphagnum covers a large part of the surface)
- Shrub-rich treed fen
- Graminoid-rich treed fen
- Black spruce-alder swamp

In addition to these wetland types, two forest types were mapped: hardwood forest and lowland black spruce forest. These are not strictly required for peatland mapping, as the wetland types can be mapped without confusion with forested areas, even if the forest themes are not specifically identified. The map provides the location and extent of individual wetlands, as well as the total area coverage of individual themes across the map.

To test the accuracy of the mapped extent of individual wetland areas, six bogs were chosen for comparison with the 1:15,840-scale standard provincial aerial photography. There was a difference of less than 2% between the area coverage measurements. In fact, when the LANDSAT-derived map was produced at a scale of 1:15,840 in the form of an overlay, the mapped bog areas were found to match precisely the areas delineated on the photos. This evidence indicates that the LANDSAT-based method of mapping the perimeters of general wetland areas is as accurate as the most effective conventional method, and is preferable to the expensive and time-consuming aerial photographic method for the preliminary delineation of wetland areas.

Within the 1700 km^2 area, the classification indicated that bogs and fens covered only 290 km^2. The classification of wetland types and the production of maps at scales of 1:100,000, 1:50,000 and 1:15,840 over the 290 km^2 area required 10 man-days in total. By airphoto interpretation, however, to delineate wetland types and to measure their extent at the scale of 1:15,840 over the same area would entail the interpretation of approximately 370 aerial photographs, then the transfer of the interpreted data to basemaps. At least two man-months would be required to complete this work, and the resulting map would be produced at only one scale.

Data gathered during the present study indicates that peat volume cannot be reliably estimated at this stage on the basis of the wetland map alone, no matter how it is produced: a range of peat depths from 1 m to 4 m was found among occurrences of the same bog or fen type in close proximity to one another.

FIELD SAMPLING OF WETLAND TYPES

Field work was conducted, using helicopter transport, with the following objectives:

1. To assess the accuracy of the identification of wetland types on the LANDSAT-based maps;

2. To conduct spot sampling of peat on the basis of these maps;

3. To compare the spot sampling results with the results of traditional transect sampling performed in one large bog containing a wide variety of wetland types.

Peat samples taken by both sampling systems were obtained using a modified McCauley peat auger. Full sampling for either transect sampling or LANDSAT-based spot sampling included the following steps. A botanist fully familiar with wetland types collected, identified and recorded plant specimens and established the wetland types on the basis of the dominant species. Other scientists, experienced in the identification of types of peat, sampled peat layers at 50-cm depth intervals;

established the decomposition value of each sample according to the von Post humification scale; determined the proportions of Carex, Sphagnum, Eriophorum, wood and shrubs present in the peat; and recorded the pH value of the surface water and of the water content of different peat layers. The full depth of the peat was measured and the underlying mineral soil identified.

The density of tree cover was estimated on the basis of two or three 100 m^2 plots, within which the number and heights of the trees were recorded, and the area coverage (including branches) of each tree over approximately 1.5 m high was measured. The area coverage and number of trees were multiplied and the product divided by the plot area to determine the percentage tree cover. The proportions of Carex and Sphagnum ground cover were identified, the prevalence of hummocks and depressions assessed, and the average height of the hummocks measured. Peat and water samples were taken for laboratory analysis of the calcium content of the water and the ash and water content of the peat. For some selected samples, the peat was examined for trace minerals.

Within the transect survey, full sampling was carried out every 300 m; in addition, a measurement of peat depth alone was made every 100 m along the transects. Spot sampling sites were selected to represent all distinct types present on the wetland map, to sample different areas of large homogeneous types, and to provide a good spatial distribution of samples. Eighty (80) spot samples were taken using helicopter transport, which in nearly all cases verified the accuracy of the wetland types on the LANDSAT-derived map. The extent of each type was verified by the visual comparison of the mapped boundary with the transitions between types visible from the helicopter. Some boundaries between fens and bogs were as well defined on the ground as they were on the map, but the transitions between graminoid-rich bog and open bog were not always as well defined. Some instances of confusion occurred on the map between poor treed fen and low-density treed bog, where the fen had extensive sphagnum cover and little tree cover. When these conditions occurred, however, it was also difficult to recognize poor treed fen on the ground. For the purpose of peat inventory, it is not critical to make a precise distinction between these types.

COMPARISON OF SAMPLING METHODS

One test bog 6.3 km^2 in area was selected which was known from the LANDSAT colour composite to contain all of the previously-described bog and fen types. Four transects along which sampling was performed in this bog are delineated on a 1:15,840-scale aerial photograph in Figure 3. Although fens, open bogs and treed bogs can be identified on this photograph, no distinction can readily be made between poor treed fens and treed bogs, and among the different densities of tree cover on treed bogs. Figure 4 shows the test bog on an aerial photograph at approximately 1:60,000-scale, on which only a few of the types can be clearly identified. However, a LANDSAT colour-composite, printed at 1:50,000-scale (Figure 5) permits all the types to be distinguished by their reflectance characteristics.

These types are then readily classified and mapped (Figure 6). It is significant that no training sites for the classification of the study area were taken from this bog: the accuracy achieved in the mapping of types is purely a result of the classification procedure. A computer print-out (Table 1) provides the area coverage for each type within a few minutes after the classification is completed. This information can then be included in the map legend.

Ten spot sampling sites marked on Figure 3 were investigated within one day. At each site, the wetland type identified on the map was found to be accurate. Figure 7(a) to (c) shows aerial views of some of the types. It took the same size of field crew 5 days to complete the transect survey, which consisted of 28 full samples and 48 separate peat-depth samples.

Table 2 compares the results of the transect and spot sampling methods. The spot sampling was completed in one-fifth of the transect sampling time; nevertheless, the difference between the results of the two methods for average overall peat thickness and average thickness by decomposition class is insignificant. The minimum depth was the same for both methods; the maximum differed only by 5 cm. Peat profiles interpolated from samples taken along each transect are shown in Figure 8(a) to (d). The thickness of the peat is shown with reference to a horizontal which does not represent the terrain surface exactly, even though there was very little topographic variation.

During 5 days of transect sampling, a distance of 7.5 km was surveyed, for an average rate of 1.5 km per day, covering 5 to 6 full samples. No significant increase in this rate can be expected because of the difficulty of walking between bog sampling points.

Five other large bogs were selected for a comparison of the sampling methods with regard to average peat thickness measurements alone. Full spot sampling was performed in these bogs using helicopter transport; the transect sampling, however, consisted only of peat depth samples every 100 m, which were completed at the rate of 2 to 3 km per day. Table 3 indicates that the mean peat thickness measurements obtained by both sampling systems are almost identical. The results presented in both Tables 2 and 3 indicate that transect sampling does not provide any information on average peat conditions in a given deposit over the above the information provided by LANDSAT-based spot sampling.

DISCUSSION OF THE COMPARISON RESULTS

From the foregoing comparison of the traditional transect sampling and LANDSAT-based spot sampling methods, it is possible to evaluate the efficiency of each method for a regional peat inventory.

Within the 1700 km^2 study area, peatland extended over 290 km^2. When high-density treed bog areas are excluded from the survey, the remaining peatland measures 200 km^2 in area. This area was surveyed by the spot sampling method within 10 days. Extrapolating from the 5 days required to sample along 4 transects in the test bog (a 6.3 km^2 area), it would take at least 150 days to complete the entire 200 km^2 area by transect sampling. A study prepared by Peat Consultants Finland Oy (1982), suggests that for a preliminary survey by the transect sampling method, 100 hectares could be completed within 1 to 2 weeks. On the basis of the lower estimate of one week, it would take 200 weeks (over four years) to complete the 200 km^2 area. The purpose of any preliminary sampling is to achieve a basis for the selection of areas for operational peat extraction. The results of the present study indicate that the spot sampling method provides an accuracy comparable to that of the transect survey method, in at least one-fifteenth (1/15) of the time. Since the majority of peat surveys in Ontario would be conducted in areas accessible only by helicopter, the field expenses per day of both sampling systems would be virtually the same. It is, therefore, safe to estimate that the cost of the LANDSAT-based spot sampling method would be, likewise, one fifteenth (1/15) of the cost of the transect sampling method.

CONCLUSION

Over the 200 km^2 peatland area surveyed in this study, no significant deposits of peat with a decomposition level of more than 5 on the von Post scale were found. The minimum decomposition level required for fuel peat is 6; therefore, the peat present in this area, where useful at all, is only suitable for agricultural use. Some areas of peat with a decomposition level of 6 or 7 were encountered, but either in isolated pockets or in thin layers.

In view of the very small proportion of fuel-quality peat to the total peatland area, the following two conclusions can be drawn:

1. The most rapid and cost-efficient survey technique available should be employed to locate areas of fuel-quality peat;

2. The preliminary estimates of the extent of fuel peat produced to date for Ontario may be unrealistically high.

ACKNOWLEDGEMENTS

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Dr. John Jeglum of the Great Lakes Forest Research Centre and Arthur Boissonneau of the Ontario Centre for Remote Sensing gathered and evaluated botanical data and established wetland types during the field study. Without their expert assistance, the study could not have been completed.

The author also wishes to acknowledge the valuable assistance of scientific staff of the Ontario Centre for Remote Sensing and the Ontario Geological Survey during the field work.

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Table 1. Area coverage of each type within the map boundaries of Fig. 6.

SUMMARY FOR FULL AREA CONTAINING 12546.0 PIXELS

		PIXELS	HECTARES	PERCENT	
FILE 1	THEME 1	0.	0.0	0.0	WATER
FILE 1	THEME 2	540.	135.0	4.3	OPEN GRAMINOID RICH BOG
FILE 1	THEME 3	435.	108.8	3.5	OPEN BOG
FILE 1	THEME 4	245.	61.3	2.0	LOW DENSITY TREED BOG
FILE 1	THEME 5	726.	181.5	5.8	POOR TREED FEN AND BOG COMPLEX
FILE 1	THEME 6	131.	32.8	1.0	MEDIUM DENSITY TREED BOG
FILE 1	THEME 7	167.	41.8	1.3	HIGH DENSITY TREED BOG
FILE 1	THEME 8	2133.	533.3	17.0	BLACK SPRUCE-ALDER SWAMP
FILE 2	THEME 1	206.	51.5	1.6	SHRUB RICH TREED FEN
FILE 2	THEME 2	89.	22.3	0.7	GRAMINOID RICH TREED FEN
FILE 2	THEME 3	230.	57.5	1.8	HARDWOOD AND SOME DENSE ALDER
FILE 2	THEME 4	7635.	1908.8	60.9	LOWLAND BLACK SPRUCE FOREST
		9.	2.3	0.1	UNCLASSIFIED
		0.	0.0	0.0	MULTIPLY CLASSIFIED
		12546.	3136.5	100.0	TOTAL

TABLE 2

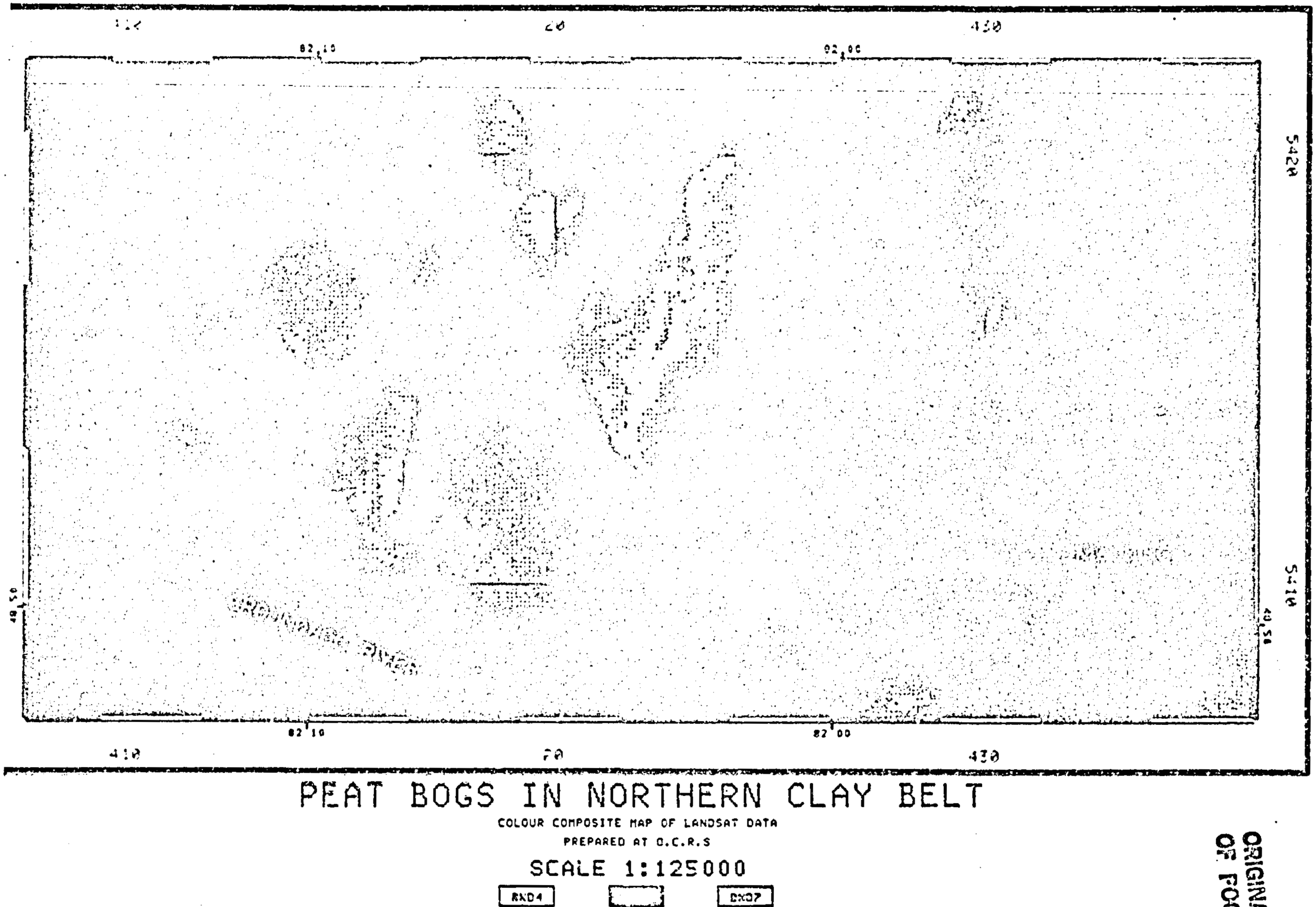
COMPARISON OF THE TRANSECT AND SPOT SAMPLING RESULTS FROM THE TEST BOG

SURVEY TYPE	SIZE OF THE WETLAND km^2	DURATION OF THE SURVEY	NUMBER OF DEPTH MEASUREMENTS	MINIMUM DEPTH cm	MAXIMUM DEPTH cm	AVERAGE DEPTH cm	NUMBER OF FULL SAMPLING SITES	AVERAGE THICKNESS OF HUMIFICATION ON VON POST SCALE (IN cm) H 1-3	H 4	H 5	H 6
TRANSECT SAMPLING (4 TRANSECTS)	63	5 DAYS	76	50	230	173	28	100	56	(FROM 3 SITES) 20	(ONLY ONE SITE) 5
SPOT SAMPLING BASED ON LANDSAT MAP	63	1 DAY	10	50	225	163	10	104	40	(ONLY ONE SITE) 50	(ONLY ONE SITE) 75

TABLE 3

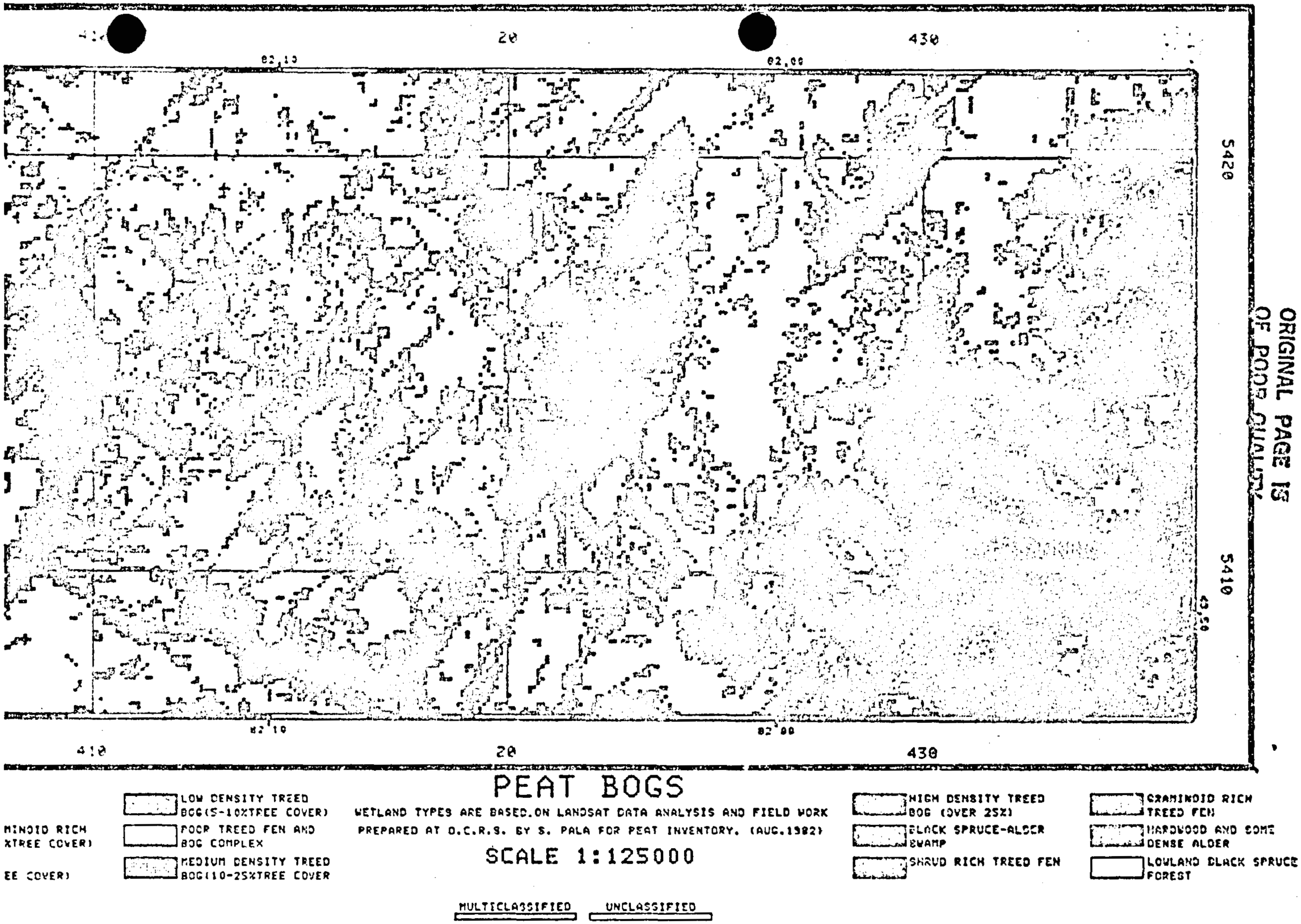
COMPARISON OF AVERAGE PEAT THICKNESS OBTAINED BY TRANSECT AND SPOT SURVEYS

GROUND TRANSECT SURVEY (DEPTH MEASUREMENTS ONLY EVERY 100m)						HELICOPTER SPOT SURVEY (FULL SAMPLING AT EACH SITE)									
SIZE OF THE WETLAND IN HECTARES	NUMBER OF MEASUREMENTS	DURATION OF THE SURVEY (IN DAYS)	MINIMUM DEPTH cm	MAXIMUM DEPTH cm	AVERAGE DEPTH cm	NUMBER OF MEASUREMENTS	DURATION OF THE SURVEY (IN DAYS)	MINIMUM DEPTH cm	MAXIMUM DEPTH cm	AVERAGE DEPTH cm	AVERAGE THICKNESS OF HUMIFICATION ON VON POST SCALE (IN cm) H1-3	H 4	H 5	H 6	H7-10
1300	24	1	80	240	178	13	1	120	300	178	120	52	50	30	–
786	46	2	30	335	188	9	1	80	260	182	93	62	10	–	–
803	40	2	35	560	295	10	1	85	400	285	170	55	33	36	–
2019	23	1	150	410	294	11	1	160	450	341	168	128	–	10	52
2731	33	2	30	285	162	5	1/2	100	300	180	123	73	30	–	–



ig. 1. A colour-composite map of a portion of the study area, produced from digital LANDSAT data. The light colours indicate bogs and fens; the dark colour indicates black spruce forest;

the magnitude of drastic forest change. A five percent decrease over a six year perio



. A thematic map showing the extent and distribution of wetland types over a large part of the study area. Once digital analysis of the LANDSAT scene was completed, it took 5 minutes to print this map.

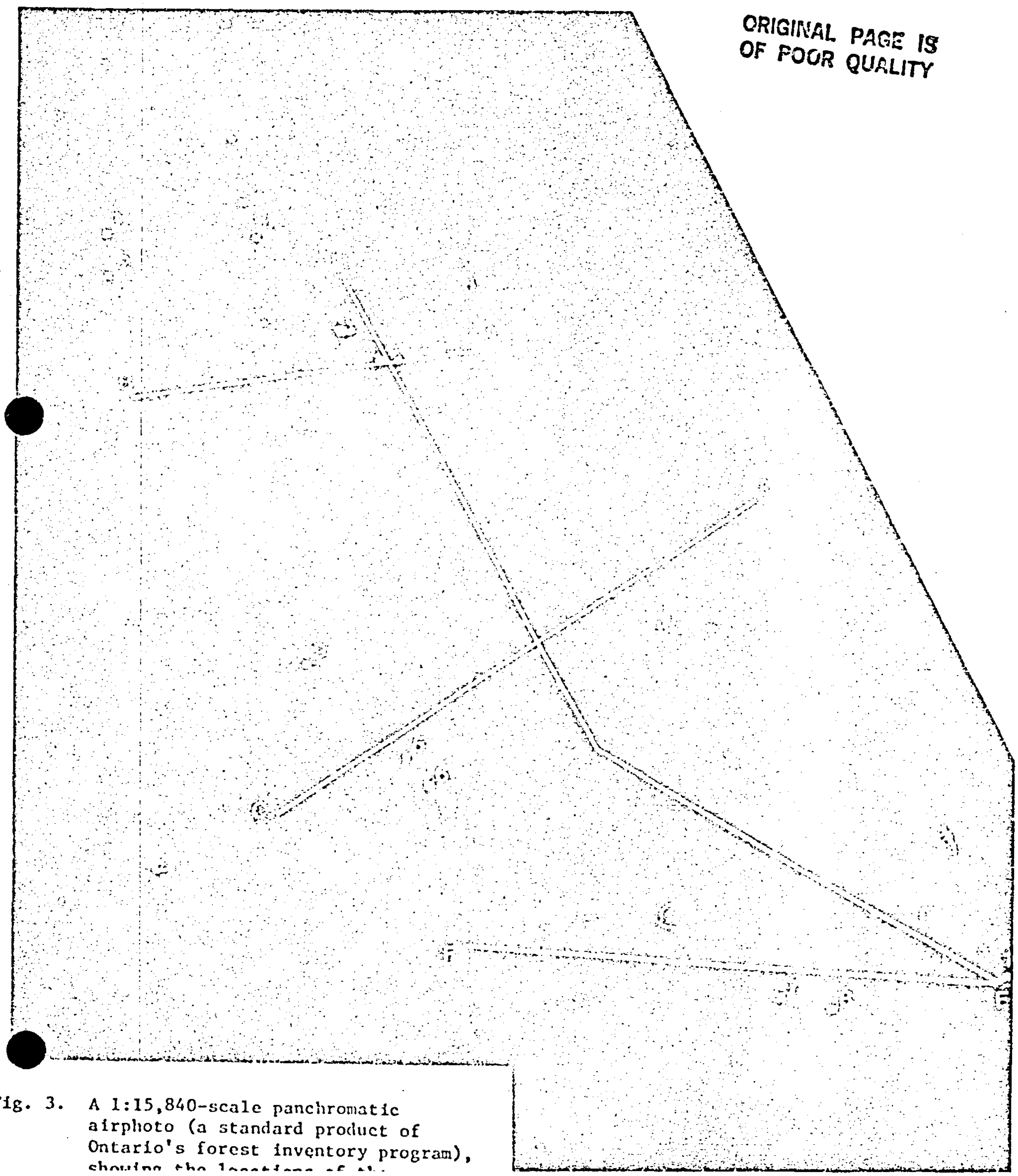


Fig. 3. A 1:15,840-scale panchromatic airphoto (a standard product of Ontario's forest inventory program), showing the locations of th

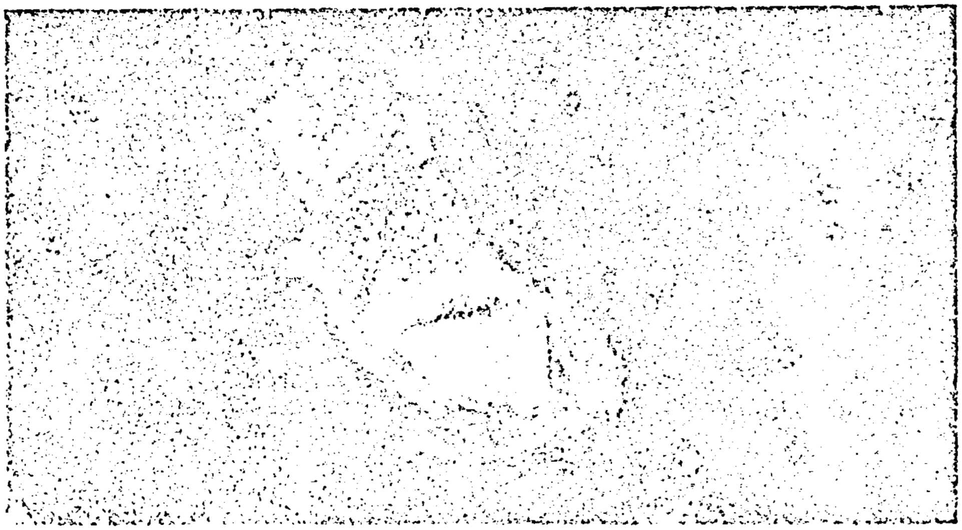
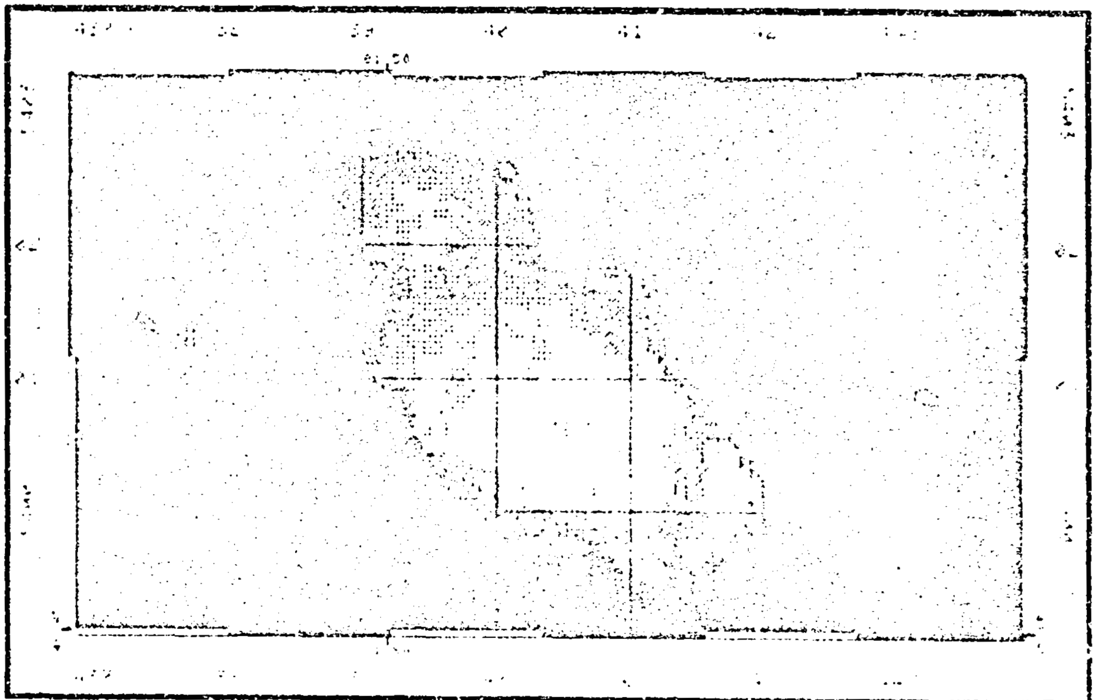


Fig. 4. 1:60,000-scale airphoto of the test bog, on which no clear distinction can be made among wetland types.



PEAT BOG

COLOUR COMPOSITE MAP OF LANDSAT DATA

PREPARED AT O.C.R.S.

SCALE 1:50000

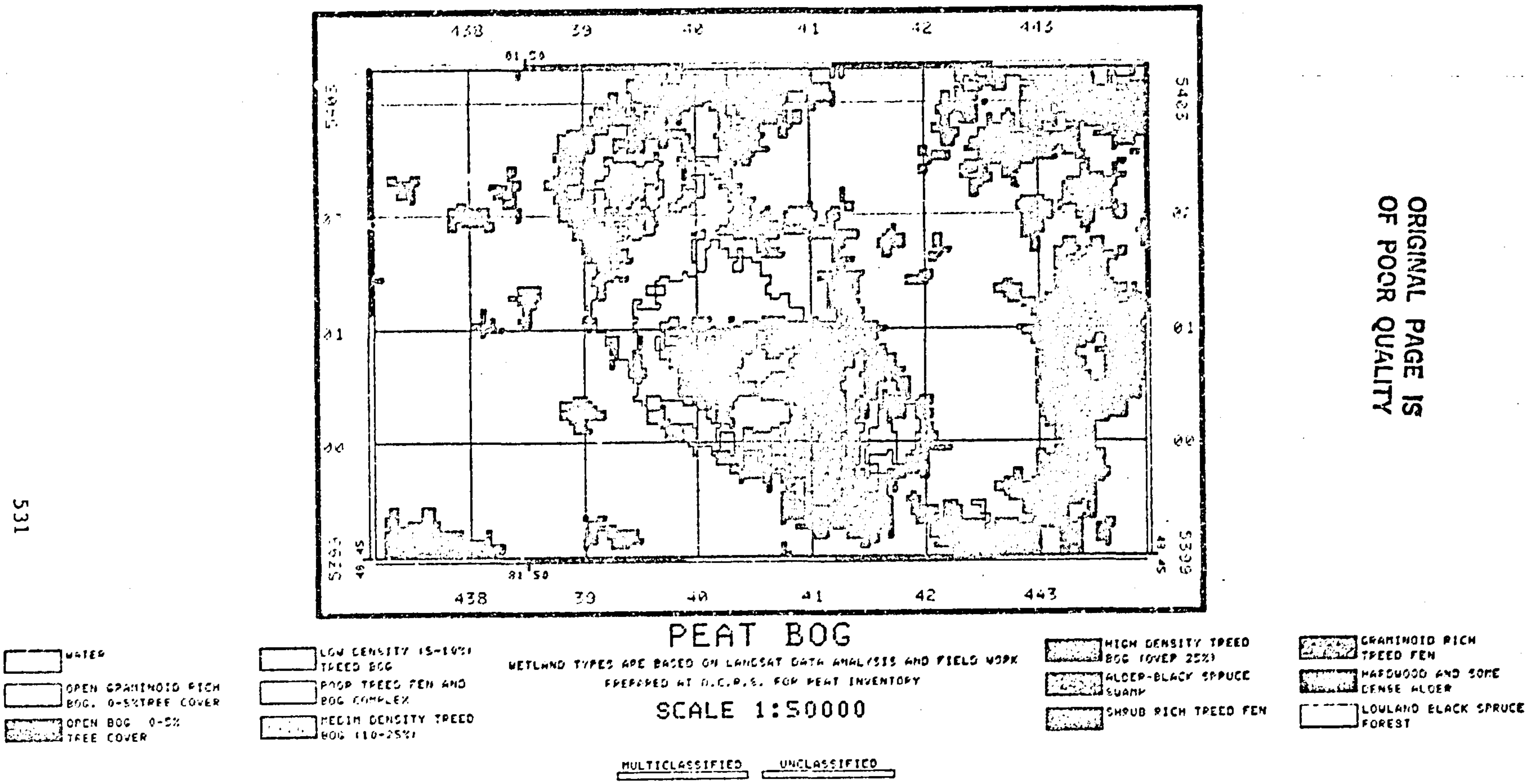


Fig. 6. A thematic map showing the wetland types within the 6.3 km^2 test bog.

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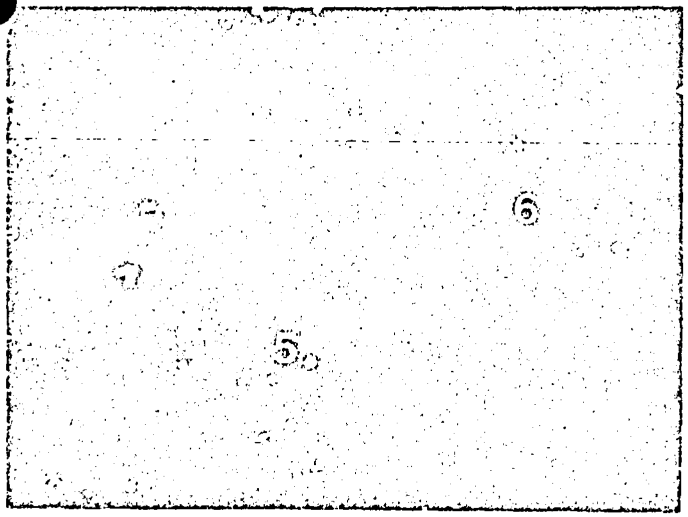
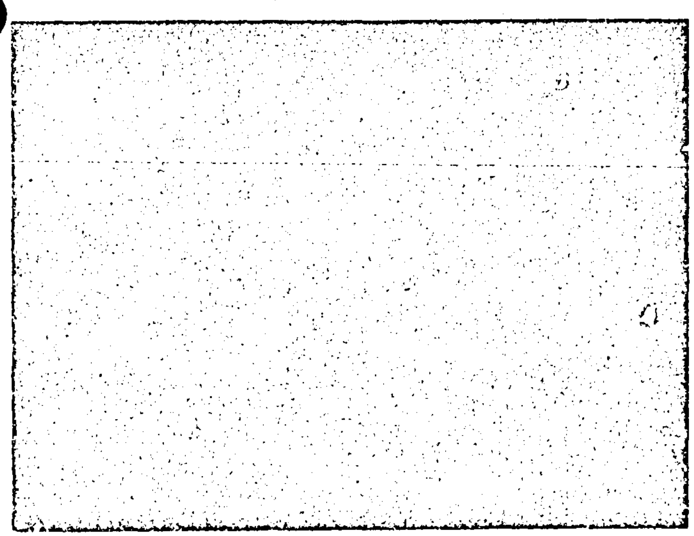
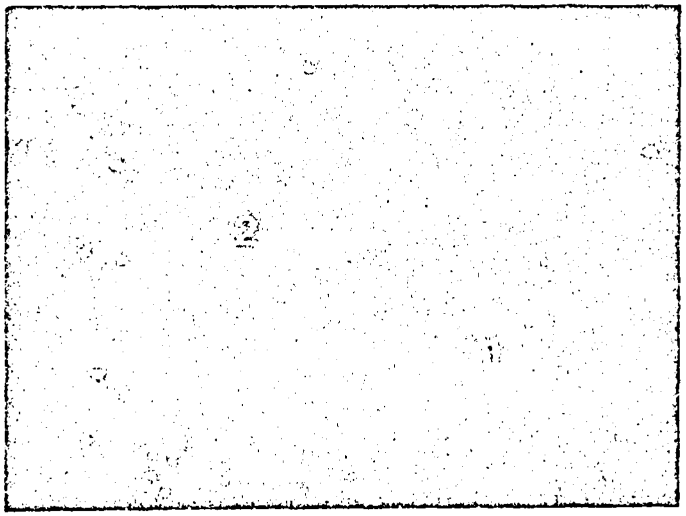


a.



b.



c.

Fig. 7a-c. Photographs taken from the helicopter showing the ground conditions of some of the wetland types in the test bog.

(a) Open bog with graminoid-rich patches. Spot sampling sites 5 and 6 (see Figure 3) were located within this type.

(b) A poor treed fen/bog complex located in the middle of transect AB (Figure 3).

(c) An area in the northwest part of the test bog containing poor treed fen (light green) and shrub-rich treed fen (dark green). These types correspond to sampling points 1 and 2 (Figure 3).

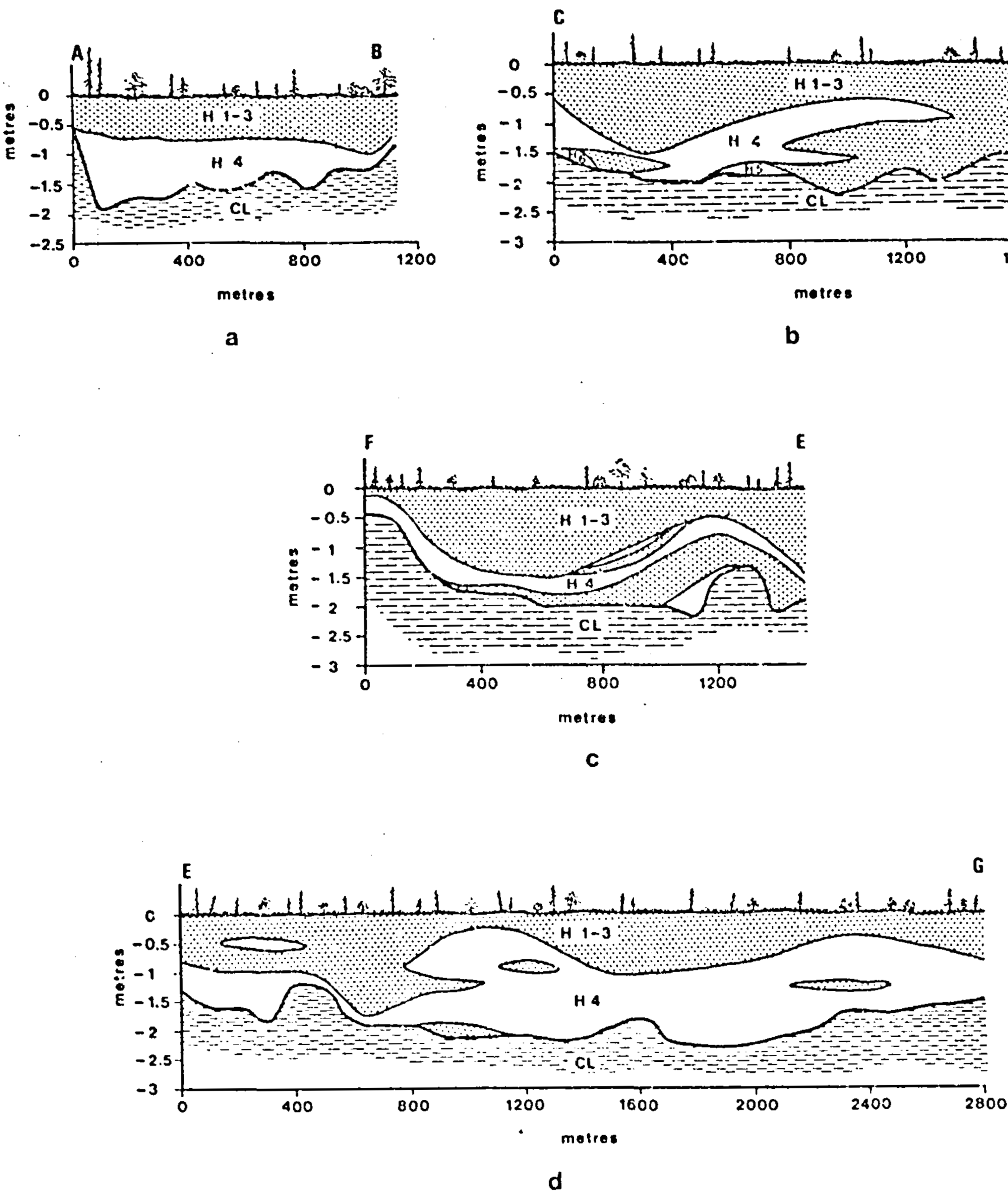


Fig. 8 a-d : Peat Profiles interpolated from full samples taken along each transect every 300 metres. Depth measurements are made every 100 m.
(Transects are marked on fig. 3)

Part 5

APPLICATIONS FORUM AND SYMPOSIA

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REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS
FOR ENVIRONMENTAL INFORMATION NEEDS

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Project Manager, ERRSAC
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Nuclear Regulatory Commission

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ENERGY FACILITY SITING BY MEANS OF ENVIRONMENTAL MODELLING WITH LANDSAT, THEMATIC MAPPER AND GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

Users Background Information:

1. Pennsylvania Power and Light (PP&L) is a public utility that provides service to about 1 million customers in a 29-county area in central-eastern Pennsylvania with test site index map locations (Figure 1). The service area includes the major population areas centered on Harrisburg, Wilkes-Barre, Allentown, Easton and Lancaster. PP&L has the responsibility of providing adequate electrical power to its customers in a cost effective manner. To accomplish this, it is essential that the company be able to predict customer-growth trends and to closely estimate future power needs for all segments within its service area.

2. The Nuclear Regulatory Commission (NRC) has the mandate to assure that all proposed nuclear power plants meet the stringent structural and environmental safety constraints dictated by present Federal regulations. Many of the factors required to evaluate proposed plant sites and estimate their effects on the regional environment can be measured and modelled by incorporating remotely sensed data into a GIS.

Description of Remote Sensing Applications in the Context of the User's Business/Mission:

In support of its requirement to accurately project future power requirements, the PP&L Company has developed a land cover data base for its entire service area; the information sources are currently based on ground and aircraft surveys. These data are now being routinely used for modelling electricity requirements in areas of future growth, predicting where generating capacity will be required, and modelling the effects of alternative generating plant and transmission line sites on the local and regional environment. The data are stored in a GIS based on a system developed by the Environmental Systems Research Institute (ESRI). This GIS is nearly identical to the one currently being used at GSFC for ERRSAC and the Earth Resources Branch research.

The NRC is responsible for compliance with the National Environmental Protection Act (NEPA, 1969) by the nuclear power industry. This act requires that terrestrial and aquatic resource inventories be made and included with descriptions of preferred proposed nuclear generating station sites and transmission corridors. This forms a part of the information required from energy corporations before environmental impact assessments can be completed and construction permits issued. In the past, applicants response to NEPA regulatory guides has been to provide ever increasing volumes of data which do not necessarily always increase assessment comprehension. Due to the site specific nature of environmental assessment, obtaining detailed information has proven to be a costly, time consuming operation. Development of an acceptable satellite-based GIS would facilitate both the preparation of environmental impact statements by power companies and assessment of the data by NRC authorities.

This cooperative project will demonstrate the methodology for incorporating satellite data into an existing operational GIS. The project will further evaluate the ability of satellite data in modelling environmental conditions that would be applied in the preparation and assessment of environmental impact statements.

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Data Integration/Remote Sensing at
Los Alamos National Laboratory: An Update

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The DIRS (Data Integration/Remote Sensing) program at Los Alamos National Laboratory was begun two years ago to develop efficient interpretive techniques for use on very large quantities of data. Some of these large data sets, for example, Landsat satellite imagery and geochemical sampling programs, represent tremendous resources for the geological sciences, but the analysis of these data is slow. The DIRS program has evolved through three phases: development, exploration applications, and, currently, regional geologic studies. This work is currently being performed on the CRAY-1s at Los Alamos.

The first phase was the development of the integration and display techniques. Twenty-two data sets from the Talkeetna $1^o x 3^o$ quadrangle, Alaska, were used, including 17 elements from the NURE (National Uranium Resource Evaluation) geochemical data base, NURE airborne geophysics, and geology. Kriging was used to interpolate most data sets to a standard 3-km grid, and all data sets were put on the same grid. Using image-processing concepts, computer routines were developed that displayed each data set as an image. Correlation analysis was investigated by overlaying three data images, projected in the three primary colors.

The second DIRS phase involved a study in the Montrose $1^o x 2^o$ quadrangle, Colorado, to identify areas of mineralization. The number of data sets used in this study was 35, and included Landsat imagery, 25 elements from the NURE geochemical data base, NURE airborne geophysics, geology, and mine and mineral occurrences. Again, kriging was used to interpolate the geochemical and geophysical information to a 1-km grid. The Landsat imagery and the geologic information were subsampled to the same 1-km grid. The routines developed in the first phase were refined, and a classification scheme was developed. In one application, areas that had similar characteristics to the uranium districts in the quadrangle were identified. Using the three-color overlay and the mine and mineral occurrence information, areas favorable for copper, lead, and zinc mineralization were identified. Field work has verified the validity of both techniques.

Work has now begun on combining data into state-wide data bases and analyzing the data on a regional scale. Geochemical atlases are being produced for Alaska and Colorado. The data bases will initially consist of NURE geochemical data and digitized geology. The Alaska data base includes over 61900 sample locations. The Colorado data base includes over 16800 sample locations. Each sample location has 55 geochemical and field parameters associated with it. The Alaska atlas will be produced with a 5-km grid cell, and

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the Colorado atlas will have a 3-km grid cell. The Alaska atlas, similar in format to the Wolfson Geochemical Atlas of England and Wales, is scheduled for printing in early 1983. The Colorado atlas will follow at a later date. Several important facts have been determined from the DIRS study: reconnaissance-scale data can provide information about mineralized areas and define mineral districts; multivariate information can be integrated and evaluated in an efficient manner; and the quantity of information extracted from an integrated data base is larger than the total amount of information extracted from each data set separately. In addition to resource evaluation, computer routines developed during this study can be used for facility siting, identification of natural hazards, and basic geological, geochemical, and geophysical studies.

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ENERGY REMOTE SENSING APPLICATIONS PROJECTS AT THE NASA-AMES RESEARCH CENTER

S. D. Norman, W. C. Likens, and D. A. Mouat[1]

INTRODUCTION

Remote Sensing can be of integral importance to the solution of energy problems. The manner in which the technology is used depends, of course, on the nature of the problem. These problems range the gamut from locating new sources of petroleum to locating power plants and transmission corridors to monitoring pollution from facilities. In nearly all instances, remote sensing is one input into a larger system for the solution of the problem.

The NASA Ames Research Center has been involved in energy projects for a number of years primarily in the role of providing assistance to users in the solution of a number of problems related to energy. The underlying thread to these projects has been the production of data bases which can be used, in combination with other sources of information, to solve spatially related energy problems.

Six project activities at Ames are described which relate to energy and remote sensing. Two of these projects involve power demand forecasting and estimations using remote sensing and geographic information systems, two others involve transmission line routing and corridor analysis, one involves a synfuel user needs assessment through remote sensing and the sixth involves the siting of energy facilities.

Fig. 4. 1:50,000-scale LANDSAT colour-composite map of the test bog, on which different wetland types are readily distinguished by their reflectance characteristics. See Figure 6 for an identification of each type.

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Land cover information generated through Landsat image analysis can be a useful component in siting analysis, specifically as an input into cost feasibility or environmental impact analyses. One of the corridor analyses and the waste disposal project are both using simulated Thematic Mapper data. The other projects all utilize Landsat Multi-Spectral Scanner (MSS data generated by Landsats 1, 2, and 3).

CORRIDOR ANALYSIS

Corridor analysis involves the selection of a route through which a resource or phenomenon can be moved in some manner. The primary consideration is that the route fulfill some least cost, environmental, or other constraints. The Pacific Gas and Electric Company (California) has cooperated with NASA in two projects specifically evaluating the potential uses for remotely sensed data in electric transmission line corridor cost analysis. The Gates to Gregg (PG&E) 500 kilovolt Corridor Analysis (Bergis et al, 1982), completed in June 1982, evaluated the costs of corridor right of way acquisition through an agricultural area in Fresno County. California.

The Pacific Gas and Electric Company had had a proposal for a transmission line between the Gates and Gregg power substations (in the San Joaquin Valley) rejected by the California Public Utilities Commission on the ground that alternatives were insufficiently examined. One of PG&E's efforts to obtain additional data involves a joint research project with NASA Ames Research Center to evaluate Landsat MSS data as a tool for obtaining information on various alternative routes. From NASA's perspective, this would be a useful demonstration of a potential application for Landsat data. As a result of the effort a map was created of agrifactors include the cost of trellis wire grounding if vineyards are present, and the high land acquisition cost of tomato fields. PG&E will be using this data in future discussions with the Public Utilities Commission when efforts for a corridor authorization are resumed.

A second corridor analysis project carried out with PG&E began in early 1982. The Transmission Line Routing Joint Research Project involves an examination of basic issues concerning features relevant to corridor analysis which can be detected with the thematic mapper sensor. The Thematic Mapper (TM) has seven spectral channels and 30 meter resolution, an improvement over the four channels and 80 meter resolution of the Multispectral Scanner. This four year project involves delineating: 1) Crop types having specific cost impact in transmission line routing (specifically tomatoes and vineyards, both of which were difficult to separate with MSS imagery), 2) the agricultural infrastructure (roads, canals, irrigation patterns, row direction), 3) riparian vegetation and small water bodies (areas of unique ecologic interest), and 4) rural subdivision developments. Because of the greater spatial, spectral, and radiometric resolution of the Thematic Mapper, the project is also developing and evaluating advanced image analysis techniques, many involving texture, in order to better utilize the added information.

POWER DEMAND FORECASTING

Another project involving the relationship of land use/land cover to resource demands (Clayton, 1981), resulted in an assessment of some relevant issues with remotely sensed as one component of a data base for power demand forecasting. It was observed that remotely sensed data by itself is insufficient to calculate energy demand; the data must also be integrated with socio-economic and demographic data in a data base. As the latter are commonly tabular data, the

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data base system would include and be able to manipulate both spatial and tabular data. Landsat data is mentioned as a major potential source for spatial land cover. A major portion of this effort centered upon change detection and prediction techniques. Presumably, this is because land cover and power demand changes are assumed to be dependent variables. The reader is directed to Clayton's paper for a description of image change detection concepts, and change prediction models.

In addition to demonstrating applications using remotely sensed data in the utility industry, Ames asked the Environmental Systems Research Institute (ESRI) to survey the current uses of remotely-sensed and other spatial data by the utility industry. Carried out by William Hodson (ESRI, 1981), the survey consisted of a questionnaire survey of 12 utility companies. The results indicated that three cited no use of any spatial data (for purposes other than billing), six used the data in a computer automated form. The final three indicated that they had used remotely sensed data other than Landsat.

Interviews were conducted with four utilities actively using remotely sensed data: 1) Pacific Gas and Electric, 2) Southern California Edison, 3) Houston Light and Power, and 4) Pennsylvania Power and Light. Each of these companies used automatic spatial data bases, including aerial photography derived land use, and with the exception of Southern California Ldison, each had used Landsat data.

ESRI formulated several conclusions based upon the results of the questionnaire survey and interviews. The larger utilities were investigating automated geographic information systems for use in siting and environmental analyses. Energy demand forecasting was conducted through econometric modeling without any spatial reference. ESRI noted that while accurate in the

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past, econometric models no longer accurately project energy demand.

WASTE DISPOSAL IMPACT ASSESSMENT

Our waste disposal impact assessment project is being carried out in conjunction with Woodward Clyde Consultants. The current test site is located in the Carquinez Straits region of San Francisco Bay (a subsequent test site will soon be developed). The purpose of the project is to investigate the use of TMS-derived data for: 1) Identification of waste disposal impacts resulting from energy-oriented facilities, and 2) monitoring existing hazardous waste disposal facilities. The development and utilization of remote sensing techniques for monitoring these facilities should be of great importance in insuring a rational location and distribution of the activity.

Util TM data is available, this phase has employed data collected with an airborne scanner. The Daedalus DEI-1260 airborne scanner mounted on the ER-2 high altitude aircraft was configured to provide data with spectral and spatial characteristics nearly identical to those of the Thematic Mapper on Landsat 4. However, in order to initiate analysis prior to the availability of fully configured TMS data, research began with an existing aircraft data set over the pilot test site to be updated with a fully configured data set. In the current effort, with an emphasis on the development and testing of digital techniques, the initial analysis of partially configured TMS data provided the basis for developing a detailed design for the next phase. The current work includes an assessment of software requirements, specification of new software development and testing of software developed and implemented in support of the project.

A reliable land cover map of the Carquinez pilot test site was required to provide the basis for determining the proximity of urban classes and water to abandoned and existing hazardous waste disposal sites. To meet this objective, three separate land cover classifications were generated, each from a different combination of bands:

- o Landsat MSS equivalent bands
- o Four optimal TMS bands
- o Five TMS bands plus texture

The Landsat equivalent band classification provided baseline information when compared to the other two classifications. The optimal TMS classification gave an indication of the level of information available in the four most favorable TM bands. The six-banded (five TMS bands plus texture) classification will encompass all available TMS bands, including texture for addition of a spatial element.

These classifications were evaluated by means of a random generation of 2 x 2 pixel sample sites so as to produce a reference data set. Ninety one (91) of these polygons were then merged into a three band image (TM equivalent bands 2, 3, and 4) and displayed. The locations of the random polygons were photo-interpreted on color infrared photographs and assessed on topographic maps.

SYNFUELS USER NEEDS ASSESSMENT

A project with the synfuels industry involved the identification and determination of remote sensing use by private companies and public agencies working with synfuels (there was an emphasis placed on oil shale development).

This user needs assessment included the development and subsequent analysis of a questionnaire soliciting information on remote sensing use (Hedrick, 1982). It was distributed to

79 companies and agencies identified by the U.S. Synfuels Corporation as being involved with synfuels in some capacity. The project also included on-site interviews with a selected cross-section of these companies and agencies.

FACILITY SITING

An on-going project involves an integration of remotely sensed data with ancillary data for energy facility siting in Utah. The selection of a facility site requires several stages of analysis and the evaluation of numerous factors. Although only a small physical site may need to be located, large regions must be investigated. The site selection and assessment process involves three stages: (1) A regional overview to eliminate areas that are unsuitable and to select candidate areas; (2) More local reconnaissance to select feasible sites within the "candidate" area; and (3) Site specific investigations. The information layers or "screens" utilized at each level are progressively more detailed and site specific, and as such, more expensive to acquire. The siting process currently involves extensive ground data collection, aerial photography analysis, and review of published data that is often unsuitable, dated, or not available. TM based techniques could reduce this total effort and in the process, result in considerable cost-saving in a timely manner.

Facility siting involves the detection, identification, and analysis of physical and cultural factors. The selection of screens and the relative importance of those screens varies with each stage of analysis. The types of factors analyzed for site selection and waste disposal assessment may be the same but for waste disposal impact assessments, more emphasis is placed on land cover, hydrologic factors and characteristics.

The facility siting test site involves the location of ideal sites more-or-less through a process of elimination. Geology,

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surface and ground water, and land cover factors are used in distance modeling, or information layers, in the siting process. Distance models depict the proximity of any point to a geologic fault or to surface water. Certain land cover types may be more-or-less desirable than others, and the land cover map may be integrated into the model for elimination of those sites of undesirable cover type.

Digital analysis techniques are used for generation of the data factors. Techniques such as histogram stretching, edge enhancement, and multi-channel classification are performed using the TM channel equivalents represented by the TMS data. As the project ensues, other techniques that are particularly successful will be investigated and possibly utilized in the analysis. Digital terrain data are processed for generation of slope, slope aspect, and elevation using ESRI software. Statistical significance tests are employed to aid in interpretation of results, quantification, and final accuracy assessments.

Output products are generated upon completion of the digital analysis. Selected factors are reproduced in the form of color-coded maps, line-printer maps, and photographic positive and negative film. Additionally, factor or screening maps are provided for integration into the GIS. WCC may in turn be requested to produce color-coded line-printer and plotter products.

Evaluation of the resulting data includes: (1) An accuracy assessment of selected products, (2) A cost comparison between TMS-derived data layers and traditionally generated data layers, (3) A technical assessment of the information contents (level of detail) of TMS-derived data layers.

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A METHODOLOGY FOR ASSESSING THE REGIONAL TRANSPORTATION ENERGY DEMANDS OF DIFFERENT SPATIAL RESIDENTIAL DEVELOPMENT SCENARIOS: A CASE STUDY FOR THE UPPER HOUSATONIC RIVER BASIN, MASSACHUSETTS

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1.0 INTRODUCTION

In 1980 the METLAND research group at the University of Massachusetts began research into three separate, but related, areas of concern to landscape planners. The three studies, which all have energy as a common denominator are:

1. Assessment and planning of renewable energy resources
2. Study of energy land use relationships for future residential planning efforts
3. Developing bio-energy management scenarios and assess impacts thereof

This paper focuses on the second topic mentioned above, more specifically it suggests a method whereby regional landscape planning efforts can be aided by the use of a geographic information system (METLAND) to determine sites for more energy efficient residential and mixed use (commercial, recreational, institutional, light industrial, etc.) developments within a study area.

Initial research into energy efficient land use management has elucidated a number of residential development planning options which are becoming increasingly more popular in the western world, especially those areas experiencing significant housing demand due to population growth and relocation. Especially prominent is the notion that the spatial location of new developments have a marked effect on the energy demands of these developments. As noted by the primary impetus for the readjustment of location patterns (and land use management techniques) within urban areas are in the areas of automobile transportation and residential heating and cooling which comprise the largest consumers of energy in the residential sector (13% and 12% respectively) (unidentified source). Hence, three development options/scenarios were formulated to serve as the basis for comparison of different management techniques. This project of the METLAND research greatly facilitated the location of land parcels suited for residential and mixed land use developments in the Upper Housatonic River Basin Study Area in Berkshire County, Massachusetts. The next section describes briefly the three development options. Following that will be a discussion of the methodology developed for this research and finally a section covering the results of an application of this methodology.

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2.0 THE MANAGEMENT/DEVELOPMENT OPTIONS

As denoted briefly in Figure 1, there are three distinct land use management development options with corresponding characteristics and criteria for implementation. This figure summarizes a comparison of these development options as well as some of the assumptions upon which this study is based. The first of these options is the most energy efficient of the three and requires the least amount of developable land yet an important criterion, is the fact that these 640 acres stated and assumed as necessary for a CUD must be for the most part contiguous. This insures that most dwelling units within this type of conceptual development are within walking distance to many of the non-residential land uses (shopping and working and recreation places) offered within the routine of the total development. The CUD option is much like the name implies meaning that the development is comprehensive in the sense that many different, but compatible, land uses are included in this development so as to insure that many services and opportunities can be offered in close proximity to the residents.

The second development option, a Planned Unit Development (PUD) is similar in many ways to a Comprehensive Urban in that there is a higher residential density than in traditional subdivisions and there is an attempt to integrate generally urban-related land uses into the total residential plan. However, the degree of this integration is not nearly as great as with a CUD, meaning that commonly recreation open space and often convenience-type shopping facilities are often located at a central portion of the development. In some instances, office space has been integrated into PUD's to provide limited employment opportunities for those who live there and thereby decrease the overall transportation energy demand of the community.

The third and final development option is that which provides a baseline for comparison for the two previous options. This scenario, a traditional, dispersed-type growth is noted as having greater energy inefficiencies both with respect to space conditioning and transportation as noted in Figure 1. The lack of land use mix and common open space greatly increased the amount of energy that must be expended to travel for work, shopping, and recreation trips. Thus, this type of community development can best be described as grossly inefficient.

Examination of energy-land use relationships in both rural and metropolitan areas of the country has revealed that the residential sector was accountable for approximately 20% of the total principle energy consumed in the United States in 1970 (Carrol, et al., 1977). In regions such as New England, where 72% of all primary energy consumed is based on fossil fuels, particularly imported oil, the need to increase the efficiency of the use of this resource becomes paramount in the development of long-term growth scenarios. Inherent in the development of these scenarios is the understanding that they will be formulated as a means to stabilize regional and national economies through the introduction of less capital and energy

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Comparison of Development Options/Scenarios

OPTION	OPTION #1 SCENARIO	OPTION #2 SCENARIO	OPTION #3 SCENARIO
Type of Development/land use management	Comprehensive Urban Development (CUD)	Planned Unit Development (PUD)	Decentralized Traditional Development
Total Persons Accommodated	10,000	10,000	10,000
Total Area Required	640 acres	1000-1500 acres	1600-3000 acres
Dwelling Unit Density	3-4 persons/D.U.	3-4	3-4
Residential Density	10-15/acres	5-10/acres	1-2/acres
Overall Density	3-4 DU/acre	2-3 DU/acres	1-2 DU/acres
Commerical land	10%	5%	0%
Recreational Land Use	20%	15%	5%
Other Land Use (Industrial, Institutional)	5%	0%	0%
Transportation Related			
% Reduction in Shopping Trips	80%	50%	baseline
% Reduction in Work Trips	70%	20%	baseline
% Reduction in Recreation Trips	60%	40%	baseline
% Reduction in Institutional Trips	50%	-	baseline
Total Trip Reduction	70%	30%	baseline
Total Energy Savings (Conservative)	30-40%	20-30%	baseline
FIGURE 1	*Sterling, et.al. Earth Sheltered Community Design	Real Estate Research Corporation April 1974	Real Estate Research Corporation April 1974

the introduction of less capital and energy intensive spatial patterns of new residential development. As financial burdens to homeowners increase yearly due to inflating transportation, heating, and electrical costs, it is clear that there is a need to develop a method whereby residential and mixed land use development scenarios can be constructed as to minimize these costs. One implication might be to shorten the distance between home and work as has been advocated by many comprehensive urban developments (CUD) and to a lesser degree by planned unit developments (PUD) around the world.

This research is based on the presumption that with the use of computed-aided landscape planning process comprehensive urban developments incorporating residential, commercial, recreational, light industrial and other land uses can be located in a study area that will be at the same time energy efficient, aesthetically acceptable, and create a minimum degradation to an existing natural environment. METLAND* research objectives; namely, physical landscape planning in a natural resource sensitive manner, has been one of the driving forces which prevented the advocation of extremely dense population centers often denoted as a state of maximum energy efficiency. (For further discussion consult pages 1-22 in Bulletin #637 and pages 1-16 in Bulletin #653).

This paper will discuss a means by which different regional land use development options/scenarios can be compared in terms of their relative energy efficiencies. It is presumed that future land use planning decisions will be aided by computer-based geographic information systems and furthermore, that energy will become increasingly more important issue in land use policy and planning. Therefore, a methodology has been developed whereby different spatial allocations of land parcels suited for residential and mixed use developments can be compared in terms of the transportation energy demands inherent in the location of the parcel in the region.

2.1 Methodology

The general flow diagram depicted in Figure 2 represents an overview of the significant steps in this procedure. The text which follows is meant to accompany this diagram in order to make the energy-efficient landscape sensitive routine more understandable.

Step one - establish over landscape planning objectives. This first step involves the formulation or realization of planning objectives. In this case, these objectives align closely with METLAND objectives established at the outset of the research and development of the Metropolitan Landscape Planning Model. It is stated that the research is designed "to facilitate land use decision-making based on environmental factors for the general public good". (Fabos, Joyner, and Greene, 1978, p. 3) In this instance, the primary objective is to determine whether or not a duel objective that is energy-efficient and landscape-sensitive residential or mixed use development can occur in the Upper Housatonic River Basin Study Area.

*according to Metropolitan Landscape Planning, an interdisciplinary research effort at the University of Massachusetts since 1970.

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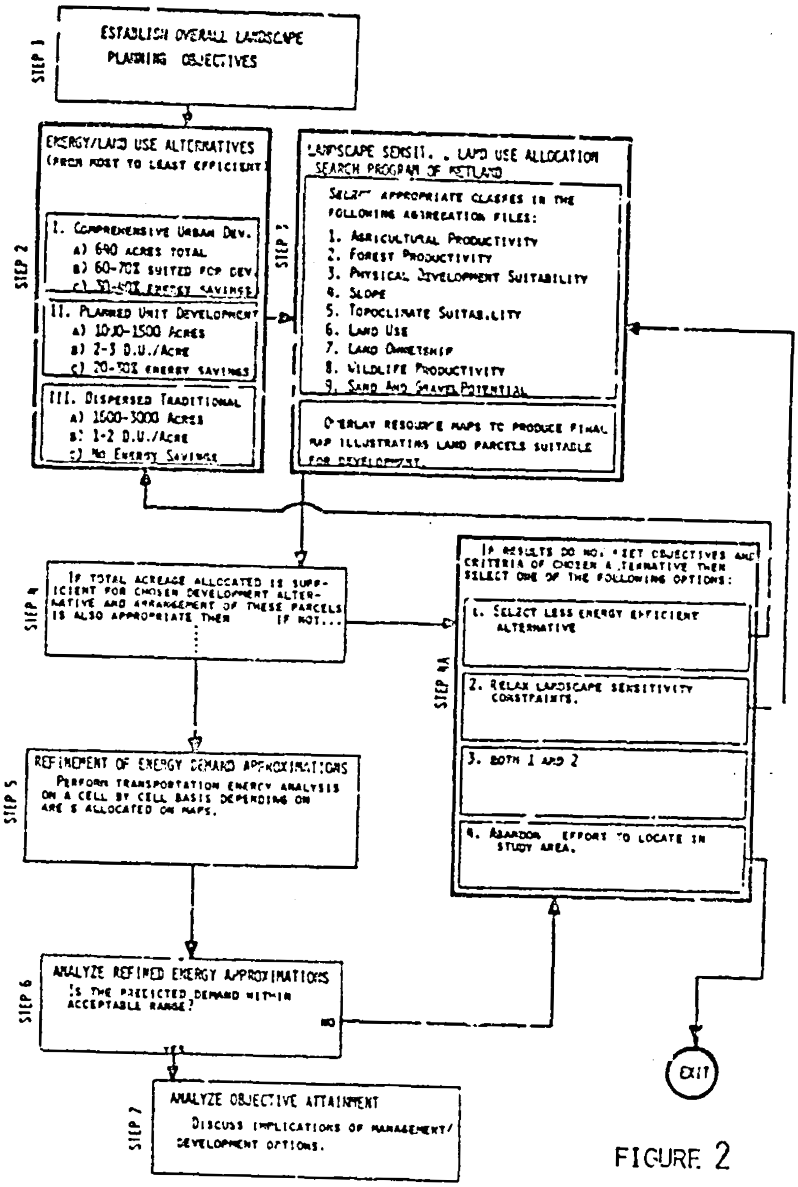

FIGURE 2
METHODOLOGY

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<u>Step two - select energy land use alternative.</u> Once the objectives have been formulated in step one, the next task, that of selecting the management development option, is performed. One of the three options presented earlier in Figure 1 is selected in conjunction with the landscape and energy constraints which are associated with it. These constraints will become more clear in the role they play when they analyze the results of the search routine performed in Step 3.

<u>Step three - landscape sensitive land use allocation search program of METLAND.</u> This step is a more functional step as opposed to steps one and two which could be considered abstract. In this step, a computer search for co-occurrences on overlaid resource and other data maps provides the basis for searching for land parcels for residential or mixed-use development which are sensitive to the environmental/landscape resource base. By indicating what classes or rankings are appropriate in each of the following data files (see Figure 2, Step 3) a "search" can be performed similar to that done in the past with established METLAND software. The interactive format provided by the ILPP system (interactive land use planning program) allows the researcher to sit at a computer terminal and enter information from his/her menu an immediately get a graphic printout/display of the results of overlaying these data (map) files. For example, the computer prompts you with the following questions: Do you want to consider agricultural productivity type in your overlay? Classes are A-B-C-D-E. One must specify whether or not he/she wants to include agricultural productivity, and if so, what classes in the aggregation file (A complete discussion on the aggregation of data files can be found in Figure 3.) After answering prompts similar to this for all data files, the computer overlays the desired information and displays co-occurrences of the ranked variables input by the user. This map and a report of total acreage allocated by the search procedure are presented as output for consideration in Step 4.

<u>Step four - analyze results.</u> This step is the first major decision making portion of the methodology. In this step the user/researcher must analyze the results of the search routine to determine whether or not the results coincide with the objectives established in Step 1 and fit the optin in Step 2. If the results are sufficient, then one can proceed to Step 5, if not there is another decision making step that must be performed, Step 4A.

<u>Step four a. - alter objectives and constraints.</u> This step is necessary if the results of Step 3 are not coincident with the initial objectives of the research and the researcher user wants to alter some of his or constraints by selecting one of the four options listed in Figure 4.2 (Step 4A). This step provides a feedback loop of sorts where one has the option of changing a few of the variables or rankings performed earlier in the methodology or, in an extreme ease, to abandoned search procedures in this particular study area.

The first option allows the user to select a less energy efficient alternative from Step 2. This situation may arise if the total acreage allocated is sufficient for the previously-chosen alternative yet the parcels are not "clumped" or "aggregated" in such a manner as to make implementation of the chosen alternative feasible.

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The second option permits the user to perform another search program after "relaxing" some of the landscpae sensitivity constraints. This "relaxing" is usually accomplished by adding more classes for consideration in one or more of the variables in order to increase the number of co-occurrences and hence allocated land on subsequent search "runs".

The third option permits the user to do both the first and second options while the fourth option, a rather drastic one, can be chosen if after many runs it is user's opinion that future development may not be feasible on the study area.

Step five - refine energy demand approximations. This step constitutes one of the more recent additions to the METLAND planning approach. In this step the transportation energy demand of the development option displayed in Step 3, the search routine, is tested in the following manner. The transportation energy consumption is based on the following variables which stem from the assumptions made earlier.

1. the number of average daily trips made (home-based work and non-work only. (HBW and HBNW). NOTE: (HBW and HBNW includes work, shopping, and recreation trips made from home)
2. the mode by which the trips are made
3. the average trip length for HBW and HBNW trips
4. the road network used for the trips is broken down into three levels of roads depending on the average speed travelled on them.

The above variables are used to better approximate the transportation energy demand for each quadrant in the data base on a per dwelling unit basis. Each quadrant represents 4 UTM grids from a 1:25,000 scale USGS topographic map. (approximately 450 acres).

This demand is approximated by determining the distances on three levels of roads (primary, secondary, and tertiary) to work, shopping and recreation places within the study area from a centroid in each quadrant. As speed varies on each level of road so to does the energy consumption. A study performed by P.J. Claffey estimated the running costs as a function of fuel consumption on these three different levels of roads. Thus, the factors estimated in Claffey's work multiplied by the distance travelled on each level of road in the network will give an approximation as to the energy consumption on that particular trip. Multiplying this by the average number of daily trips made per dwelling unit for each of three trip types mentioned above yields a dwelling unit indice for comparison among other quadrants.

Once the energy consumption per dwelling unit per quadrant has been calculated, the total energy consumption for the proposed development scenario can be determined based on the density of the development in the scenario and the portion of land in each quadrant allocated for residential growth development. As mentioned earlier, a population influx of 10,000 persons will be spatially allocated in the study area. Consequently, the transportation energy demand will vary depending on the specific location of new residences.

The total transportation energy consumption for each development scenario can be determined with the following equation which computes the total demand for all the grid quadrants in the study area.

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LAND USE CATEGORIES ARE AGGREGATED IN A MANNER SUCH THAT THE "A" CLASS REPRESENTS LAND USES WHICH OFFER MINIMUM CONFLICT TO RESIDENTIAL DEVELOPMENT (I.E. ABANDONED LAND) AND "E" CLASS REPRESENTS AREAS OF MAXIMUM CONFLICT TO DEVELOPMENT (I.E. PRESENT URBAN INDUSTRIAL USE, WETLANDS, OR FRAGILE AREAS

OWNERSHIP IS CLASSIFIED AS --
A = PUBLIC LAND
B = QUASI-PUBLIC LAND
C = PRIVATE LAND

PHYSICAL DEVELOPMENT SUITABILITY IS BASED ON SOIL CAPABILITIES FOR RESIDENTIAL DEVELOPMENT DIVIDED INTO 3 CLASSES --
A = MOST SUITABLE
B = MODERATELY SUITABLE
C = LEAST SUITABLE

TOPOCLIMATE SUITABILITY IS BASED ON ASPECT, DIVIDED INTO 8 CLASSES
A = S
B = SW
C = W
D = NW
E = N
F = NE
G = E
H = SE

FOREST PRODUCTIVITY IS DIVIDED INTO 5 CLASSES. BASED ON SOIL CAPABILITY FOR TIMBER PRODUCTION. WHERE CLASS "A" SOILS ARE MOST PRODUCTIVE AND CLASS "E" SOILS ARE LEAST PRODUCTIVE.

AGRICULTURAL PRODUCTIVITY IS DIVIDED INTO 5 CLASSES, BASED ON SOIL CAPABILITY FOR POTENTIAL AGRICULTURE PRODUCTION. WHERE CLASS "A" SOILS ARE MOST PRODUCTIVE AND CLASS "E" SOILS ARE LEAST PRODUCTIVE.

SLOPE IS DIVIDED INTO 5 CLASSES -
A = 0-3%
B = 4-7%
C = 8-15%
D = 15-25%
E = 25+%

FIGURE 3

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$$\text{Total Scenario Transportation Energy Consumption} = \sum_{i=1}^{n} \sum_{j=1}^{m} e_q D_q \text{ where}$$

e_q = energy consumption per quandrant q per D.U.

D_q = # of Dwelling Units in quadrant q

n = number of rows of quadrants

m = number of columns of quadrants

Determination of the transportation energy demand of this scenario will serve as an indice for comparison with other more or less efficient spatial arrangements of residential and mixed use development.

This figure when combined with approximations for space conditioning energy consumption will result in an index for comparison of the energy consumed for different scenarios for new residential development in the study area.

Step six - analyze results. The following step is much like Step 4 in that a decision is made depending on the results of the previous procedures and then one of two options is taken. If the results are sufficient for the planning objectives established in Step 1 and if the researchers professional opinion no better solution is possible, one can then proceed to the final step, Step 7. Should he/she think that a different spatial arrangement of allocated parcels developed under different design concepts may result in lower overall energy demand than Step 4A need to be performed again.

Step seven - discussion of implications; analysis of objective attainment. This is the fianl step when the researcher analyzes all results in terms of initial or revised objectives and makes recommendations and formulates policies concerning possible community of regional implementation strategies.

Furthermore, one can discuss the implications of implementing the selected development option. Implications in this sense can be environmental impacts of conflicts with existing or future land uses.

2.2 Conclusion to Methodology

This methodology provides a means by which regions projecting reasonably substantial population growth (e.g. 10,000) can establish plans for this growth in more energy-efficient spatial patterns with the aid of an existing geographic information system (METLAND) and a relatively nominal data base. Thus, it can benefit regional planners as well as policy makers as they should adapt and implement growth and land use policies commensurate with the changing political, economic and social environments in a town or region.

However, it must be ascertained that though it is hypothesized that such magnitudes of residential development can be accomplished with little or no conflict with existing land uses, hazard or special resource area, this may be somewhat unrealistic in regions with a sparse availability of such land. As such, the methodology outlined in Figure 2 provides a means

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by which constraints imposed by the aforementioned existing condition can be relaxed to some extent reflecting a possible change in land use policies or zoning patterns. Use of this methodology in conjunction with previously established means of assessing the economic value of these special resources can provide an index for comparison of new growth policies with those that exist to determine patterns of residential development which achieve overall efficiency goals.

3.0 APPLICATION OF METHODOLOGY & DISCUSSION

In the following section, verification of the aforementioned methodology will be illustrated with the use of data collected by the USDA Soil Conservation Service and the METLAND research team for the Upper Housatonic River Basin Study Area. The methodology covered previously allows the user (planner, developer, researcher) to perform analysis of the development suitability potentials for energy efficiency and/or landscape sensitivity on an interactive basis with the University of Massachusetts main frame computer. The interactive capability of the procedure allows for scenario formulation, display, and feasibility analysis while sitting at the computer terminal. More importantly, if an "alternative" or "run" of the program (procedure) results in a spatial display of development opportunities which doesn't meet pre-established criteria, the interactive capabilities of the methodology allow the "user" to relax one or more of the constraints imposed by energy-efficiency or landscape sensitivity objectives.

Hence, what will follow here will be a graphic and textual description of the application of the procedure. As stated earlier, the primary objectives are to determine whether the two goals of energy efficiency and landscape sensitivity can be accomplished while siting residences and dependent land uses for 10,000 people in the study area. With this in mind, one can move to Step 2 and in accordance with the above objective select alternative 1, a comprehensive urban development, as the land use management technique to be applied. Subsequently, one moves to Step 3 which involves a question (prompt) and answer (input) session with the terminal with regards to which classes is the available variable categories the user wishes to include for consideration in this particular search and overlay run. Because landscape sensitivity is an objective, one obviously would select those classes for development consideration which would exert minimal impact on the existing landscape. A summary of these selections appears in Figure 4 "First Run".

At this point it may be helpful to clarify the ranking procedures for each of the data files.

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FIGURE 4

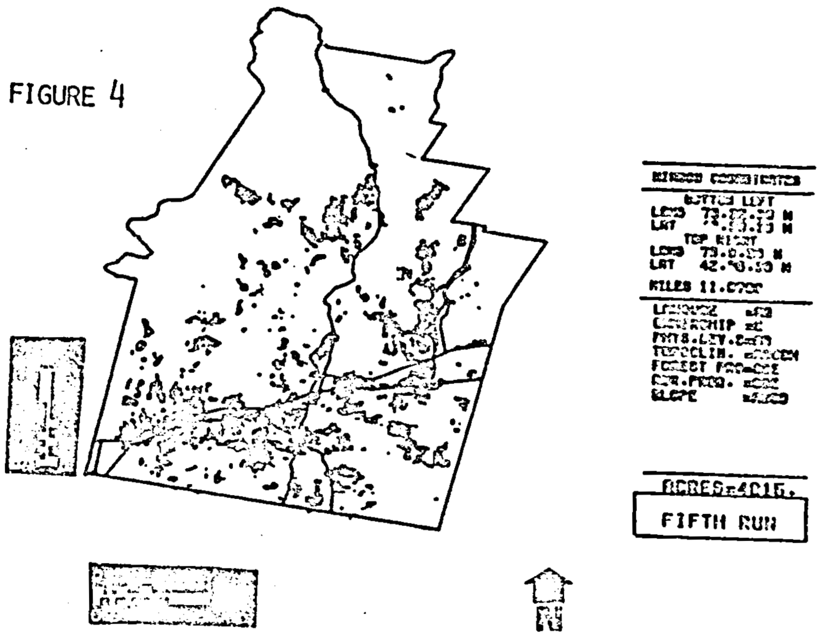
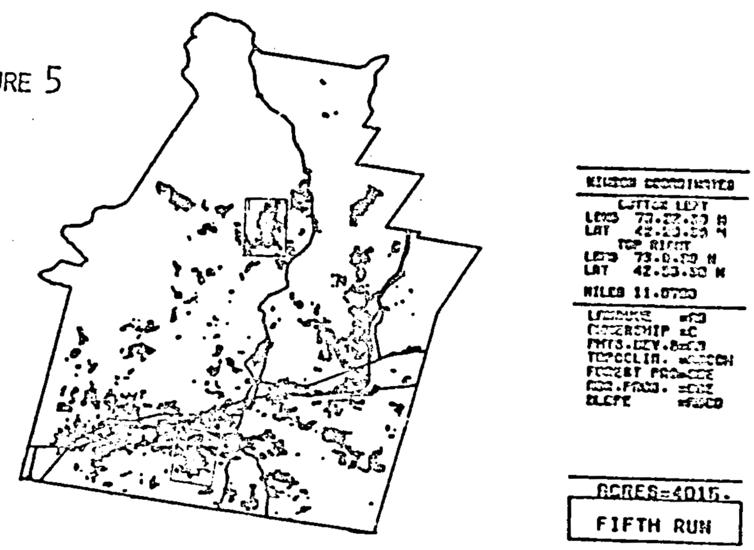


FIGURE 5



As one can see from the map displayed in Figure 4, the acreage allocated is not sufficient for the chosen alternative, therefore Step #4A must be performed. If one selects the second option in 4A this involves relaxing one or more of the constraints in Step 3. By relaxing (adding categories) in Physical Development Suitability (B) and Topoclimate (L and G) the new display in Figure 5 ("Second Run") was presented. Analysis in Step 4 again reveals that this display is not sufficient for the chosen alternative due to insufficient aggregation or clumping at the parcels that is necessary to implement a C.U.D. (need 640 contiguous acres). If again one goes to Step 4A and selects Option #1, this time meaning that a less efficient alternative is chosen, one can again see that the results are not sufficient for implementation of a P.U.D. Notice that the acreage is barely sufficient but again one must keep in mind the P.U.D. concepts mentioned earlier which also require a more contiguous availability of developable parcels in order for implementation.

Three runs later on the fifth run (See Figure 5) sufficient amount of contiguous land was allocated by relaxing land use constraints to include some low level forest lands and forested residential land. It would appear from the printout that there is more than one opportunity to develop a C.U.D. or P.U.D. in this study area. Thus, one is now ready for Step 5 which will compare the transportation energy requirements of different selected areas.

The transportation energy requirement of Area #1 in Figure 7 is computed as follows:

(Quadrant)	work trip energy	40,690 BTU's
(I,J;9,10)	shopping trip energy	13,936 BTU's
	recreational trip energy	20,943
	Total energy/dwelling unit =	75,569
	-70% (C.U.D.) =	22,670.7
	(seep)	

as compared to that of Area #2 in Figure 6 which is;

work trip energy	16,809.0 BTU's
shopping trip energy	12,477.4 BTU's
recreational trip energy	4,745.0 BTU's
Total energy/dwelling unit =	34,031.4
-70% (C.U.D.) =	10,209.42
(seep)	

As one can see, the transportation energy difference between these two C.U.D. options is close to two fold. Multiply the 10,000 BTU's saved per dwelling unit by the population of 10,000 and the resultant savings can be as high as 100,000,000 ($1x10^8$) BTU per day. In more appreciable terms, this translates to approximately 3,000 Kw (kilowatts) or enough energy to heat an average dwelling (2,500 ft^2) for one year. When compared to the savings over the conventional or traditional dispersed development, the savings would be even greater. While both could be constructed with the same inherent space conditioning energy efficiencies location in the study area can play a major role in further increasing total residential

FIGURE 6

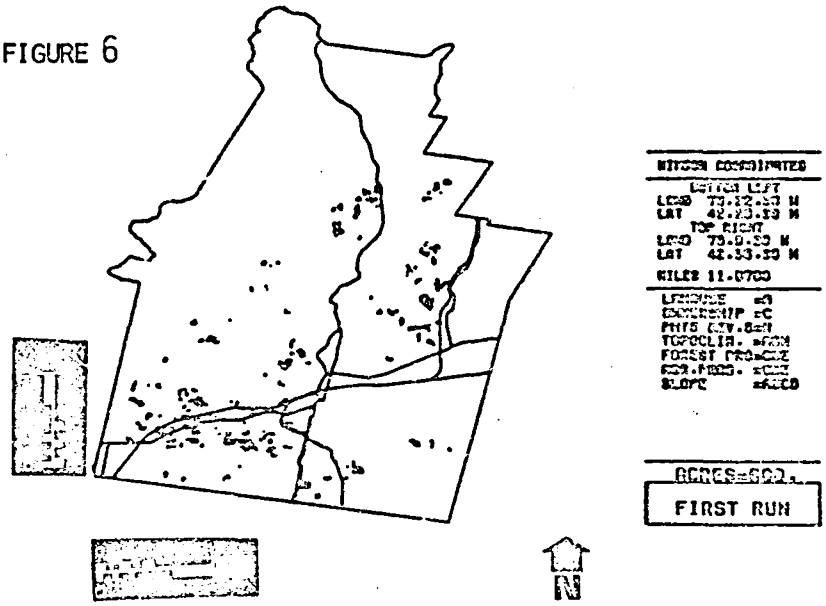
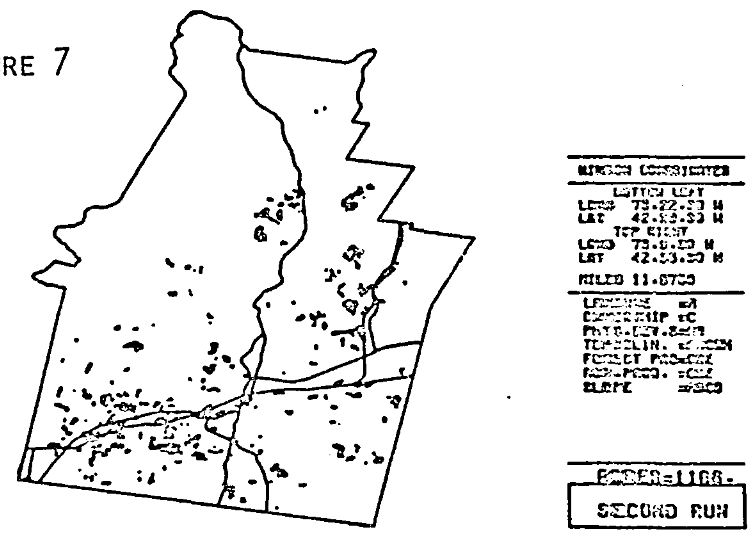


FIGURE 7



energy efficiency.

The next step one would take (Step 7) would be to analyze the conflicts and impacts that would be associated with a development of this magnitude in this particular area. Once that is accomplished, one may chose to do further "runs" or make recommendations as to future land use policies with regard to growth and relocation.

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ASSESSMENT PLANNING AND EVALUATION OF RENEWABLE ENERGY RESOURCES: AN INTERACTIVE COMPUTER ASSISTED PROCEDURE

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1.0 INTRODUCTION

This study is concerned with the adaptive use of urbanizing landscapes through the use of renewable energy resources. The need for the study arose out of the increasing uncertainty in energy supplies that most countries experienced following the Arab oil embargo in 1973 as well as 1979. Desiring to increase supply certainty, there has been an accelerated research effort in the area of renewable energy resources.

The goal of this particular study is to help communities become more energy self-sufficient while simulataneously revitalizing and re-using the landscape. Through sound renewable planning efforts, the landscape resources may be used creatively and effectively. The aims of this study are as follows:

- To ascertain the availability of renewable energy resources in urbanizing communities, specifically, hydroelectric, wind, and biomass resources.
- To demonstrate resource quantity, quality, location, distribution, and value.
- To exhibit how renewable energy resources can both provide opportunities to development and limitations to devopment.

The methods used in the study fall into three categories:

- Assessment of the most favorable wind, hydro, and biomass areas.
- Location of areas where resource opportunities may conflict or co-occur.
- The rank-ordering of the most favorable areas based on pertinent physical, economic, legal/institutional, social and environmental criteria.

The above methods are both derived and adapted. Adaptation occurred through modification of selected methods found in the state-of-the-art review. Derivation of a procedure to assess the availability of the three resources as well as the pertinent issues involved in assessment was also accomplished. The entire procedure is aided through the use of an interactive computer system. This allows planners, officials, developers, and all interest groups access to the data information network that is vital to the procedure itself. Part of the interactive system is the quantitative computer program "Fuzzy Decision-Making". This program allows for the rank-ordering of potential development areas based on a set of "evaluative criteria". The program, as well as the entire procedure, is user-friendly and available for use by all interested parties.

Application of the above procedure was accomplished for the Upper Housatonic River Basin in Berkshire County, Massachusetts. The specific area of concentration is the towns of Pittsfield, and Lanesborough Massachusetts.

The entire research effort presented herein is part of the ongoing METLAND (Metropolitan Landscape Planning) energy study at the University of Massachusetts' Department of Landscape Architecture and Regional Planning. It is the second part of a three part study which includes:

- Energy efficient land use planning
- Renewable energy resource utilization
- Impacts associated with renewable energy resource use

The paper itself is organized as follows:

- Section 2.0 gives a general overview of the state-of-the-science in renewable energy resource assessment.
- Section 3.0 outlines the methods used in the study.
- Section 4.0 covers the application of the procedure to the study area.
- Section 5.0 concludes the paper and discusses results.

2.0 STATE-OF-THE-SCIENCE IN RENEWABLE ENERGY ASSESSMENT

To provide for an updated, comprehensive assessment of renewable energy resources, it has been necessary and useful to review the current body of literature on the topic. Much has already been written in the area of hydropower assessment. A recent U.S. Army Corps of Engineers/New England River Basins Commission study has thoroughly examined many of the important issues in hydropower assessment and they are presented herein. An analysis of the issues involved in windpower assessment reveals that less has been written on the subject. The literature on biomass assessment is also quite lean in terms of discussion of the issues.

A review of the literature indicates that there are six major areas of concern:

- The current state of technology and its link to assessment.
- The availability of the resources on the landscape.
- The economics of resource use.
- The legal and institutional issues involved.
- The social implications involved with resource use.
- Various environmental impacts and implications.

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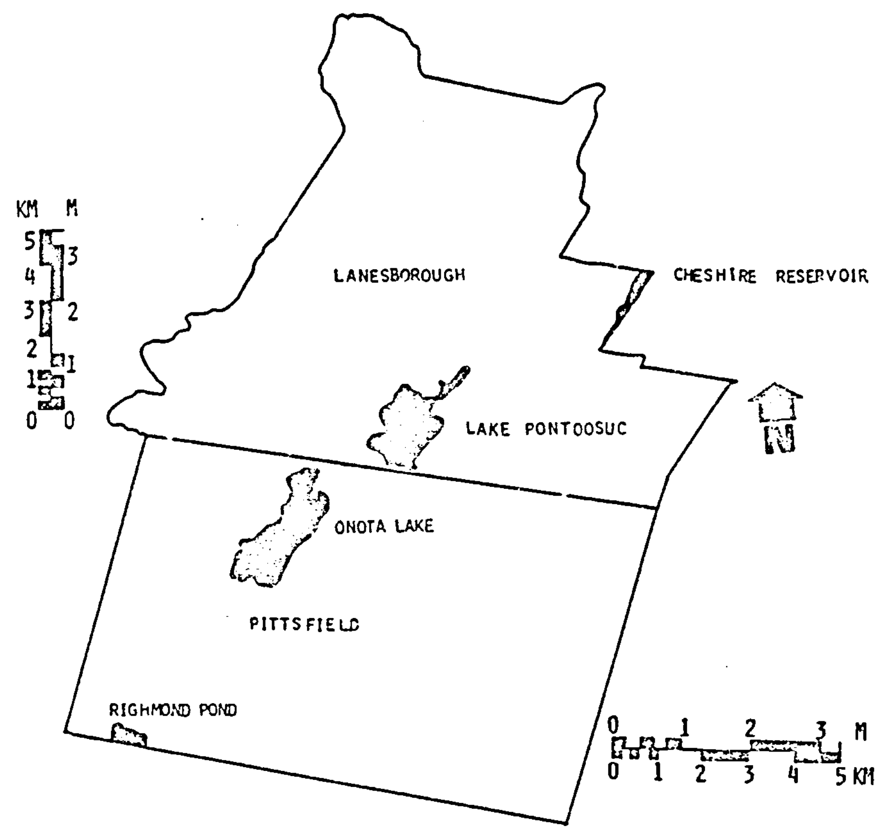

FIGURE 1: THE UPPER HOUSATONIC RIVER BASIN STUDY AREA. WESTERN MASSACHUSETTS.

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The section concludes with what has been learned, and what is lacking in the literature in order to provide for a more comprehensive assessment.

2.1 Hydropower Assessment

Hydropower is one of this country's most accessible energy resources. It currently supplies 13% of this nation's electrical energy. In New England inparticular, past industrial activity has left behind thousands of dams which can be retro-fitted for hydropower production (Glidden, High, 1980). Hydropower technology has matured greatly since the world's first central hydro station was erected in Appleton, Wisconsin in 1882. Improvement in dam structure and design as well as mechanical operating equipment has made hydroelectric energy an attractive alternative.

Assessment of hydroelectric power potential has been a task already undertaken in a 1954 U.S. Army Corps of Engineers Interagency report, The Resources of New York and New England. Broad-scoped in nature, this report inventoried potential hydro sites in the region. It's concern was mainly in the engineering and economic aspects of hydro development with little regard given to the various legal/institutional, social, or environmental issues.

The energy crisis of the early 1970's prompted a more thorough investigation of hydro potential. In 1976, section 176 of the Water Resources Development Act authorized a detailed assessment of the national hydroelectric power potential. In response to this, the U.S. Army Corps of Engineers published a series of reports that specifically addressed the hydro potential in different regions of the U.S. Some studies pertinent to New England include:

- National Hydroelectric Resources Study - A Preliminary Inventory of Hydropower Resources (July, 1979)
- The Potential for Hydro Development at Existing Dams in New England (January, 1980)
- Water, Watts, and Wilds (August, 1981)

Assessment of the availability of the resource on the landscape has been undertaken in many studies, however the most updated is in the January, 1980 report put out by the Army Corps and the New England River Basins Commission, The Potential for Hydro Development at Existing Dams in New England. Here, existing dam sites are assessed as to their power production capabilities, as are undeveloped or "virgin sites". Virgin site potential is assessed using the following power equation:

$$P_{kw} = (KC)\ (HG)\ (A)$$

where:

P_{kw} = The power potential, in kilowatts with a plant factor ... of forty.

KC = The capacity constant (varies from river to river)

HG = The gross head of the site in question.
A = The drainage area in square miles.

(NERBC, 1980)

Power production potential for existing dams are inventoried in the above NERBC document as well. It is evident then, that the resource issue is well documented in the literature.

The issue of economics is also well documented. The New England River Basins Commission has subjected the inventoried sites to an economic feasibility analysis in which all costs and benefits that are anticipated are arranged into a benefit to cost ratio to determine economic viability.

Legal and institutional issues involved in hydro assessment are many. Development of a hydro site will involve diversions of stream flow and may be located on river reaches used for other purposes. This being the case, mitigation will be needed, and the Federal Energy Regulatory Commission (FERC) has a standard mitigation procedure it uses. It's application process for hydro operating permits exposed potential conflicts associated with proposed projects. In short, the process consists of submission of application, notification of the public of receipt of the application, and a FERC ruling on the application which takes one of three forms:

- Deny the application
- Award the license with certain conditions
- Award the license without conditions

Social issues in hydro assessment include land ownership considerations, land use, and the various competing uses that come into play. Although other issues such as employment are important, most of the vital social issues in terms of development possibilities will be mitigated.

Environmental issues in hydropower assessment vary widely depending on the nature of the site in question. Obviously, virgin site development will have a more profound impact in the following areas:

- Fish migration
- Wildlife habitat
- Water flow
- Water quality

Environmental impacts are often the most difficult to account for because they may be secondary or tertiary in nature. It is, however, these impacts which quite often make or break project development.

In concluding, what has been documented in the literature on hydopower assessment has been detailed and thorough in nature. The issue has been explored as a realistic energy alternative and research has been

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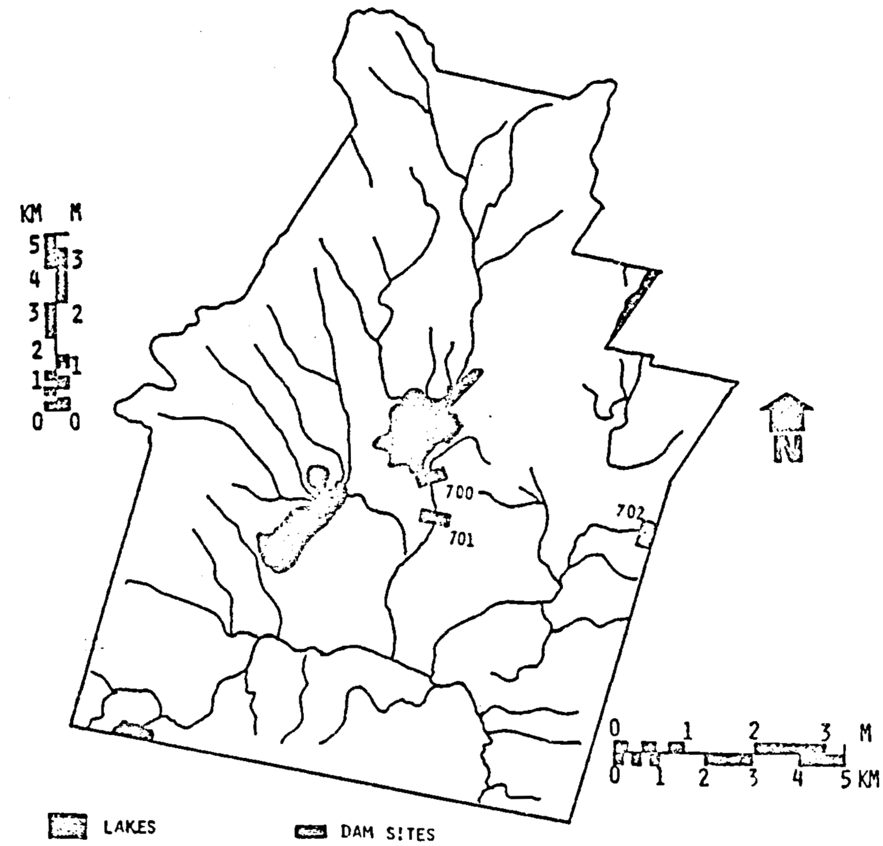

FIGURE 2: THE UPPER HOUSATONIC RIVER
BASIN.
MOST FAVORABLE HYDROPOWER SITES.
ARMY CORPS NUMBERS 1980.

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extensive. What is lacking however is a detailed procedure which accounts for all of the above issues. This is the task of the METLAND-developed procedure.

2.2 Windpower Assessment

Wind energy is a by-product of solar radiation. It is derived from the sun's uneven warming of the earth. Global atmospheric movements cause prevailing winds. The conversion of kinetic wind energy into usable electrical energy involves capturing the wind flow through the drag on a propellor. The turning propellor turns a drive shaft which in turn is connected to a generator. Although the windmill has been in existence for centuries, the technically advanced wind energy conversion system (WECS), with its design and engineering improvements, has made wind energy an attractive alternative. Although wind energy currently supplies only a fraction of our total energy needs, it is estimated that a concerted government wind program could lead to a displacement of 730 million barrels of oil per year by the year 2000. That figure is representative of total Canadian oil demand in 1980 (New England Energy Congress, 1980, p.2).

The state-of-the-science for wind energy assessment is less well documented than the hydro resource. Although the engineering issues as well as the economics are covered in detail, little is said of the other pertinent issues. Important documents include:

- A Siting Handbook for Small WECS(Wegley, 1978)
- Renewable Energy Resource and Technology Assessment (the Southern Tier Regional Planning and Development Board, 1980)
- A Planning Manual for Utility Application of WECS (Park, 1979)

In assessing the landscape potential for wind energy, areas with the greatest overall mean annual windspeed are delineated. From a regional standpoint, this includes:

- Northwest hillsides more than one mile downwind from any topographic obstruction.
- Hilltops with elevation higher than upwind hills.
- Long valleys lying parallel to prevailing winds and the hillsides associated with them (STC, 1980).

Once these areas are delineated on a topo map, they may undergo limited site analysis to assess any vegetational flagging (trees tilted significantly in one direction due to strong winds). The flagging effects on vegetation may be reflective of high mean annual windspeeds, and an index, the Griggs-Putnam Index (GPI) relates the degree of flagging to windspeed. In any case, utilization of the GPI on the sites delineated above can lead to a more detailed site monitoring that must place before any WECS construction occurs. Power potential may be determined using the following equation:

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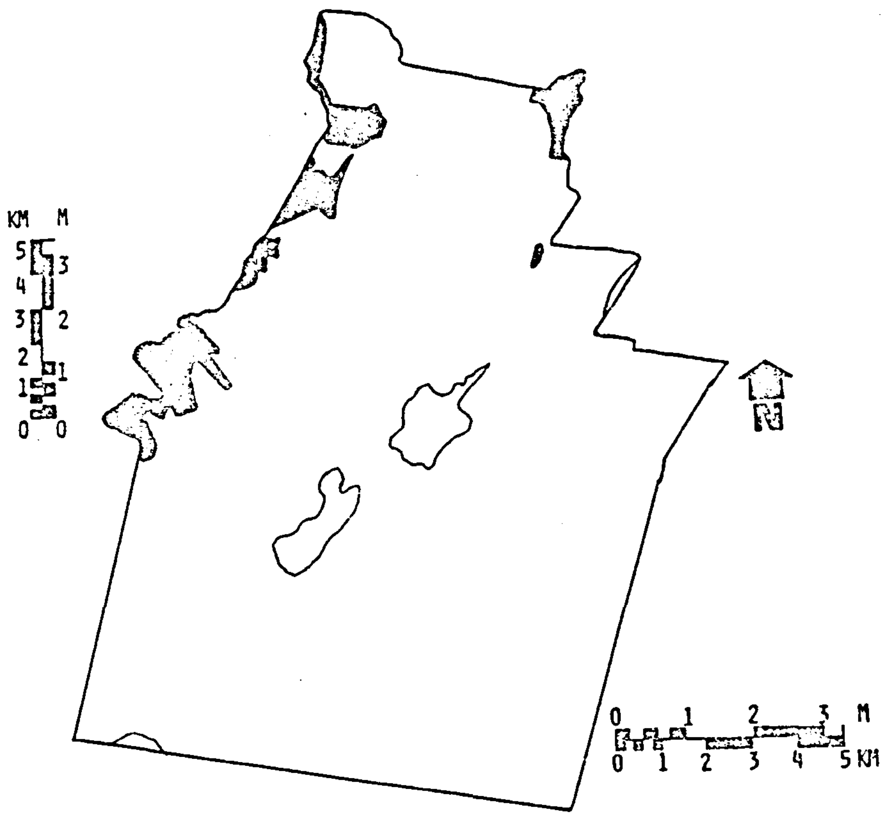

FIGURE 3: THE UPPER HOUSATONIC RIVER BASIN
MOST FAVORABLE WIND ENERGY SITES.

$$P = pV^3$$

where:

P = Power availability in watts/meter^2
p = Air density
V = Wind velocity

(Glidden, High, 1980)

As was the case with hydropower, the economic question centers around expected costs and benefits. A benefit to cost ratio may be derived to measure project viability. The acceptable B/C ratio will vary from project to project.

The remaining legal, social, and environmental issues are less well documented. Any comprehensive assessment procedure must include these issues. What is needed is a step-by-step procedure that will account for all of these issues in such a way so as to be useful to all interest groups in resolving real or perceived conflicts. This is the task of the METLAND-developed procedure.

2.3 Biomass Assessment

All plant matter is considered "biomass", but for the purposes of this study, biomass has been limited to agricultural biomass such as hay, grains, and corn silage, and wood biomass such as coniferous and deciduous trees. Only plants can covert solar energy to chemical energy through photosynthesis. Upon combustion, this energy can be captured and used.

Historically, wood has been used as a fuel to heat homes but recently biological and thermochemical conversion processes have been used to convert various biomass feedstocks to ethanol (grain alcohol) and methanol (wood alcohol). Given these advances in technology, it has become necessary to assess biomass resources as to their current and future availability.

Currently, wood energy in places has significantly contributed to energy supplies. In 1980, wood supplied about two quads of energy while nuclear supplied about .8 quads (Gilbride, p. 13a). In order for a continued wood energy contribution to the energy supplies of the nation, its future use must be planned for. The following documents have explored wood and biomass ingeneral in terms of energy use:

- The New England Energy Atlas (Glidden and High, 1980)
- Current and Future Biomass and Resource Inventory Techniques (Young, et al., 1977)
- The Identification of Wood Energy Resources in Central Michigan (Hudson and Kittleson, 1978)

In assessing the physical resource potential of the biomass resource,

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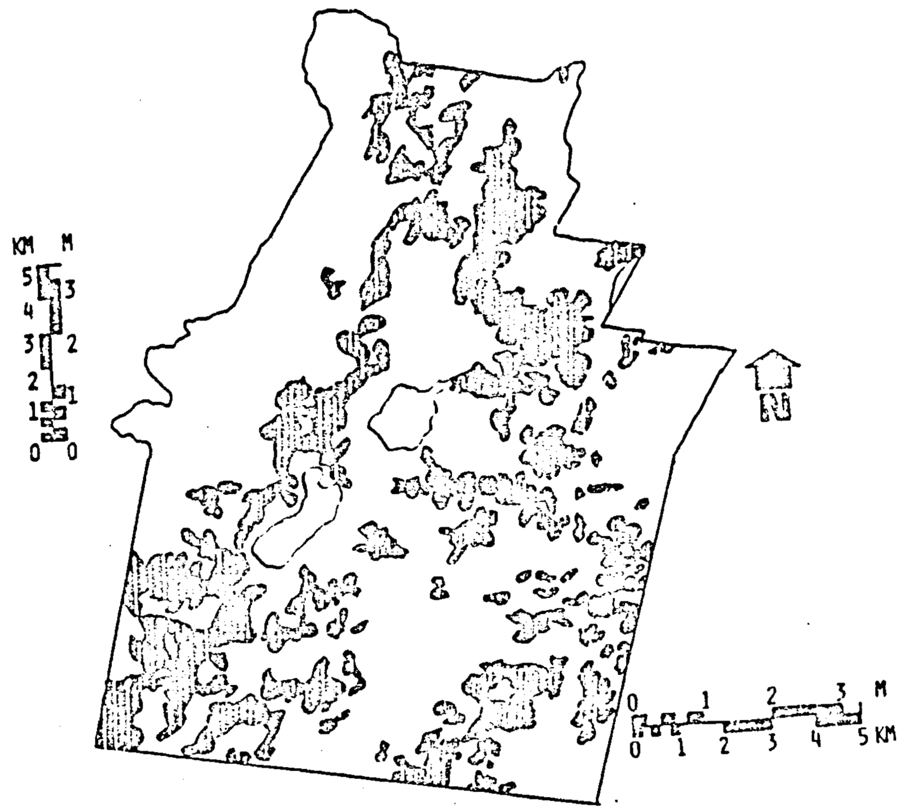

FIGURE 4: THE UPPER HOUSATONIC RIVER BASIN.
MOST FAVORABLE AGRICULTURAL BIO-MASS SITES.

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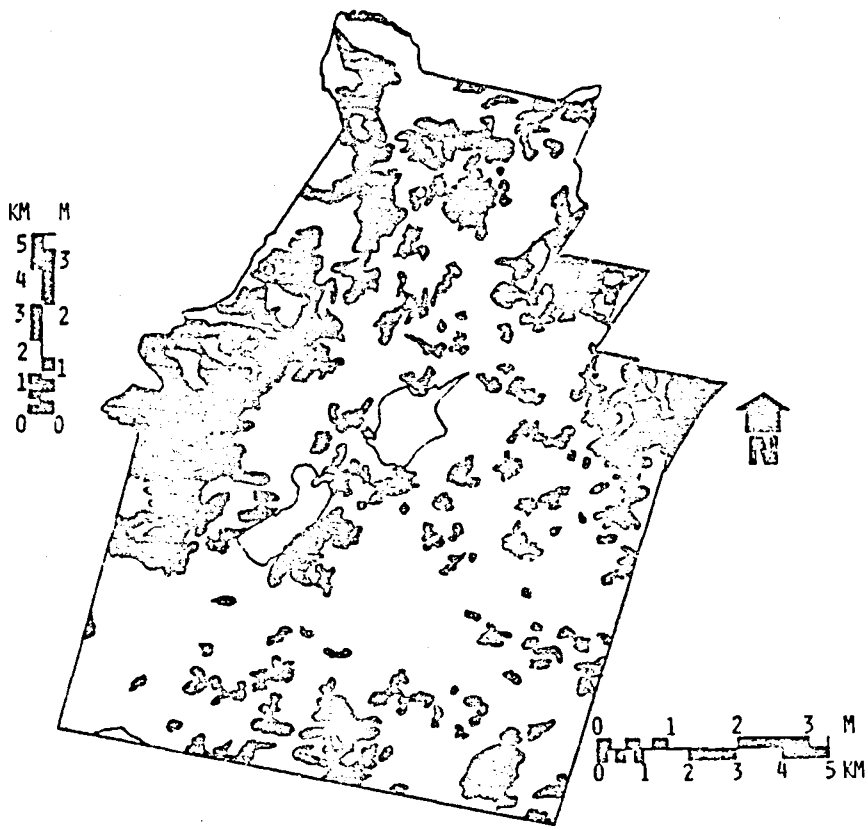

FIGURE 5: THE UPPER HOUSATONIC RIVER BASIN.
MOST FAVORABLE FOREST BIOMASS SITES.

we must first identify where the agricultural or forest parcels are, and to what extent they may be useful in the near term in producing energy. To do this, one may employ a combination of approaches. The simplest is to use a topo map to delineate forested or agricultural lands. This, however gives few clues as to the usefulness of the parcel in question. More detail can be derived from land use/land cover map. In Massachusetts, MacConnell land cover maps give useful information as to each parcel that is recorded. MacConnell maps (see references) detail types of active and inactive agricultural lands (tilled and untilled farmlands, abandoned fields, pastureland, etc.) as well as forest lands (detailed in height and density classifications). Using the MacConnell maps, one may gain significant insight into biomass parcels without actual field reconnaissance Other documents in the body of literature recommend a combination of aerial and field reconnaissance to inventory the biomass resource. In any event, much has been written on the topic of biomass resource inventory techniques.

The other issue extensively documented is that of environmental impact. Forestation over the years has become a topic of great concern in terms of overharvest. Much has been written on the topic and various methods that minimize impact may be found in the state-of-the-science. While the environmental implications in biomass operations are indeed important, the other legal/institutional, social, and economic issues warrant extensive documentation as well. In that biomass technology is advancing to the point where the resources is becoming more widely considered as an energy source, they must be included in an overall procedure to assess biomass resource availability. This is the task of the METLAND-developed assessment procedure.

In retrospect, the current body of literature on state-of-the-science techniques to assess renewable energy resources is heavily biased toward the resource issues and their availability on the landscape. Much has also been written on the economics of resource use, but the remaining legal/institutional, social, and environmental issues are less well documented. In terms of the resources themselves, most research has been done in terms of hydropower. Overall what is lacking is a comprehensive, step-by-step procedure that will assess all of these resources while simultaneously finding the most favorable sites for development. This is the task of the following procedure.

3.0 ASSESSMENT, PLANNING, AND EVALUATION OF RENEWABLE ENERGY RESOURCES: A COMPUTER-ASSISTED PROCEDURE

To utilize the findings of the state-of-the-science review and build upon it the METLAND team has derived a procedure that will assess the availability of the renewable energy resources on the landscape and simultaneously account for the other issues vital to the procedure. The procedure is done in a step-by-step fashion and can be used interactively at the computer terminal.

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The procedure uses the "eliminative approach" in its assessment in that all sites that are potentially productive from an engineering standpoint are located first. Then sites that are not economically viable are eliminated. Resulting sites are rank-ordered using the quantitative computer program, Fuzzy Decision-Making (see references). Here, the alternative sites are evaluated based on certain physical (power production potential), economic (benefit to cost ratio), legal (affected zoning classes), social (# of affected landowners, # of affected historic sites), and environmental (% slope of site) criteria. What results then is a comprehensive, accessible, and flexible assessment, planning, and evaluation procedure for the above resources which can be used by all interest groups and individuals with an interest in Renewable Energy Development.

3.1 Step 1: The Landscape Resource Assessment

This step of the procedure locates the various renewable energy resource that are developable from an engineering and resource base standpoint.

For the hydro resource, a U.S.G.S. topographic map is used to locate the river and stream network in question. Consulting the pertinent U.S. Army Corps of Engineers inventory report will yield all the necessary information on any existing dam sites that may be retrofitted for hydropower use. Once this data is obtained, all sites with a power production potential of fifty kilowatts or more and a head greater than five feet may be considered viable for hydro use (from strictly an engineering standpoint). These "eliminative criteria" are used by the Army Corps in that they may be potentially productive using current technology

Wind energy resource areas are delineated on a topo map. First, from a regional standpoint, the following areas are considered "prime" wind collection areas:

- Northwest hillsides more than one mile downwind from any topographic obstruction
- Hilltops with elevations higher than upwind hills
- Long valleys lying parallel to prevailing winds and the hillsides associated with them

Once this is done, the vegetation at these sights is examined to determine flagging effects. Tree flagging, using the Griggs-Putnam Index (GPI) (see Appendix) can be representative of certain windspeeds. Once these windspeeds in excess of 9 miles per hour is delineated (Hewson, 1978). These areas are representative of the most favorable wind sites from an engineering standpoint.

Biomass resource areas are delineated, but here one is advised to use a more detailed land use or land cover map such as the MacConnell maps described above (these available in Massachusetts). All active and inactive agricultural lands (tilled and untilled farmland, pastureland, and abandoned fields) are representative of the most favorable agricultural biomass areas from a strictly physical standpoint. In terms of forest biomass, the tallest and densest forest stands represent the most favorable opportunities for near-term development. The "eliminative criteria" used here are forest stands in excess of forty feet with a crown closure density over 80%. These areas are most favorable for forest biomass use.

3.2 Step 2: Economic Assessment

Taking the procedure one step further, the above sites are now viewed in terms of economic viability. All costs and benefits should be tallied over the economic life of the project and arranged into a benefit to cost ratio. The "acceptable" B/C ratio will vary from project to project. To come up with a uniform rule of thumb, the METLAND "eliminative criterion" of a B/C ratio in excess of 1.0 is used. In other words, at this stage of the procedure, if a project's anticipated benefits are expected to exceed the costs,it should be considered economically viable. A more detailed economic analysis will of course be used in examining each project at a later stage of assessment.

3.3. Step 3: Fuzzy Decision-Making: Evaluating the Viable Alternatives

At this point in the procedure, only engineering and economic issues have been analyzed. Most of the current literature stops here in the assessment procedure. The METLAND-developed procedure goes one step further by now accounting for the various legal/institutional, social, and environmental issues as well. Using the Fuzzy Decision-Making program, "evaluative criteria" are selected which are representative of the issues described above. They include:

- Energy potential of the renewable energy site
- B/C ratio of the site
- # of affected landowners in potential development
- # of affected zoning classes
- # of affected historic sites
- %slope of the site

Assuming we wish to:

- Maximize the energy potential
- Maximize the B/C ratio
- Minimize the # of affected landowners
- Minimize the # of affected zoning classes
- Minimize the # of affected historic sites
- Minimize the % slope of the site

```
FUZZY DECISION ASSISTANCE FOR PLANNING AND DESIGN
BASED ON WORK BY R.R. YAGER, 'MULTIPLE OBJECTIVE DECISION-MAKING
USING FUZZY SETS,' INT. J. MAN-MACHINE STUDIES (1977), 9
375-382
WILL DATA BE ENTERED FROM TERMINAL OR A FILE (T/F)  ?  T
NUMBER OF ALTERNATIVES? 3
ENTER LABELS FOR ALTERNATIVES
#  1  ? DAM 700
#  2  ? DAM 701
#  3  ? DAM 702

NUMBER OF CRITERIA FOR DECISION ? 5
ENTER CRITERIA LABELS
#  1     ? POWER POTENTIAL
#  2     ? BENEFIT TO COST RATIO
#  3     ? LAND OWNERSHIP
#  4     ? ZONING CLASSES
#  5     ? AFFECTED HISTORIC SITES

ENTER RATINGS OF ALTERNATIVES FOR EACH CRITERION
'POWER POTENTIAL' RATING FOR 'DAM 700'? .3
'POWER POTENTIAL' RATING FOR 'DAM 701'? .5
'POWER POTENTIAL' RATING FOR 'DAM 702'? .9
'BENEFIT TO COST RATIO' RATING FOR 'DAM 700'? .2
'BENEFIT TO COST RATIO' RATING FOR 'DAM 701'? .3
'BENEFIT TO COST RATIO' RATING FOR 'DAM 702'? .5
'LAND OWNERSHIP' RATING FOR 'DAM 700' ? .7
'LAND OWNERSHIP' RATING FOR 'DAM 701' ? .7
'LAND OWNERSHIP' RATING FOR 'DAM 702' ? .7
'ZONING CLASSES' RATING FOR 'DAM 700' ? .8
'ZONING CLASSES' RATING FOR 'DAM 701' ? .8
'ZONING CLASSES' RATING FOR 'DAM 702' ? .6
'AFFECTED HISTORIC SITES' RATING FOR 'DAM 700'? .6
'AFFECTED HISTORIC SITES' RATING FOR 'DAM 701'? .6
'AFFECTED HISTORIC SITES' RATING FOR 'DAM 702'? 1.0

 SUMMARY TABLE OF RATINGS OF THE ALTERNATIVES

 DAM 700    .3  .2  .7   .8  .6
 DAM 701    .5   3  .7   .8  .6
 DAM 702    .9  .5  .7   .6  1

 ENTER PAIRED COMPARISONS OF CRITERIA
 POWER POTENTIAL (1), COMPARED WITH BENEFIT TO COST RATIO (2)
 MORE IMPORTANT (1 OR 2) ? 1
 DEGREE OF IMPORTANCE (1 TO 9) ? 3
 POWER POTENTIAL (1), COMPARED WITH LAND OWNERSHIP (2)
 MORE IMPORTANT (1 OR 2) ? 1
 DEGREE OF IMPORTANCE (1 TO 9) ? 5
 BENEFIT TO COST RATIO (1), COMPARED WITH LAND OWNERSHIP (2)
 MORE IMPORTANT (1 OR 2) ? 1
 DEGREE OF IMPORTANCE (1 TO 9) ? 4
 POWER POTENTIAL (1), COMPARED WITH ZONING CLASSES (2)
 MORE IMPORTANT (1 OR 2) ? 1
 DEGREE OF IMPORTANCE (1 TO 9) ? 7
 BENEFIT TO COST RATIO (1), COMPARED WITH ZONING CLASSES (2)
 MORE IMPORTANT (1 OR 2) ? 1
 DEGREE OF IMPORTANCE (1 TO 9) ? 6
 LAND OWNERSHIP (1), COMPARED WITH ZONING CLASSES (2)
 MORE IMPORTANT (1 OR 2) ? 1
 DEGREE OF IMPORTANCE (1 TO 9) ? 5
 POWER POTENTIAL (1), COMPARED WITH AFFECTED HISTORIC SITES (2)
 MORE IMPORTANT (1 OR 2) ? 1
 DEGREE OF IMPORTANCE (1 TO 9) ? 8
 BENEFIT TO COST RATIO (1), COMPARED WITH AFFECTED HISTORIC SITES (2)
 MORE IMPORTANT (1 OR 2) ? 1
 DEGREE OF IMPORTANCE (1 TO 9) ? 7
 LAND OWNERSHIP (1), COMPARED WITH AFFECTED HISTORIC SITES (2)
 MORE IMPORTANT (1 OR 2) ? 1
```

CONTINUED....1

FIGURE 6: FUZZY DECISION MAKING FOR HYDROPOWER

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```
DEGREE OF IMPORTANCE (1 TO 9) ? 6
ZONING CLASSES (1). COMPARED WITH AFFECTED HISTORIC SITES (2)
MORE IMPORTANT (1 OR 2) ? 1
DEGREE OF IMPORTANCE (1 TO 9) ? 2

PRINT TABLE OF PAIRED COMPARISONS (Y/N) ? Y
           SUMMARY OF PAIRED COMPARISONS
      (DEGREE OF IMPORTANCE IS IN PARENTHESES)

CRITERION # 1   POWER POTENTIAL
    CRITERIA OF EQUAL IMPORTANCE

    CRITERIA OF LESSER IMPORTANCE
         BENEFIT TO COST RATIO( 3 )
         LAND OWNERSHIP( 5 )
         ZONING CLASSES( 7 )
         AFFECTED HISTORIC SITES( 8 )

    CRITERIA OF GREATER IMPOPTANCE

CRITERION # 2 : BENEFIT TO COST RATIO
    CRITERIA OF EQUAL IMPORTANCE

    CRITERIA OF LESSER IMPORTANCE
         LAND OWNERSHIP( 4 )
         ZONING CLASSES( 6 )
         AFFECTED HISTORIC SITES( 7 )

    CRITERIA OF GREATER IMPORTANCE
         POWER POTENTIAL( 3 )

CRITERION # 3 : LAND OWNERSHIP
      CRITERIA OF EQUAL IMPORTANCE

      CRITERIA OF LESSER IMPORTANCE
           ZONING CLASSES( 8 )
           AFFECTED HISTORIC SITES( 6 )

      CRITERIA OF GREATER IMPORTANCE
           POWER POTENTIAL( 5 )
           BENEFIT TO COST RATIO( 4 )

  CRITERION # 4 : ZONING CLASSES
      CRITERIA OF EQUAL IMPORTANCE

      CRITERIA OF LESSER IMPORTANCE
           AFFECTED HISTORIC SITES( 2 )

      CRITERIA OF GREATER IMPORTANCE
           POWER POTENTIAL( 7 )
           BENEFIT TO COST RATIO( 6 )
           LAND OWNERSHIP( 5 )

  CRITERION # 5 : AFFECTED HISTORIC SITES
      CRITERIA OF EQUAL IMPORTANCE

      CRITERIA OF LESSER IMPORTANCE

      CRITERIA OF GREATER IMPORTANCE
           POWER POTENTIAL( 8 )
           BENEFIT TO COST RATIO( 7 )
           LAND OWNERSHIP( 6 )
           ZONING CLASSES( 2 )

  EIGENVALUE =  5.40658
```

FIGURE 6: FUZZY DECISION MAKING FOR HYDROPOWER

CONTINUED.... 2

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```
UNIT EIGENVECTOR          WEIGHTED EIGENVECTOR
      .49                         2.45
      .28                         1.42
      .14                          .70
      .05                          .24
      .03                          .17

CONSISTENCY OF PAIRED COMPARISONS.     .23

WEIGHTED CRITERIA

POWER POTENTIAL:          .05   .18   .77
BENEFIT TO COST RATIO:
                          .10   .18   .37
LAND OWNERSHIP:          1.00  1.00  1.00
ZONING CLASSES:           .95   .95   .88
AFFECTED HISTORIC SITES:
                          .92   .92  1.00

DECISION VALUES

DAM 700:                   .05    WORST
DAM 701:                   .18
DAM 702:                   .37    BEST

DO YOU WISH TO CHANGE ANY VALUES? (Y/N)
? N
DO YOU WISH TO SAVE THE RATINGS AND PAIRED COMPARISONS ON A FILE
(ANALYSIS RESULTS CANNOT BE SAVED)
? Y
FILE NAME ? FDM
************ BE SURE TO 'REPLACE,------', WHERE ------ IS FILENAME
SRU        1.068 UNTS.
```

FIGURE 6: FUZZY DECISION MAKING FOR HYDROPOWER

CONFLICTS (OR OVERLAPS) RESOLVED BY F.D.M. (FUZZY DECISION MAKING SET; MACDOUGALL, 1981) each alternative can be valued numerically as to how well it satisfies these assumptions. For instance, a site with an energy potencial of 500 kwh is favored over a site with 300 kwh. Likewise, a site that,if developed, will affect 20 landowners, is favored over a site that will affect 30 (because of reduced legal hassles, etc.). Using the FDM program, each criterion may be compared to the other in pairwise fashion so as to determine which is more important. Each criterion is given an "importance value" (rating from 1-9). In this manner certain criteria are valued as more important depending upon who is running the program. This is a vital aspect of the procedure in that all interested parties can make use of the procedure in an interactive manner, so as to arrive at the best alternative in their own opinion, hence this procedure is useful in determining the degree of conflict and also in resolving the conflict.

4.0 APPLICATION OF THE PROCEDURE

The procedure was applied to part of the Pittsfield metropolitan region in the Upper Housatonic River Basin in Western Massachusetts (see Figure 1). The study area consists of 40,000 acres and represents over sixty square miles. Of this area, one third is in forest while another third is in rural residential use. As part of the METLAND Energy Study, a complete energy data information network was constructed and stored on the Cyber 175 computer at the University of Massachusetts at Amherst. The data base includes:

- Road network
- Utility grid
- Zoning patterns
- Land use patterns
- Ownership patterns
- Historic site information
- Slope Hazard

4.1 The Hydropower Resource

Three existing dam sites were found physically capable of being retrofitted for hydropower. They include dams 700, 701, and 702 and represent 454 kw of potential power production (see Figure 2).

4.2 The Windpower Resource

Three general areas were seen as conducive to windpower from a physical standpoint. Each has a mean annual windspeed exceeding 14 m.p.h. Using the Griggs-Putnam Index, the sites are delineated in Figure 3.

4.3 The Biomass Resource

Perhaps the greatest near-term potential for renewable energy resource

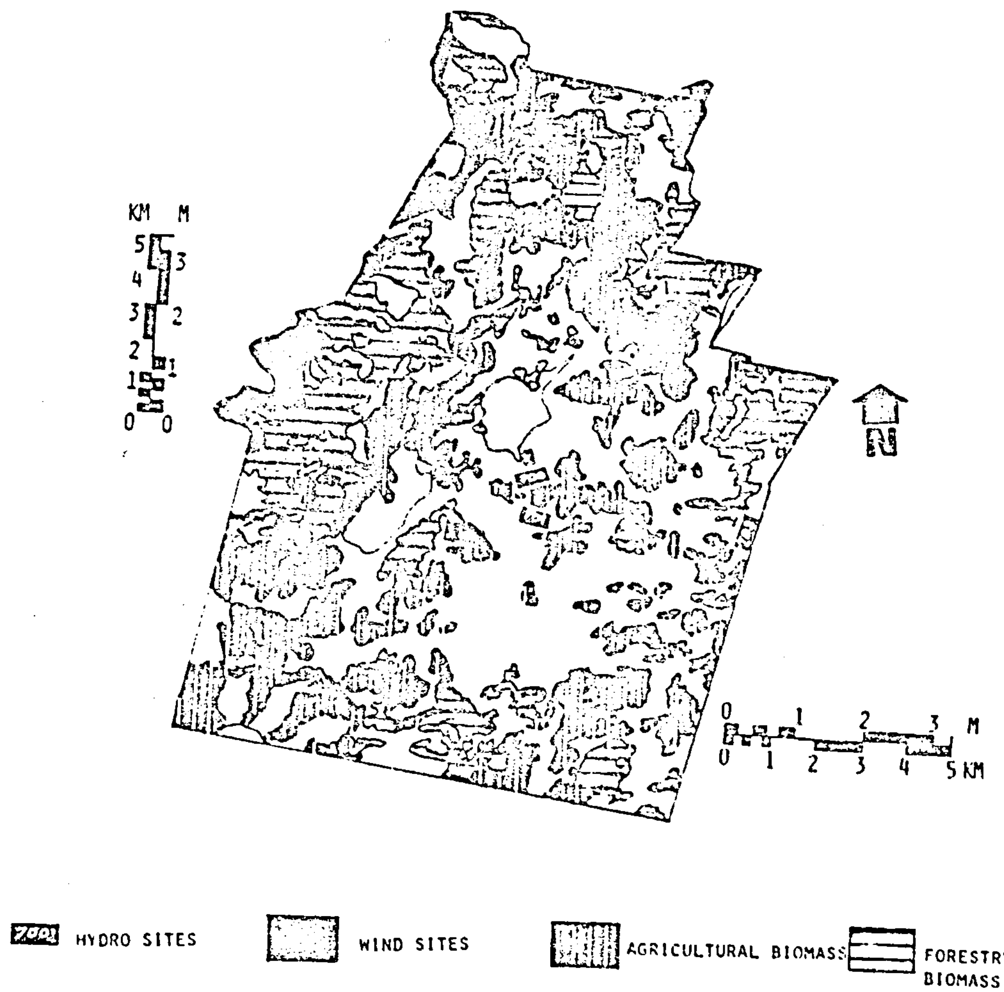

FIGURE 7: THE UPPER HOUSATONIC RIVER BASIN.
COMPOSITE RENEWABLE ENERGY RESOURCE MAP.

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utilization is in the area of biomass. Almost 20% of the total land area consists of "prime" agricultural biomass opportunities while 30% of the area is "prime" forest biomass land (see Figures 4 and 5).

4.4 Fuzzy Decision-Making and the Hydropower Resource

The entire FDM program was run for only the hydro resource of the area (see Figure 6) and the "best" choice for hydro development was dam #702. This was done using the judgement of the principal author alone and reflects his bias. Yet it does provide the reader with an illustrated example of how the various alternatives and criteria can be numerically rated, in an interactive format.

5.0 CONCLUSIONS

The procedure described above is an attempt to make planning more comprehensive and perhaps more democratic in its approach. Alternatives and criteria are plainly spelled out for all parties to see. Using an interactive computer format allows for easy visual interpretation of all sites delineated. Fuzzy Decision-Making, by providing a rank-ordering of alternatives, allows for conflict resolution by finding the "best" site to develop. Resulting renewable energy areas can be displayed and composited using METLAND's COMLUP/ILPP graphics package. Figure 7 is a composite map of the most favorable renewable energy sites found in this study. Any areas of conflict (overlaps on the map) can also be resolved using Fuzzy Decision-Making.

It is evident then, that renewable energy resources can be planned for in a more effective, efficient, and creative manner. These resources, when properly utilized, can help to revitalize rural and urbanizing landscapes. In addition, they can provide an increased certainty in terms of energy supplies to the regions that use them. By locating the most favorable areas for renewable energy development, conflicts can be minimized, and opportunities in the same realm, maximized.

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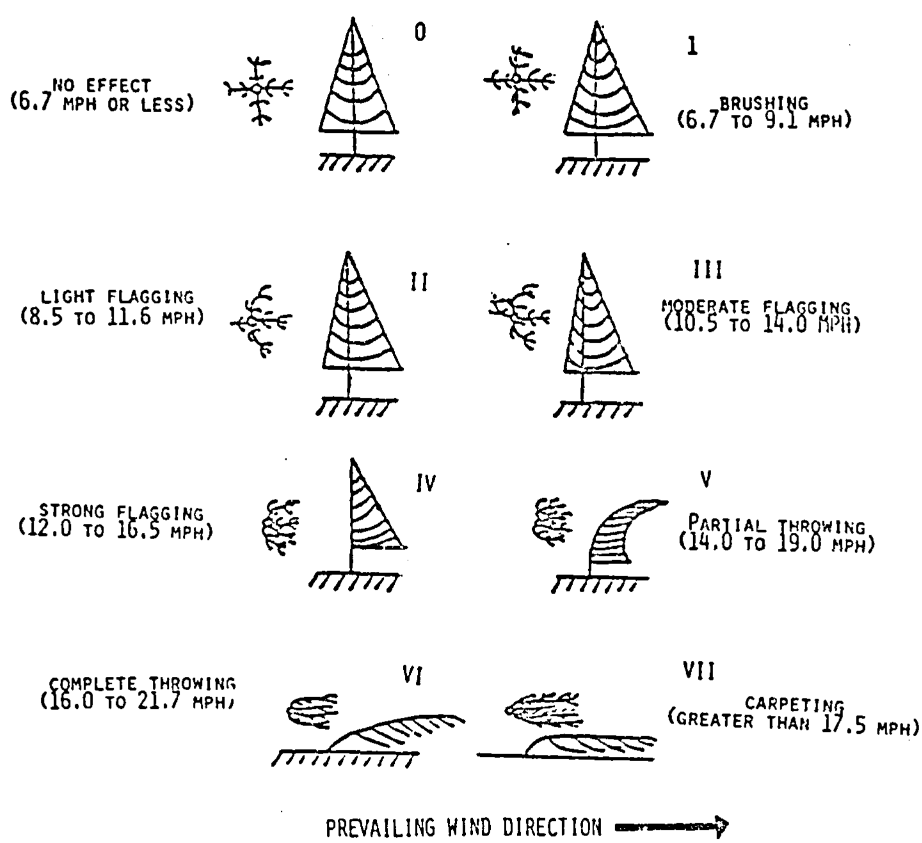
Appendix A

Griggs-Putnam Index



GRIGGS-PUTNAM INDEX

EXPECTED INTERVAL OF AVERAGE ANNUAL WIND SPEED (MPH)

N83
26199

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D23

Seattle's System for Evaluating Energy Options

Pat Logie and Malcolm J. Macdonald
City Light Department
City of Seattle, Washington

I'm here to share with you some of Seattle's experiences developing a system for making electrical energy choices, a system that rests on a base of data organized and presented in order to document references, highlight assumptions and permit valid comparisons among different options.

Seattle City Light, the city's municipally owned utility, is one of the largest public utilities in the country with about 1750 employees serving nearly 300,000 accounts in a service territory of over half a million people. Rivers plunging swiftly from Washington state's mountains provide abundant low-cost hydroelectric power to city and state residents. Seattle owns and operates six hydroelectric power plants that generate enough power to meet two-thirds of the city's needs. Much of the rest comes from the Bonneville Power Administration (BPA), the Northwest's federal marketing agency that until recently had access to a seemingly endless supply of electricity from federal multi-purpose dams. As a result, Northwesterners racked up the highest per capita use in the country while paying the lowest bills. But times are changing.

The era of abundant hydro power is over. Hydro sites are hard to find; other power sources are hard and costly to develop; rates are climbing; ratepayers are irate. In fact, the planning process I am about to describe is one indication of the new climate of electrical power scarcity in the Northwest. In contrast to the earlier days of surplus supply when the cost of errors was low, the costs of inadequate planning are now ruinous.

Fortunately, in those earlier days, Seattle had begun to establish guidelines and policies that were to stand us in good stead when we had to face up to current energy realities. Let me give you a few examples of these precedents and of the climate in which we set to work.

In 1975, while deciding whether to participate in two projected nuclear power plants, the city developed a blueprint called "Energy 1990" for meeting its future electric energy needs. After twelve months of intensive effort involving a citizens committee that chose its own consultants and an expenditure exceeding $300,000, the city decided against the nuclear commitment. But, more important, in this landmark decision, it established a set of priorities to be followed in choosing any future electrical energy resources. It set a 15-year target of the amount of energy to be saved through conservation. It gave its blessing to a (then) controversial method of forecasting future demand, and it required that annual load and resource forecasts be published.

This willingness to trust and enlist involved citizens was already becoming a Seattle hallmark. In the last decade, 14 major advisory committees numbering 8 to 20 members each plus other citizen groups have spent countless hours reading, questioning, testifying and reporting as they became deeply involved in key problems influencing how the city gets its electric power and what it pays for it.

These recent trends strongly supported our development of an energy planning process. Other experiences, however, made it at once more urgent and more difficult to approach our planning tasks. A host of new problems hang over the Northwest because of the two ill-fated nuclear plants Seattle declined to support plus three in which it is involved. Long construction delays and horrendous cost overruns have led to huge rate increases and bitter charges of mismanagement .. while the first kilowatt hour of electricity from these plants is still months or years in the future.

If a new state law that grew out of a citizen-sponsored initiative survives an appeal process, public utilities like Seattle City Light will have to secure voter approval before participating in any generating project whose total cost exceeds $250,000.

Briefly, then, our long-term energy resources planning process was developed in a city with a strong environmental commitment, an active citizenry willing to turn out en masse at public hearings, a history of low rates and a new awareness that large generation projects could be stopped by public veto or jeopardized by the inability to secure access to capital markets saturated with bonds from the languishing nuclear projects.

Although the decade of the '70's had brought us several sophisticated planning tools (load forecasting, resource forecasting and long-range financial planning, for example) there was no central body with responsibility for long-range energy resource planning. Moreover, the potential of the utility's research and development effort was not being fully realized. Although it was generously supported through a commitment of 1 and 3/4% of all revenue from sales of electricity, it was not specifically geared to provide information about resource options with identified promise for meeting identified utility needs.

Correcting these deficiencies was one reason for developing our new planning process. Avoiding inappropriate decisions and unnecessary

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expenditures for projects that should not be supported was another. But, our major objectives were more comprehensive. The City Council (City Light's policy making body) wanted to make -- and City Light wanted to recommend --the best and most timely energy choices from the widest possible range of options, supported by the most complete information possible. We wanted to provide warnings about the possible pitfalls, trade-offs and mitigations of potential new energy resources. We wanted to insure public access to relevant information prepared with laymen in mind. And we wanted to assure continuity of the planning effort by concentrating accountability for energy resource planning in one place.

Existing city policies provided several other clear guidelines. As part of the Energy 1990 decision, the city's priorities for meeting or offsetting expected growth in demand are, in order: (1) conservation, (2) hydroelectricity, (3) other renewable sources such as wind, biomass, solar and geothermal energy, (4) abundant non-renewable sources such as coal, and (5) other non-renewables.

Other guidelines established or reinforced city preferences for energy sources that are (1) self-owned or jointly owned (as opposed to those owned by others); (2) cost effective, (3) environmentally benign, and (4) diverse, meaning that a number of projects of different types and in different locations are favored over a few large and similar projects.

To help meet these objectives, in 1979 the Council approved a new Energy Resources Planning group. Ten new positions were created -- including several engineers, an economist, power analyst, environmental analyst, and information specialist. Three years was allocated for the progressive development and integration of the planning system. But from the beginning, the Council required annual reports giving the description, status, planned expenditures and projected research activities for all conservation and generation projects under consideration. Additionally, it required placing each of these options in one of six specified resource categories. Placement, reflecting the utility's level of knowledge and the option's readiness to be brought into our system, would be annually affirmed or changed by the Council.

The planning categories were only titles when they were established by the City Council. Subsequently, they have undergone continuing definition and evaluation. Resource possibilities do not have to start at square one; they may be dropped from consideration at any stage, and they may skip stages or back track. But the typical proposal would require progressive study and developmental planning in three categories before being endorsed by the Council. If problems develop, or a resource is not needed, it could spend an indeterminate period of time in one of two "holding" categories. In order, the straight-ahead categories are:

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1. Resource Proposal -- concepts, possibilities or potential projects, described in tentative terms based on the experiences of others or our own highly incomplete information. We try to pinpoint gaps in information needed for later firm estimates --data about project sites, water rights, licensing requirements and costs, for example.

2. Preliminary Assessment -- potential projects undergoing appropriate research, study and surveys to give us more precise estimates -- the costs of needed generation sites and equipment or how many customers would take part in a conservation program, for example.

3. Candidate for Endorsement -- projects the utility wants and expects to recommend for Council endorsement within two years. During this time, we may seek preliminary permits, acquire site options, refine economic calculations and draw up preliminary purchase contracts.

4. Endorsed Project -- projects that have received favorable Council votes and funding commitments. At this point, their expected energy gain enters the utility's official 20-year forecasts.

If a project is still alive but not moving straight ahead, it will be in one of two holding areas -- as a contingency reserve project or project in abeyance.

5. Contingency Reserve: Projects that are complete from a planner's viewpoint but currently not the utility's best choices. Perhaps their costs are higher than those of other alternatives, or they may furnish energy of the wrong kind or at the wrong time. If and when the utility's need changes, they can be available on short notice. In the meantime, they're not cleared for construction or implementation.

6. Project in Abeyance: Projects whose incomplete planning work has been halted because of barriers (often environmental, legal or institutional) discovered during the planning process. If the barriers are removed or overcome, planning may be revived.

Some possibilities are dropped entirely because of barriers that apparently cannot be covercome -- e.g., economic or technical infeasibility, extraordinarily long develoment times or development by someone else. For planning and reporting purposes, however, every proposal that starts through the system is tracked, together with reasons for dropping projects that do not appear in the six planning/resource categories.

It was soon apparent that we needed some system to facilitate and justify placement in the six resource categories, to determine the most appropriate use of R&D money, and to display information so that it would

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be useful both within and outside City Light. Although it was not a City Council requirement, a Data Base emerged as a logical way to display the systematic and separate analyses of all our resource options. Eventually, such a base became a highly detailed appendix to the annual Energy Resources Report, our other major planning document.

In contrast to the Data Base, the report is flexible in both format and scope from year to year. It is intended to analyze the current need for power, discuss possibilities for meeting the need, and recommend a course of generation and conservation development together with supporting research and other planning and expenditures needed for the ensuing year. It's also a convenient place to highlight problems or benefits important to planners. But the current form of these publications was hardly apparent when we began the three-year development process.

Year I: During 1980, the utility's primary task was to develop a very preliminary Data Base and Report. Because we didn't yet have budget authority to hire our new team, this task was added to the full workload of our Engineering Division. They developed a first effort -- largely single-page computer printouts -- that did not fully meet the utility's, the Council's or the public's needs. The citizens' advisory committee found it inadequate in several respects and recommended changes. In the 1980 report, the utility pointed to the need for strengthening the Data Base in several ways: better documentation of sources, better identification of uncertainties, improved display and format, review of economic models and assumptions and identification of person(s) responsible for each resource.

Year II: Early in the second year, the planning team was selected. Before it reached full strength, temporary and limited assistance was enlisted from two local consulting firms. One provided part of the technical evaluation of certain potential energy sources. The other continued a user-needs assessment that affirmed the utility's earlier perceptions about needed improvements, made preliminary suggestions for a new format, and assisted with public review and comment.

During the second quarter of 1981, our permanent planning group was in place and performing the vast amount of needed work -- designing and redesigning formats for Data Base writeups and summaries, developing and trying out a variety of schemes for organizing our data, tapping into hundreds of information sources, designing computer programs, crunching numbers, holding public workshops, establishing a documentation system, and securing and incorporating needed review.

Some of the knottiest problems were determining how much material to include and reconciling and identifying relevant costs, data and data collection approaches already in use for other purposes.

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At the end of the year, the City Council approved our first full-scale Data Base, a 572-page document. It begins with resources we're now using and ends with 21st century possibilities. In order, it presents our current generating projects and firm purchase contracts; next are conservation programs and generating projects that have already received a go-ahead from the City Council in earlier years. Obviously, although they're not yet in evidence, their potential energy is already being counted to meet deficits forecast in earlier years; hence, they're not available to help close the currently forecasted gap. It ends with pilot projects, reasearch projects, technologies being monitored for their twenty-first-century potential, options being dropped and prospective projects expected in succeeding Data Bases. Notice that none of this information -- the here-and-now in the beginning of the book or the maybe-someday at the end -- contributes to meeting the current problem: choosing options to meet the currently identified deficit.

Genuine resource options -- those with deficit-reducing potential -- comprise the central core and by far the largest section of the Data Base. The 1981 Data Base contains more than 100 options, ranging from 3 to 12 pages in length, each placed in one of the six resource categories. If selected or moved ahead, any of the 100-plus proposals would reduce our expected load or add to our projected energy supply. Of particular importance to planners are the explicit statements about assumptions underlying all calculations; the standard, easily scanned, single-page summaries; and the use of eight standard headings or data elements for organizing and displaying all data. In order, the data elements are:

1. General: resource, project or program description; existing features, if any, and those to be added; state-of-the-art of relevant technologies; ownership arrangements, funding possibilities.

2. Timing: significant milestones and time required for major activities that must precede endorsement and energy production or savings.

3. Energy: amount and kind (on peak, intermediate peak, off peak, firm, non-firm) generated, offset or saved during particular time periods; seasonal profile showing energy available each month.

4. Economics: four key indicators (net present value, savings/investment ratio; benefit/cost ratio, and levelized cost) along with expected capital costs (or Seattle's expected share of costs) for construction or program development for each year prior to energy availability as well as each year of project or program life.

5. Environmental and Social: reference to environmental checklists, analyses and/or impact statements; possible impacts and corresponding

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mitigations for changes to animal, plant and human populations caused, for example, by generation, transmission, rights of way, manufacture of needed materials, procurement of fuels.

6. Legal and Institutional: other agencies involved, rights to be protected, existing and projected legislation, judicial review, rulings and documents of importance.

7. City Light Planning: pre-endorsement, research and other planning activities (as distinct from project development activities), proposed methods, likely costs and probable planning times.

8. References: all sources used and locations of these documents.

Year III: During the third year (1982) we were expected to produce mixes of resources, each capable of meeting future needs with different costs, benefits and trade-offs. The 1982 exercise turned out to be far from academic. Seattle was, and is, thinking about acquiring a share of the Creston Coal Plant sponsored by Washington Water Power, an investor-owned utility. To help make this decision, the Council directed us to identify at least 230 megawatts of alternatives to Creston.

The ensuing work required using and expanding the Data Base, working with a new citizens' committee and responding to advocates for particular approaches ranging from all conservation to all thermal power.

As a temporary target, we used the 306-megawatt deficit in our own load forecast, a gap based on an expected increase of 46% from our current 950-megawatt load to an anticipated 1351-megawatt load in 1982. Another bleak and expensive prospect was our seasonal load imbalance. Our winter load, now 15% higher than our annual average, will be 30% higher in another 20 years. But hydro, for decades our all-purpose answer, can't meet our winter bulge unless the run-off from one winter's frozen streams and snow packs can be stored and released the following winter. And hydro sites able to support large reservoirs have long since been exhausted.

Still other problems were posed by an array of moving targets: substantial variations among the region's forecasts; changing technologies, timetables and end uses; sites yet to be located; a Regional Power Plan yet to be announced; a BPA contract still being negotiated; BPA rate increases greatly exceeding our own.

After developing four different 306-megawatt mixes, none of which gave us a reserve margin, we faced up to the need for more flexibility to deal with this planners nightmare of unknowns. We developed a larger target:

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450 megawatts. And we began meeting it with the City's designated priority --conservation. In addition to conservation impacts over the last five years, the City Council has already approved programs expected to shave another 198 megawatts from future loads. These projected savings range from a 3 megawatt streetlight conversion program to 40 plus megawatts from stringent new requirements that are deterring conversions or enforcing conservation measures when homeowners add electric heat. Finding out how much more conservation can be squeezed from our service area required an exhaustive study. This assessment turned up 178 additional megawatts from all sources except bans and connection charges.

Another assessment turned up 172 megawatts that could come from alternative generation (cogeneration, small hydro, solid waste, biomass, geothermal and wind), three quarters of it no more costly than the Creston Coal Plant. Finally, we recommended 100 megawatts of some kind of thermal energy -- possibly from the coal plant, possibly from other sources. The recommendations and a summary of the backup work are described in six documents: the title of the summary volume is Energy Options.

If we meet the entire target, we can reduce our BPA purchases from 25% of our current load to 11% of a larger load. If we exceed our goals, we'll have a source of revenue or a contribution to make to the resource pool the Northwest will need in the 1990's and beyond. Whatever the case, we'll be adding to our customers' equity in a system in which they already have a $600 million investment.

In 1983, we'll be testing the effect of energy options on our projected deficit, not only singly but in a large number of combinations to determine desirable resource mixes.

In the meantime, the same planners who were earlier inundated with paper are now visiting industries with cogeneration potential and tramping the countryside to inspect small hydro sites. Their examination of a myriad of possibilities is, or will be, mirrored throughout the region for very few of our current energy possibilities will have major load impacts individually. Any major impact must come from many separate options, individually located, chosen and developed, all with risks and none with money-back guarantees.

The theme of Energy Options is that these kinds of preparation and risk go hand in hand with the commensurate benefits of an energy future that is selected instead of imposed. Acquiring useful information and making systematic plans are the essential foundation of Seattle's energy future.

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INTEGRATION OF FISH AND WILDLIFE DATA WITH GEOBASED AND REMOTELY SENSED LAND USE/LAND COVER DATA -- A DEMONSTRATION USING SITES IN PENNSYLVANIA

Charles T. Cushwa[1], Germain LaRoche[2], and Calvin W. Du Brock[3]

ABSTRACT

The U.S. Fish and Wildlife Service developed a statewide fish and wildlife data base for the Pennsylvania Game Commission that includes 125 categories of information on each of the 844 species. This species data base is integrated with geobased and remotely-sensed land use/land cover data from two sites in Pennsylvania. One site is an energy development project; the other is a high-energy use area. Analyses using the combined animal and land use data bases will be demonstrated for a variety of land use/land cover types at both sites. The ability to make "what if" analysis prior to project implementation is presented. The Pennsylvania Fish and Wildlife Data Base will also be demonstrated during the Poster Session.

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INTRODUCTION

An abundance of animal information is available for resource planning and management (Du Brock et al. 1981); however, much of this information is not used because definitions are not consistent and the information is in a variety of formats (Cushwa and Du Brock 1981). In an attempt to alleviate this problem, the U.S. Fish and Wildlife Service developed, "A Procedure for Describing Fish and Wildlife (Mason et al. 1979). The "Procedure" provides a framework for compiling and standardizing fish and wildife species information in a computerized data base and has been applied in Pennsylvania and seven other States.

The Fish and Wildlife Data Base developed in Pennsylvania following the "Procedures" includes distribution, legal status, life history and management information for 844 species of vertebrate and invertebrate animals which are resident and common migrants in the State. The data base management system, MANAGE (Wilcott 1981), is used to store and retrieve species information.

The Pennsylvania Fish and Wildlife Data Base and other data bases compiled using the "Procedure" are applicable to many resource planning and management needs, including:

- Inventory and descriptions of species and their life history needs by county, drainage basin, food preferences, etc.
- Preparation and review of permit applications for surface mining, base load power plants, point source discharge, and other regulatory uses.
- Preparation and review of environmental impact assessments and basinwide planning for fish and wildlife enhancement and protection.
- Preliminary evaluation and review of fish and wildlife resources on alternate sites for energy development projects.
- Environmental education, extension, and research.

In terms of environmental analysis, fish and wildlife information needs include the following six categories of information (Cushwa et al. 1980, NRC Regulatory Guides 4.2, 4.7, 4.8, and 4.11):

1. Animal distribution and abundance. (Species present, including actual and potential geographic ranges.)
2. Animal habitat relations/association. (Species habitat requirements.)
3. Availability of habitat and value. (Quantity of required habitat available.)
4. Habitat distribution. (Habitat location, including juxtaposition and interspersion)
5. Interrelations and effects. (Animal species and habitat response to land use/land cover changes)

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6. Human relationships/desires. (Project/management wildlife goals or objectives)

Past environmental analysis focused on a few high value species such as -- sportfish and game, pest species, threatened/endangered species -- regardless of their value in the ecosystem. However, the Pennsylvania Fish and Wildlife Data Base permits the decisionmaker to: (a) quickly and cheaply access and review the fish and wildlife species as well as animal communities likely to occur in a project area, (b) synthesize animal-habitat association, (c) integrate fish and wildlife data with other resources on the project area, and (d) simulate the effects of alternative land use/land cover changes. Typically, weeks or months of effort were expended in literature searches to make preliminary environmental analysis at the species level of detail. This can now be accomplished in minutes using the Data Base. In addition, species information can be aggregated by habitat type, land use or cover, location and a variety of other parameters for integration with other data bases.

To supplement animal information systems, computer-generated maps (geographic information systems - GIS) are being used more frequently in environmental analysis and planning. The long established capabilities of aerial photography and the more recent landsat imagery are being integrated with GIS's. In this paper, we demonstrate a third element; a computerized fish and wildlife data base to provide an even more useful information system for siting energy facilities, and for use by land use planning and resource management.

Utilizing state-of-the-art remote sensing techniques to identify the land use/land cover types in a project area and integrating this information with selected GIS elements (e.g., USGS topographic sheets, U.S. Bureau of Census DIMES) provides information on fish and wildlife habitat availability and distribution (items #3 and #4 above). Using a computerized fish and wildlife data base like the one in Pennsylvania provides information (items #1 and #2). Even more desirable, we can now examine "what if" situations to explore inter-relationships and objectives (items #5 and #6) before initial construction of a project.

In this presentation and in the Poster Session (to be held tomorrow evening in the Calhoun Room), we will demonstrate our integrated approach utilizing two areas in Pennsylvania -- the Berwick site, centered on a base-load power plant and the Lancaster site, a high-energy use urban and agricultural area (Figure 1).

DESCRIPTION OF STUDY SITES

The National Aeronautic and Space Administration (NASA), Pennsylvania Power and Light Company Company (PP&L), and the Nuclear Regulatory Commission (NRC) conducted a four-point evaluation to determine the applicability of GIS and remotely-sensed data in environmental analysis on the Berwick and Lancaster sites (Campbell and Ballard 1982). PP&L has an environmental land use data base with 42 elements that covers their entire service area (10,400 square miles) in Pennsylvania (Schoonhoven 1982). PP&L is building a nuclear power plant near the town of Berwick and has site-specific information as required by NRC regulations, such as a list of plants and animals actually observed on-site and in the nearby Susquehanna River. The Berwick site is also typical

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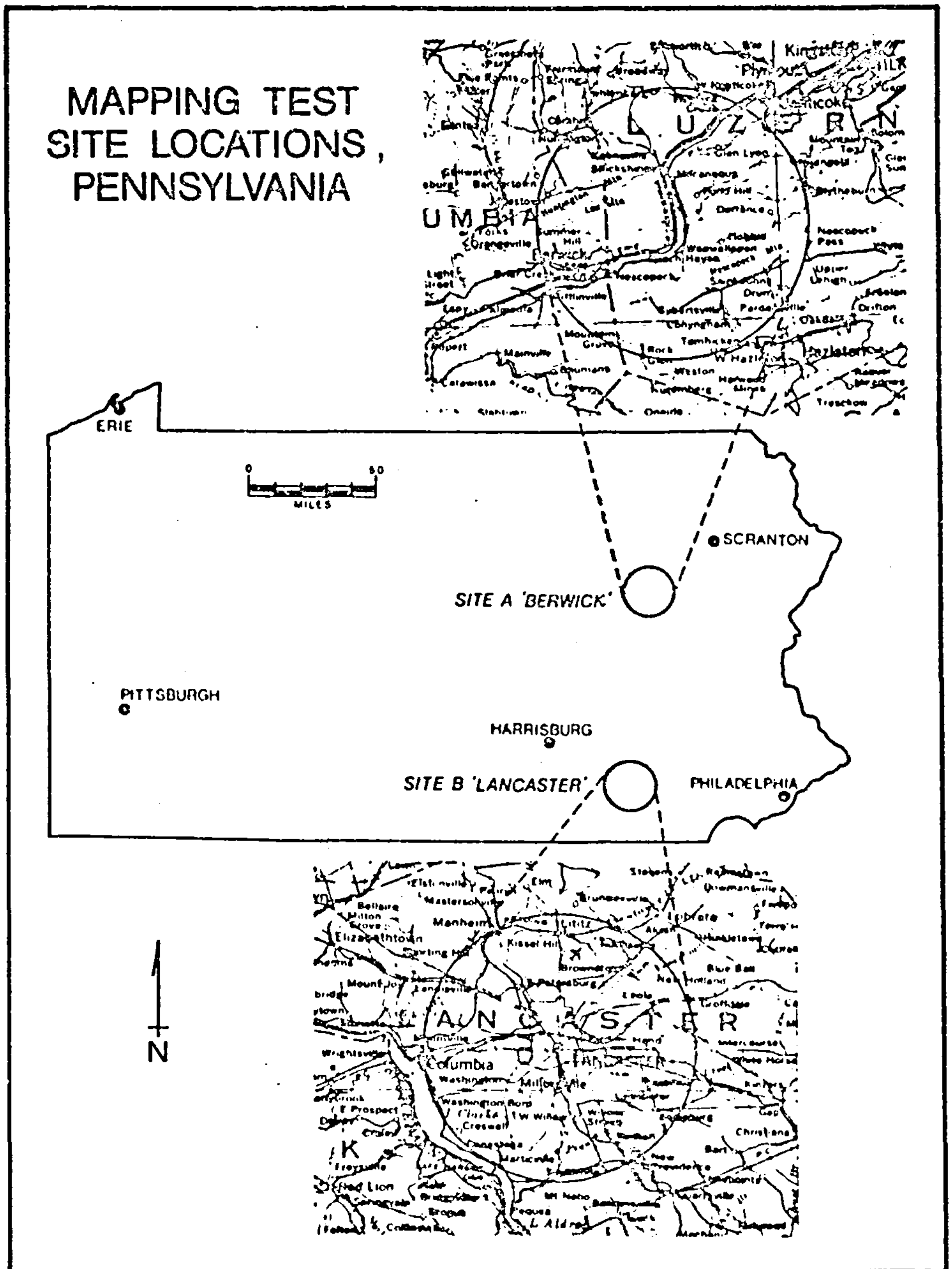

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of many areas in the East -- it is located in a large river valley, with sparse population, forested hills and small farms on the more level areas. The Lancaster site and county is one of the most productive agricultural counties in the U.S. By centering the study area on the city of Lancaster, an urban area surrounded by a highly agricultural area, NRC could evaluate this type of area's suitability for siting a nuclear power plant.

Both project sites contain 400 square miles, 20 miles on each side. NASA's Goddard Space Center determined the areas of each land use/land cover type within the two sites (Tables 1 and 2) utilizing PP&L's environmental land use data system (ELUDS).

The Lancaster site has more than twice the area in agriculture (cropland-pasture and orchards) (73.8%) as compared with the Berwick site (33.2%). On the other hand, the Lancaster site has only about 1/10th (9.8%) of its area in forest land compared to the Berwick site with slightly more than half (55.8%).

FISH AND WILDLIFE DATA BASE

The Pennsylvania Fish and Wildlife Data Base includes 125 fields of information for each species in the following categories: taxonomy, distribution, legal status/use, species origin, population descriptors, habitat associations, food habits, niche requirements, management practices, and references (Mason et al. 1979). Species descriptions were compiled from existing scientific literature; standard, consistent definitions and terminology were ensured by the coding instructions and 25 standard references. Each entry in the Data Base is based upon research, field studies, field notes, or other valuable expert knowledge and referenced in the Data Base (Cushwa et al. 1980). The Data Base was not designed to replace biological field studies, but to provide supplementary information to complement site-specific (biological field) studies.

COMBINING THE LAND USE/LAND COVER DATA WITH FISH AND WILDLIFE DATA FOR TWO ENERGY SITES IN PENNSYLVANIA

The Lancaster Site

The areas of land use and cover types at the Lancaster, Pennsylvania, site were determined from ELUDS (PP&L's Environmental Land Use Data System) as modified by NASA (Table 1). The LU/LC classes and definitions used in ELUDS were the same as those in the Pennsylvania Fish and Wildlife Data Base. Both used a classification developed by Anderson et al. 1976. We searched the Pennsylvania Data Base and developed a set of animal data for species known to occur in Lancaster County, and to be associated with each land use/land cover class on the Lancaster site (Table 3). We found 233 animal species associated with the land use/land cover class agriculture (level I) - cropland/pasture and orchards (level II) (Anderson et al. 1976). This "type" comprises 73.8% of the project site and provides potential habitat for 9 amphibians, 149 birds, 24 mammals, 14 reptiles, 35 terrestrial insects and 2 other terrestrial invertebrate species. Total computing cost to generate this set of animal information was $0.45. The common and/or scientific names of these animals plus any of the 125 fields of species information could be reported in this "set."

TABLE 1. AREAS OF LAND USE/LAND COVER TYPES AT THE LANCASTER SITE.

Original data, in polygon form, obtained from the Pennsylvania Power and Light Company's Environmental Land Use Data System (ELUDS) and gridded to 67 meter pixels by NASA/Goddard Space Flight Center.

Type	Miles Sq	Acres	Kilometers Sq	Hectares	% of Total
Urban	51.9	33,233.7	134.5	13,449.5	13.0
Cropland & Pasture	295.0	188,850.1	764.3	76,426.6	73.7
Orchards	0.7	469.2	1.9	189.9	0.1
>70% Evergreen Forest	0.2	159.6	0.6	64.6	0.0
>70% Deciduous Forest	34.7	22,232.3	90.0	8,997.3	8.7
Mixed Forest	3.6	2,336.1	9.5	945.4	1.0
Shrub Land	0.1	49.9	0.2	20.2	0.0
Herbaceous (Meadow) Rangeland	0.0	0.0	0.0	0.0	0.0
Wetland Forested	0.4	229.6	0.9	92.9	0.1
Barren Land	0.4	259.4	1.1	105.0	0.1
Waterbody	11.9	7,617.1	30.8	3,082.6	3.0
Unclassified	1.1	563.0	2.2	226.0	0.3
Total	400	256,000	1,036.0	103,600	100.0

TABLE 2. AREAS OF LAND USE/LAND COVER TYPES AT BERWICK SITE.

Original data, in polygon form, obtained from the Pennsylvania Power and Light Company's Environmental Land Use Data System (ELUDS) and gridded to 67 meter pixels by NASA/Goddard Space Flight Center.

Type	Miles Sq	Acres	Kilometers Sq	Hectares	% of Total
Urban	21.5	13,737.8	55.6	5,559.6	5.0
Cropland & Pasture	132.1	84,549.0	342.2	34,216.5	33.0
Orchards	0.8	492.5	2.0	199.3	0.2
>70% Evergreen Forest	3.3	2,097.6	8.5	848.9	0.8
>70% Deciduous Forest	150.6	96,387.8	390.1	39,007.6	38.0
Mixed Forest	63.0	40,336.1	163.2	16,323.8	16.0
Shrub Land	1.9	1,215.7	4.9	492.0	0.1
Herbaceous (Meadow) Rangeland	0.4	234.0	0.9	94.7	0.1
Wetland Forested	4.0	2,580.0	10.4	1,044.1	1.0
Barren Land	15.2	9,701.4	39.3	3,926.1	4.0
Waterbody	6.5	4,135.2	16.7	1,673.5	1.6
Unclassified	0.7	532.9	2.2	213.9	0.2
Total	400	256,000	1,036.0	103,600	100.0

Other land use/land cover classes on the Lancaster project site included:

1. Urban (level I) (Anderson et al. 1976) occupies 13.0% of the project site and 140 animal species occur in Lancaster County and are associated with this class. Computing costs to produce this set were $0.37 (Table 3).

2. Deciduous forest covers 8.7% of the project site in Lancaster County and there are 247 animal species which occur in the county and are associated with this "type." Computer costs to produce this set were $0.42.

3. Three percent of the project site is covered with water. There are 167 animal species in Lancaster County that are associated with this habitat type. Cost to produce this set was $0.37.

Total computing costs to associate animals in Lancaster County with four land use/land cover level I or II classes was $1.60. These four types account for 99% of the project sites (Table 3).

In addition to associating the animal data with land use/land cover classes, the animal data base can be used to make simulations or "what if" types of preliminary analysis. For example, "if" PP&L and NRC want to look at Lancaster as a potential energy development site, we can develop a "set of animal data" which includes species in Lancaster County and are associated with any of the four land use/land cover classes in Table 3. This "set" included 440 animals in the following groups:

```
 24 AMPHIBIANS
225 BIRDS
  1 CRUSTACEANS
 47 FISH
  7 INSECTS-AQUATIC
 51 INSECTS-TERRESTRIAL
 38 MAMMALS
 20 MOLLUSCS
  2 OTHER-TERRESTRIAL INVERTEBRATES
 25 REPTILES
440 ANIMALS

COMPLETED.
COST:   I/O   $   .11   CPU   $   .03   CONNECT $ .03   TOTAL   $ .17
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Table 3. Animals known to occur in Lancaster County, Pennsylvania, and to be associated with four land use/land cover classes by animal group.

	Agriculture Cropland - Pasture & Orchards (73.8%)	Forest (9.8%)	Urban (13.0%)	Water (3.0%)
AMPHIBIANS (38)	9	17	7	15
BIRDS (250)	149	140	88	64
FISHES (184)				47
MAMMALS (65)	24	36	16	5
REPTILES (41)	14	15	5	8
CRUSTACEANS (4)				1
MOLLUSCS (69)				20
AQUATIC INSECTS (90)				7
TERRESTRIAL INSECTS (92)	35	37	22	
OTHER AQUATIC INVERTEBRATES (3)				
OTHER TERRESTRIAL INVERTEBRATES (8)	2	2	2	
TOTALS (844)	233	247	140	167
	$0.45	$0.42	$0.37	$0.36
TOTAL COSTS = $1.60				

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We were interested in the status of these 440 animals that may occur on the Lancaster site, so we group the animals by status, as follows:

72 UNLISTED
27 COMMERCIAL
81 CONSUMP-RECREATIONAL
22 INDICATOR
245 NON-CONSUMPTIVE RECREATIONAL
340 SEE COMMENTS
25 SENSITIVE
1 STATE-ENDANGERED
26 UNKNOWN

NUMBER OF VALUES LISTED: 9

COMPLETED.
COST: I/O $ .11 CPU $ .03 CONNECT $ .05 TOTAL $ .19

One of the 440 animals species is classified by the State of Pennsylvania as endangered, the bog turtle. We prepared a report which contains ALL of the information in the data base for the bog turtle. The cost to report the profile for 125 fields of information was $2.64.

We sorted the data on 440 animals known to occur in Lancaster County and to be associated with one or more of the four land use/land cover classes by:

A. Major habitat types

122 species associated with aquatic habitat types
76 with riparian habitat types
274 with terrestrial habitat types
@ cost of $0.15

B. Trophic level of the adult life stage

1 Unlisted
214 Carnivore
68 Herbivore
144 Omnivore
13 Unknown
@ cost of $0.12

C. Forest size class

82 Unlisted
183 Mature size class
150 Pole size class
144 Seedling/sapling size class
124 Unknown
145 Unstocked size class
@ cost of $0.19

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D. Wetland type

91 Unlisted
74 Estuarine
141 Lacustrine
3 Marine
156 Palustrine
196 Riverine
99 Unknown
@ cost of $0.27

E. Food habits of the larval life stage

359 Unlisted
2 Arthropods-other terrestrial
5 Detritus-organic
4 Flower/nectar/pollen
1 Hardwood fruit
3 Herbaceous fruit
16 Herbaceous plant parts
9 Insects-adult terrestrial
5 Insects-aquatic
11 Insects-immature terrestrial
3 Phytoplankton-diatoms
4 Plant sap
2 Rooted aquatic plants
14 See comments
1 Softwood fruit
3 Unknown
24 Woody plant parts
@ cost of $0.45

F. Occurrence in % Counties of Pennsylvania

12 10%
40 10-25%
311 100%
33 25-50%
22 50-75%
22 75-99%
@ cost of $0.16

G. Adverse management practices

4 (No practices listed)
17 Application of fertilizers
212 Application of herbicides
287 Application of insecticides
220 Application of pesticides
62 Channelization
124 Clean farming
22 Creation of small and large impoundments

22 Creation of suburban residential areas
3 Even age timber management
1 Farm pond development
16 Grassland burning
14 Grazing
26 Impoundment of waterways
6 Increase in deep water habitats
184 Industrial pollution
99 Intensive agricultural practices
103 Intensive recreational development
13 Maintain early stages of succession
1 Maintain mast producing trees
7 Maintain mature hardwood forestc
18 Maintain mudflats
14 Maintain overmature hardwood and coniferous forests
56 Man caused fluctuation in water level during breeding
20 Navigational improvements
3 Plantings
1 Prescribed burning
29 Reforestation
88 Removal of forest land for farming
83 Removal of streamside vegetation
3 Retain or produce special habitat features
4 Retention of wilderness
51 See comments
32 Siltation
1 Thinings and release cuttings
58 Timber harvest
3 Timber stand improvement
67 Unknown
79 Urban or agrarian development
@ cost of $0.59

H. Niche requirements of species with an external egg life stage

45 (No requirements listed)
1 Air temperature:see comments
2 Aquatic zonation:Littoral
6 Aquatic/terrestrial ecotone:see comments
67 Aquatic/terrestrial ecotone:unknown
5 Caves-dry:unknown
1 Caves-wet:unknown
1 Cliffs/ledges:see comments
12 Cliffs/ledges:unknown
1 Coastal zone:unknown
4 Coniferous forest association:see comments
99 Coniferous forest association:unknown
28 Decaying plants:unknown
5 Dissolved oxygen:anoxyphilous
1 Dissolved oxygen:euoxyphilous
36 Dissolved oxygen:mesoxyphilous
1 Dissolved oxygen:oligoxyphilous
1 Elevation:14000-15000 ft

2	Grasses:see comments
24	Grasses:unknown
26	Grassland:unknown
1	Groundwater:see comments
10	Hardwood forest association:see comments
103	Hardwood forest association:unknown
3	Herbs:see comments
14	Herbs:unknown
21	Human association:see comments
31	Human association:unknown
6	Inland wetland:bogs
1	Inland wetland:ditches
1	Inland wetland:embayments
4	Inland wetland:island inhabitant
11	Inland wetland:pool areas
3	Inland wetland:prairie potholes
6	Inland wetland:seasonal wet depressions
36	Inland wetland:see comments
1	Inland wetland:sink holes
16	Inland wetland:sloughs/bayous
1	Inland wetland:tundra
30	Inland wetland:unknown
5	Inland wetland:vegetated stream banks
22	Inland wetland:weedbeds-lake
15	Inland wetland:weedbeds-stream
8	Leaf litter/debris/humus:see comments
17	Leaf litter/debris/humus:unknown
33	Meadows:unknown
24	Nest sites:cavities-dead/dying trees
24	Nest sites:cavities-live trees
5	Nest sites:depressions
19	Nest sites:see comments
168	Nest sites:unknown
28	Old fields:unknown
54	Orchards:unknown
2	Pastures:see comments
33	Pastures:unknown
4	pH:alkaliphilous
15	pH:indifferent
23	pH:neutral
1	Salinity:euryhalinous
41	Salinity:oligohalobous
2	Seeps/springs:see comments
3	Shrubs:see comments
62	Shrubs:unknown
1	Soil:gravel
2	Soil:loamy
14	Substrate:embenthic
33	Substrate:epibenthic
1	Substrate:epilithic
3	Substrate:epipelic
32	Substrate:epiphytic
2	Substrate:episabulic

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11 Substrate:epixylous
15 Substrate:see comments
1 Substrate:unknown
14 Successional stage:see comments
12 Successional stage:unknown
1 Suitable host:see comments
2 Turbidity:eulichotophilous
1 Turbidity:mesolichtophilous
2 Turbidity:polylichtophilous
18 Unknown
4 Vegetation mosaics/edges:see comments
46 Vegetation mosaics/edges:unknown
1 Velocity:see comments
20 Velocity: 0.5 fps
4 Velocity:1.0-1.5 fps
18 Velocity:.5-1.0 fps
1 Vines:see comments
17 Vines:unknown
20 Water depth preference: 1 ft
23 Water depth preference:1-5 ft
4 Water depth preference:5-10 ft
14 Water level:permanently flooded
2 Water level:seasonally flooded
1 Water level:semipermanently flooded
1 Water level:steady-state reservoir levels
41 Water temperature:mesothermal
2 Water temperature:oligothermal
1 Water temperature:see comments
@ cost of $1.31

The above sets A-H demonstrate how the Data Base can provide detailed information on about 440 species of animals associated with land use/land cover classes for a project site in Lancaster County, Pennsylvania. Total costs for the Lancaster analysis were:

$1.60	individual land use/land cover analysis
.17	land use/land cover animal group
.19	land use/land cover animal status
2.64	bog turtle species profile
3.24	sets A-H
$7.84	TOTAL COSTS

Total time in making this analysis was one hour.

The Berwick Site

The Berwick site includes land in Luzerne and Columbia Counties, Pennsylvania. Five land use/land cover types included 99% of the project site (Table 2). We followed the same process in analyzing animal associations at the Berwick site as used at the Lancaster site; i.e., we grouped animal species into "sets" which corresponded to animal species known to occur in Luzerne or Columbia Counties and to be associated with each of the five land use/land cover classes. At the Berwick project site there were 253 animal species associated with

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the level I class, "forest," including 17 amphibians, 145 birds, 49 mammals, 14 reptiles, 26 terrestrial invertebrates, and 2 other invertebrates (Table 4). There were 223 animal species associated with cropland-pasture and orchards; 133 in the urban class; 17 in barren; and 144 in the water class. Computing cost for the five sets was $2.25.

A Comparison of Animal - Land Use/Land Cover Data
From Two Sites

At the Lancaster site, 73.8% of the study area was classified as agriculture, which included cropland-pasture and orchards. There were 233 animal species associated with these land use/land cover classes. At the Berwick site, 33.2% of the study area was classified as cropland-pasture and orchards. There were 223 animal species associated with this type including the same number of birds and 3 more species of mammals than at the Lancaster site. The number of animal species in the other taxonmic groups was also similar for the two sites (Table 5).

At the Lancaster site, 9.8% of the study area was classified as forest. There were 247 animal species associated with this class. At the Berwick site, 55.8% of the area was forest, including coniferous, deciduous, and mixed forest types with a total of 253 animal species associated with these types. It appears that the greater number of forest types at the Berwick site may explain why there were 13 more mammal species and 5 more bird species at this site. The significance of these differences is not clear. A much more detailed analysis within major groups of animals would be required to explain some of these differences. However, our purpose here is not to analyze differences in the ecology of the two sites, but to demonstrate the capability of the Pennsylvania Data Base to associate the animals with classes of land use and cover determined by remotely-sensed data coupled with a geographic information system. Examples of this type of analysis will be demonstrated during the Poster Session.

Information about the Pennsylvania Data Base can be obtained by contacting the Pennsylvania Game Commission: Mr. Jacob Sitlinger, Chief, Division of Land Management, Pennsylvania Game Commission, P. O. Box 1567, Harrisburg, Pennsylvania 17120. Telephone: 717/787-6818.

CONCLUSIONS AND RECOMMENDATIONS

We have demonstrated one approach of integrating fish and wildlife data with land use/land cover classes on two sites in Pennsylvania. The effectiveness of this approach depends upon the quantity and quality of information in the data base, user information needs, and how well the land use/land cover classification schemes group animals into meaningful biological units or ecosystems.

An animal data base designed according to guidelines developed in Pennsylvania can be used to make an inexpensive, quick first look at fish and wildlife resources on or near to energy development sites. It could also be a useful tool for the evaluation of potential impacts of construction of energy facilities and long-term operation of a facility on fish and wildlife.

Table 4. Animals known to occur in Luzerne and Columbia Counties and to be associated with five land use/ land cover classes by animal group.

	Agriculture Cropland - Pasture & Orchards (33.2%)	Forest (55.8%)	Urban (5.0%)	Water (1.6%)	Barren (4.0%)
AMPHIBIANS (38)	8	17	6	15	3
BIRDS (250)	149	145	88	57	4
FISHES (184)				48	
MAMMALS (65)	27	49	16	6	5
REPTILES (41)	13	14	4	6	3
CRUSTACEANS (4)					
MOLLUSCS (69)					
AQUATIC INSECTS (90)					
TERRESTRIAL INSECTS (92)	23	26	17		2
OTHER AQUATIC INVERTEBRATES (3)					
OTHER TERRESTRIAL INVERTEBRATES (8)	3	2	2		
TOTALS (844)	233	253	133	144	17
	$0.50	$0.40	$0.46	$0.45	$0.44
	TOTAL COSTS = $2.25				

Table 5. A comparison of animals associated with four land use/land cover classes at the Lancaster and Berwick project sites in Pennsylvania.

	Agriculture		Forest		Urban		Water	
	L (73.8%)	B (33.2%)	L (9.8%)	B (55.8%)	L (13.0%)	B (5.0%)	L (3.0%)	B (2.0%)
AMPHIBIANS (38)	9	8	17	17	7	6	15	15
BIRDS (250)	149	149	140	145	88	88	64	57
FISHES (184)							47	48
MAMMALS (65)	24	27	36	49	16	16	5	6
REPTILES (41)	14	13	15	14	5	4	8	6
CRUSTACEANS (4)							1	0
MOLLUSCS (69)							20	8
AQUATIC INSECTS (90)							7	4
TERRESTRIAL INSECTS (92)	35	23	37	26	22	17		
OTHER AQUATIC INVERTEBRATES (3)								
OTHER TERRESTRIAL INVERTEBRATES (8)	2	3	2	2	2	2		
TOTALS (844)	233	223	247	253	140	133	167	144

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The key to integrate the animal data with remotely-sensed land use/land cover data was that both data bases used the standard land use/land cover classes and definitions developed by Anderson et al.(1976.) Without this standardization of data elements and definitions, we could not have integrated these data bases.

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AIR FORCE ENERGY REQUIREMENTS

BRIAN R. LENZ, MAJOR USAF

HQ USAF/LEYSF

WASHINGTON D.C. 20330

The energy status, goals and objectives of the Air Force will be outlined in the areas of aircraft, vehicle and installation operations. Past accomplishments in reducing energy consumption will be used to introduce on going energy programs and challenges to the Air Force in energy management. The Air Force has developed an extensive and successful energy conservation program. New and innovative approaches must be undertaken to continue the past momentum in reducing energy consumption. Air Force activity and requirements in new energy technologies such as solar, geothermal, wind energy, refuse derived fuel, shale oil, biomass and coal will be described.

The private sector development of new energy technologies and techniques could significantly contribute to Air Force energy conservation. The Air Force is looking at innovative approaches to obtain private sector energy expertise and complete new energy projects. One approach is for a contractor to develop and operate a specific energy source or improve the on base energy system efficiency. The contractor would then be paid over a period of time by the savings that develop. This would accelerate the energy technology transfer from industry and provide a market place for private industry.

Specific procedures and points of contact will be described to assist contractors in doing business with the Air Force. The primary offices involved in energy technology development will be outlined along with areas with a potential to be contracted out. General contract procedures and contract clauses will be introduced to aid contractors interested in doing business with the Air Force.

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LANDSAT USERS FORUM

R. Koffler and D. Cotter
Department of Commerce
National Oceanic and Atmospheric Administration
National Earth Satellite Service
Washington, D. C. 20233 USA

EXTENDED ABSTRACT

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) manages and operates the nation's civil operational earth remote sensing satellite programs. Landsat D, launched in July 1982, is the space component of the new, operational land satellite system that NOAA will initiate on January 31, 1983. The mode of operation of this new system is established. Published data collection objectives, production line processing, and fixed product delivery schedules are its main characteristics.

USERS FORUM

NOAA officials will provide attendees with an overview of the new Landsat system and the way that it will be operated. System decisions that remain open, new Landsat product prices, and the issue of commercialization will be discussed. Most of the period will be reserved for questions, comments, and suggestions from the audience. NOAA will provide mailing materials for those wishing to make written comments.

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ABSTRACT

"Low Cost Laser Disk for Geo-Referenced Data Storage"

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Presently, the storage, manipulation and discrimination of georeferenced data including satellite data is handled by a variety of approaches and systems. More often than not, these systems are not compatible in storage and retrieval format nor are the different data physically stored within easy access with each other. The huge volume of data returned by satellite either in digital or analog format can be stored on video disc. Any ancillary or complementary data to a given piece or pieces of real estate can also be stored on video and cross referenced between and among these multifaceted data types. This data includes satellite imagery, images constructed from MULTIDATE Landsat MSS and RBV data, Thematic Mapper (if available), HCMM, aerial photography, topographic and thematic maps, charts, and land use statistical data.

Video discs currently on the market (GE, Discovision, Sony) will allow up to 108K (both sides) of storage with access times 1/3 to 3 seconds to seek out and display any individual frame. An obvious advantage when compared with magnetic tape is in storage space and handling. The storage access can be accomplished by a variety of computerized data base management systems such as direct, hierarchical, key word and Network searches. Finally, cost advantage for storage in the range of 10^{11} bits is approximately $40,000 vs. $20 once the initial disc is pressed.

Part 6

APPLICATIONS: POSTER SESSIONS

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SOLAR TECHNOLOGIES: WHEN IS THE RESOURCE COST TOO HIGH

Y. M. Schiffman
President
Schiffman Energy Services, Inc.
Springfield, Virginia

This poster session reports on one aspect of the Technology Assessment of Solar Energy (TASE) Project. TASE was a comprehensive multi-year analysis of the environmental and community impacts which would result by the year 2000 if major national incentives were adopted to accelerate the use of solar and biomass technologies. The study employed a comparative approach to examine the probable impacts of large numbers of solar the biomass units and the reduction of a comparable amount of energy produced by conventional units. These comparisons are made by examining the direct and indirect pollution impacts associated with energy production, the capital and labor costs of systems operations, maintenance and construction, and the materials, land, and water resources that would need to be committed.

Overall, the study concluded that major incentives for solar and biomass technology development can lead to significant air pollution and safety problems as well as to major stress on national capital and materials resources. The rapid rate of growth associated with major incentives for solar and biomass technologies could markedly increase energy demands in the manufacturing sector. The potential environmental problems and increases in worker health and safety hazards would largely derive from an increased emphasis in the manufacture of numerous small decentralized systems. Increased use of small uncontrolled biomass combustion units would also likely exacerbate existing local air quality problems in many regions of the U.S. The capital and materials resource problems derive from emphasis on the high, near term growth in solar technologies. A general solution to this problem lies in greater emphasis on biomass technologies, particularly those ammenable to controls and in emphasizing the construction of community scale solar technologies.

The poster session will focus on the resource commitments of both conventional and renewable technologies. Comparisons will be made on a 10^{12} Btu basis to provide a consistent frame of reference for all discussions. Other aspects of this three and one half year study can be explored if the audience desires. The study made use of several large scale system dynamics models, models which the author helped design. These models have several interesting features for those interested in regional and state level energy modeling.

Practical Applications Using A High Resolution Infrared Imaging System

David W. Baraniak

Donohue

Abstract

Infrared imaging systems can be classified into three general categories, low resolution, medium resolution and high resolution. It is the purpose of this paper to highlight specific applications best suited to high resolution, television capatable, infrared data acquisition techniques.

The data was collected from both ground based and aerial based mobile positions where the temperature differentials varied from 15°C to 25°C.

Specific applications include scanning building complexes from the exterior using a ground based moving vehicle, scanning buildings, concrete bridge decks and terrain from the air using a helicopter and scanning building interiors using a mobile hand truck.

Introduction

By definition, high resolution imaging equipment produces a television signal equal to 525 lines horizontally, with each line containing 400 picture elements. The minimum resolvable temperature difference of the 8 to 14 micron sensor must be at least 1/2°C.

The unit used to collect the data contained herein was a Flir Systems model 100 TTV (Thermal Television) portable infrared camera. This unit was selected because of its direct television compatability and high resolution imagery. When connected to a portable video tape recorder and television monitor, the system becomes mobile and can be used on a cart, in a vehicle, in a helicopter, or in a fixed wing aircraft.

All of the data collected for energy conservation and surveillance is qualitative (i.e. no direct temperature measurements from the emitting surface are made). The difference in picture shading (grey tones) is due to the relative difference in object surface temperature. Usually, the lighter tones are warmer and the darker tones are cooler.

Data collected from the inside or outside of a building requires a temperature differential of at least 15°C for good thermal and spatial image quality.

As a practical matter, solar loading of exterior walls and roofs is not recommended when looking for insulation voids. However, the solar loading of flat roof decks or concrete surfaces when looking for wet insulation or concrete sub surface delaminations is required to produce good thermal patterns. With these parameters in mind, the thermal surface patterns are then imaged by the camera on a television monitor and at the same time recorded on video tape. When hard copy prints are required, a picture of the television monitor is made by using a polaroid camera attachment.

Exterior data acquisition using a vehicle mounted portable infrared unit

When a great number of buildings or when very large complexes were to be scanned, the vehicle mounted unit was used to collect the exterior data. This type of scanning is usually done in the evening (three to four hours after sundown) when the objects have begun to come into thermal equilibrium.

With the unit mounted in a vehicle (See Figure A) and aimed at the exterior surfaces, the thermal data was recorded on video tape. The vehicle speed determines the quality of images. If a very detailed analysis is required, the vehicle should stop and the camera should record as much data as possible. This technique allows for hard copy photographs of the monitor to be made without blurring the picture. Samples of this data are shown in figures 1 thru 4.

Exterior data acquisition using a helicopter mounted portable infrared unit

Data acquisition using a fixed wing or helicopter mounted infrared system (See Figure B) is required when a great deal of geographic area is to be covered or a specific area such as a roof is to be scanned. The most important factor in using an infrared system in this

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manner is its ability to produce high resolution imagery from within a relatively unstable environment (i.e. vibrating helicopter). Since the field of view is fixed at 21°x28° with the Flir TTV 100, the height of the helicopter or airplane from the target determines the amount of imagery presented on the television screen.

Generally speaking, a helicopter is used when targets, such as single or multi unit complexes, power lines, substations, bridge decks, roofs and thermally polluted waters are scanned for thermal anomalies. The helicopter's ability to hover over an area make it extremely useful to collect quality data. Fixed wing aircraft may be used for long distance flying of pipelines or pavement sections. Samples of this type of aerial data can be found in figures 5 thru 14.

Where helicopters are flying over populated areas, advance warning must be given to the local authorities and public media to forewarn residents of the flight patterns. Where night flying is required, a daylight over flight of the target area is required to alert the pilot of impending dangers such as high voltage towers, telephone poles, tall buildings, etc.

Interior data acquisition using a portable infrared unit mounted on a hand truck

When site circumstances require unit portability, the imaging system can be mounted on a hand truck (See Figure C). This type of mounting allows the operator to roll the system from point to point, while continuously recording. Where detailed hard copy pictures are required, the hand cart remains stationary while the camera records the target image.

Walk through interior scans of residential, industrial, institutional and commercial buildings lend themselves to this method. The temperature differential of 15°C still applies and the lack of solar loading on the exterior surface is a must. Since the surface emissivity of interior walls is usually uniform, the data collected tends to be consistent from room to room.

The interior scan procedure is used to detect insulation voids in the wall and ceiling areas. Additionally, air infiltration can be located around windows, doors and electrical outlets. Most energy audits use the interior scan to locate specific thermal anomalies where repairs are likely made. Figures 15 thru 18 highlight typical hand truck applications.

Additional applications for hand held usage include on site inspection of concrete for sub surface delaminations, on site preventive maintenance inspections in industry where hot electrical connections and hot bearings are detected, on site inspection of areas where heat transfer problems exist such as blocked heat exchanger passages, etc.

Summary

1. High resolution infrared imaging systems allow the laymen to easily interpret the data.
2. Direct television compatability allows the data to be recorded on standard video equipment.
3. System portability allows the user to choose his mode of operation (i.e. mobile scan, aerial scan or hand truck scan).
4. Television compatible high resolution imagery with a .5°C minimum resolvable temperature differential per picture element allows the data to quantified by computer.
5. Large data bases can be compiled in a short period of time using video tape (as opposed to hard copy prints produced on site).

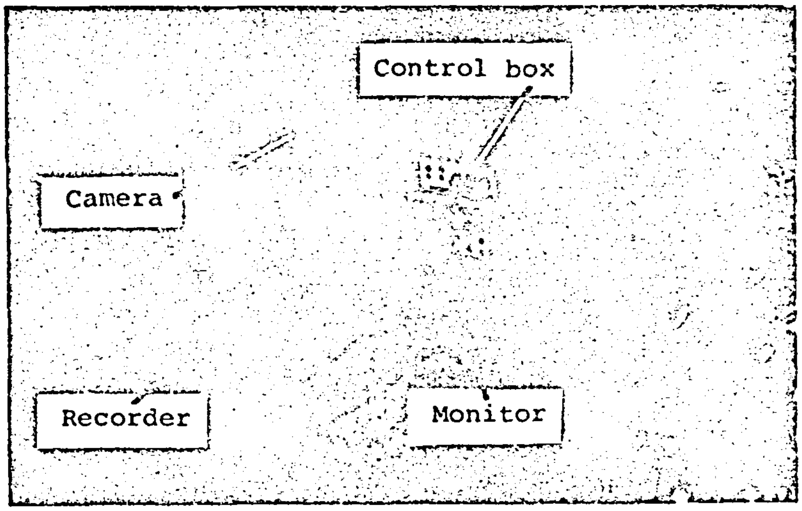

Figure A. Vehicle mounted

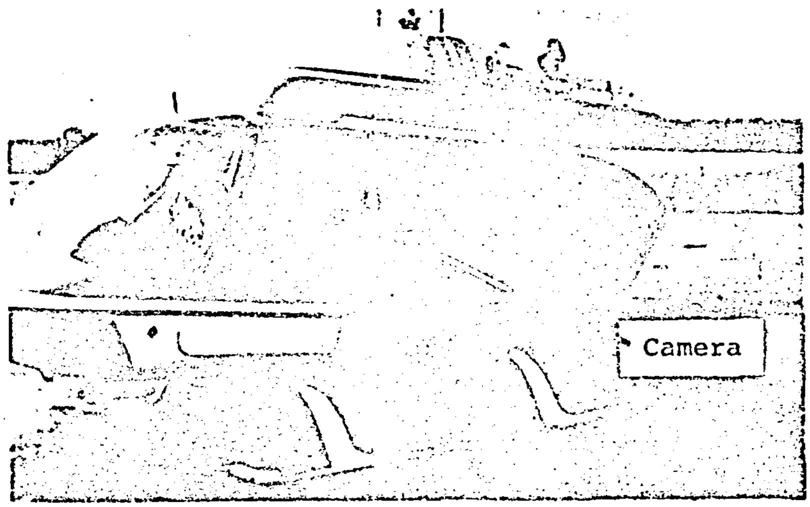

Figure B. Helicopter mounted

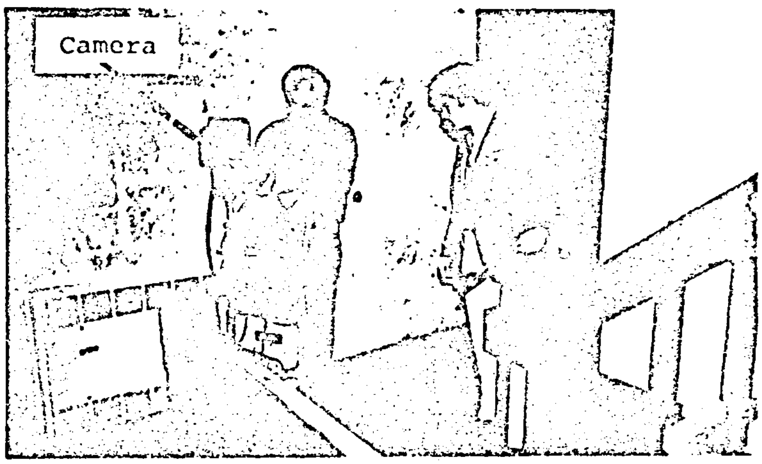

Figure C. Hand truck mounted

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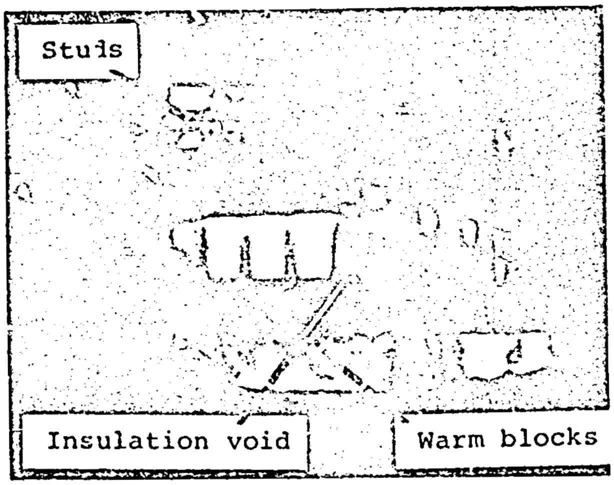

Figure 1. Frame home exterior

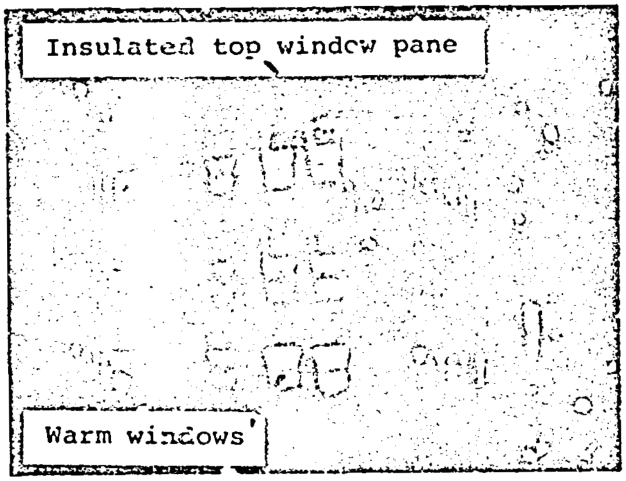

Figure 4. School exterior

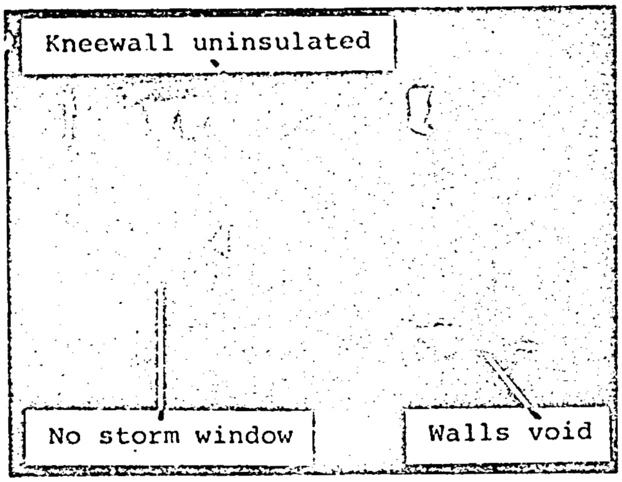

Figure 2. Sided home exterior

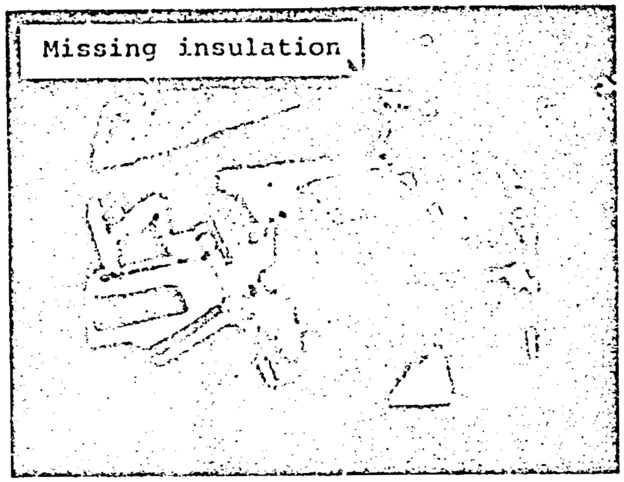

Figure 5. Condominium exterior

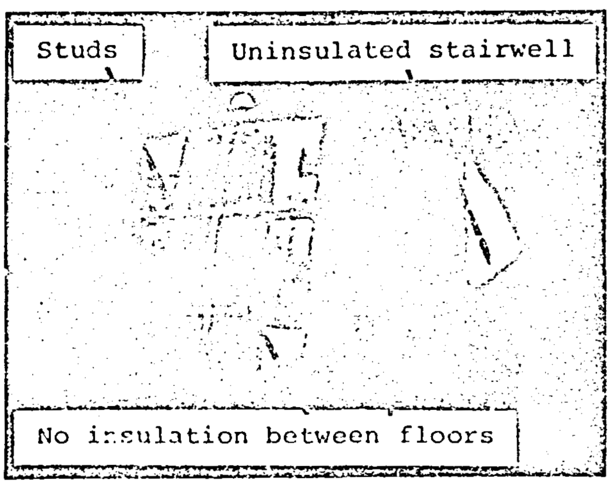

Figure 3. Condominium exterior

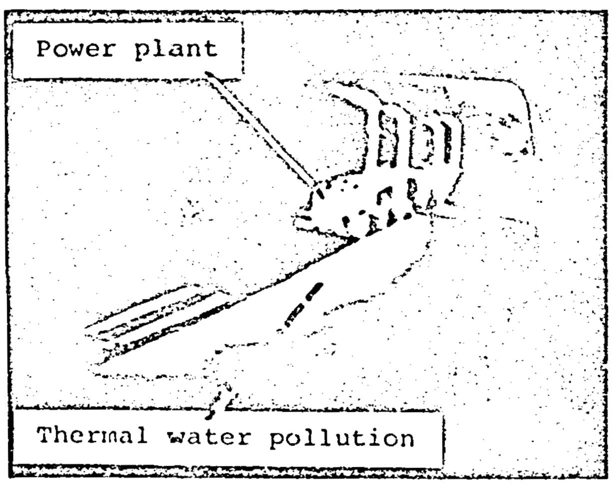

Figure 6. Wisconsin power plant

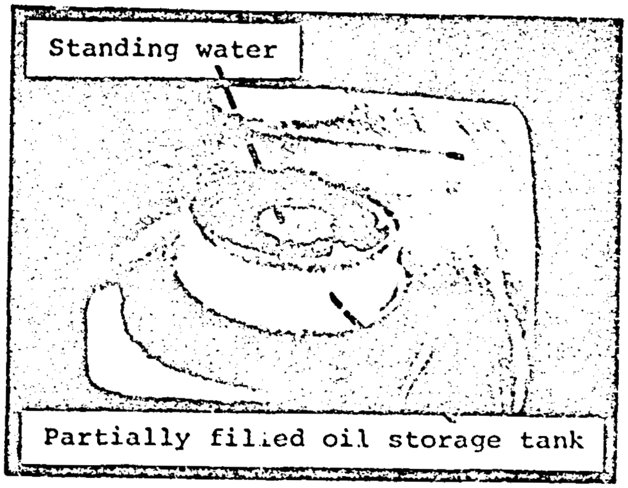

Figure 7. Hot oil storage tank

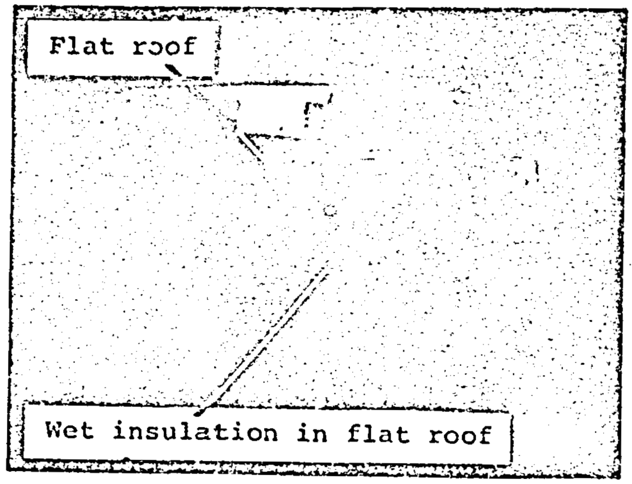

Figure 10. Flat roof school

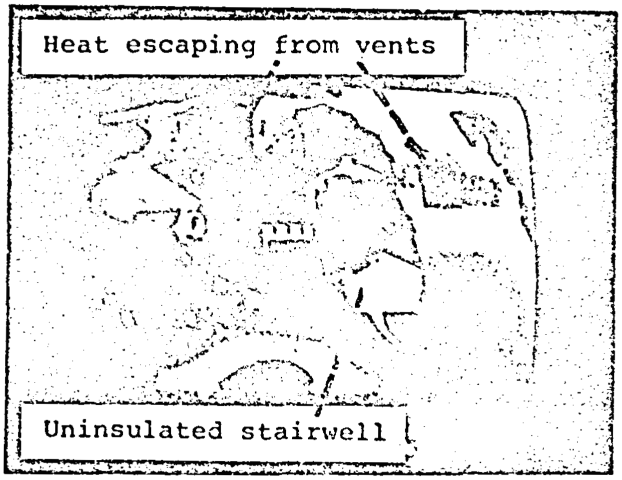

Figure 8. Condominium exterior

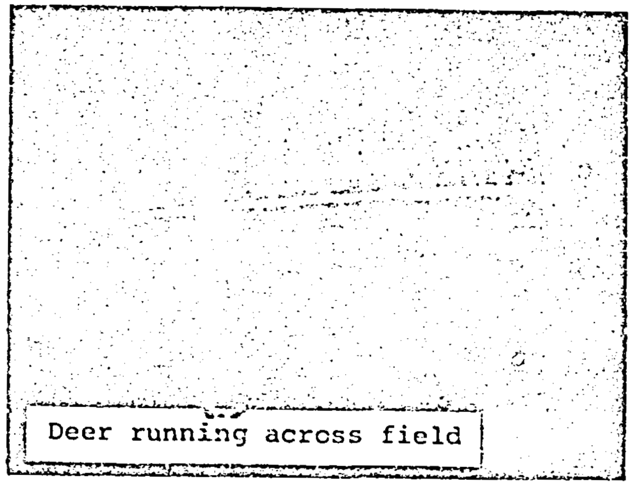

Figure 11. Surveillance in open field

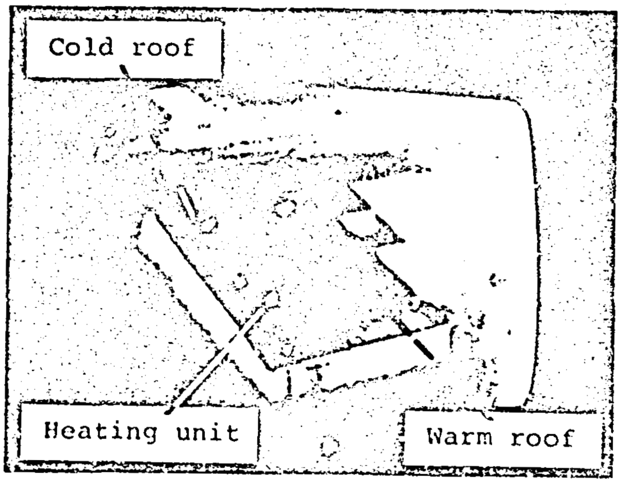

Figure 9. Flat roof building

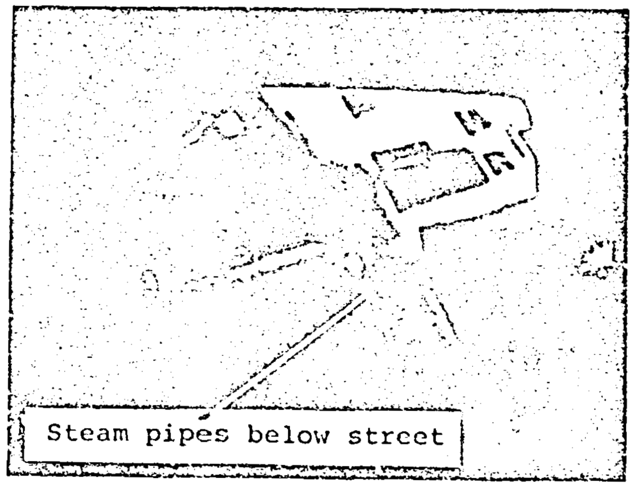

Figure 12. Milwaukee city streets

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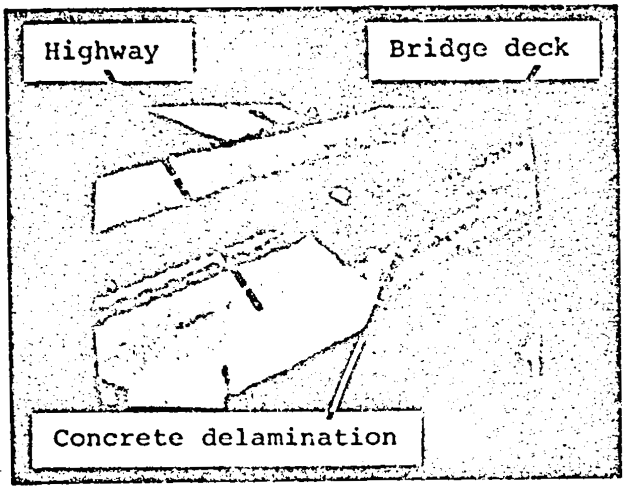

Figure 13. Interstate bridge deck

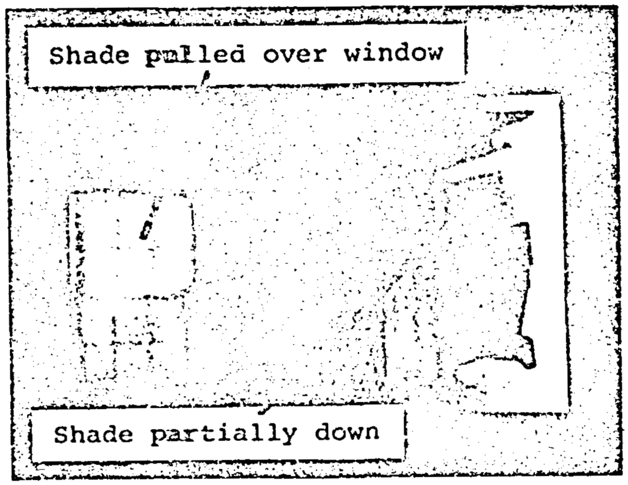

Figure 16. Home interior window comparison

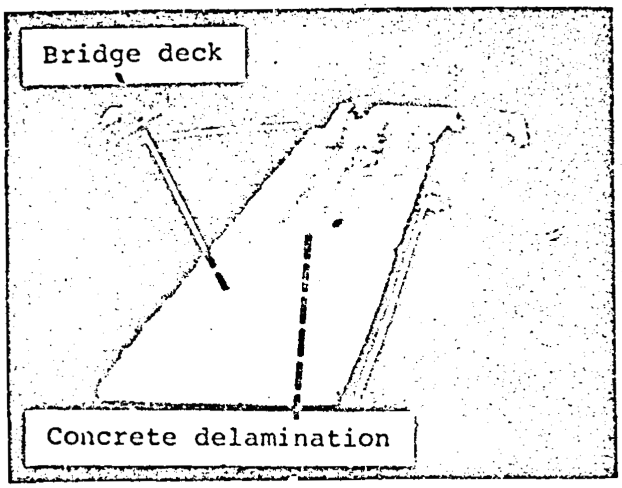

Figure 14. Interstate bridge deck

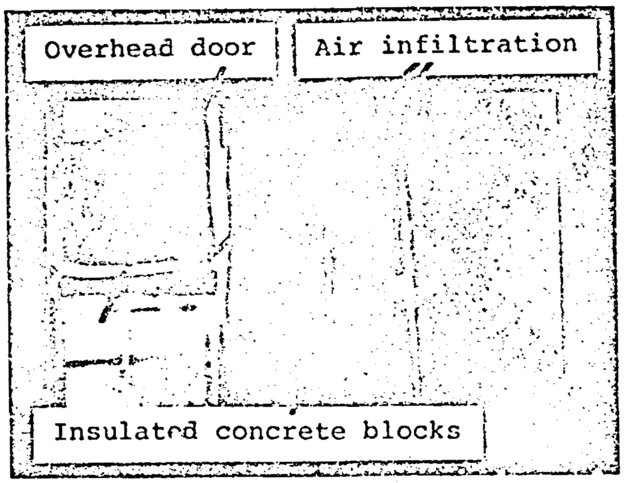

Figure 17. Block building interior

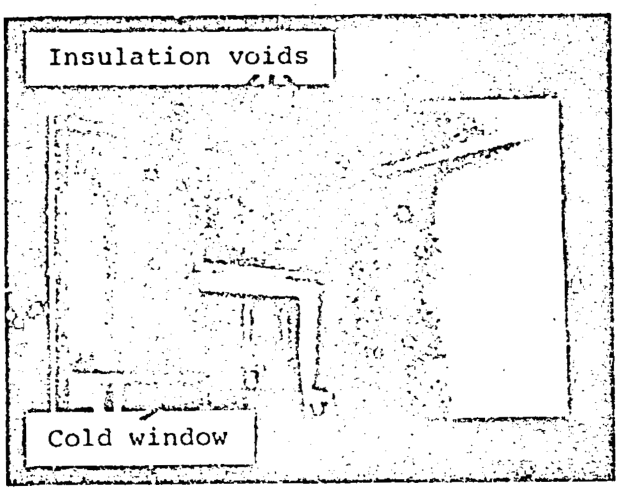

Figure 15. Home interior with voids

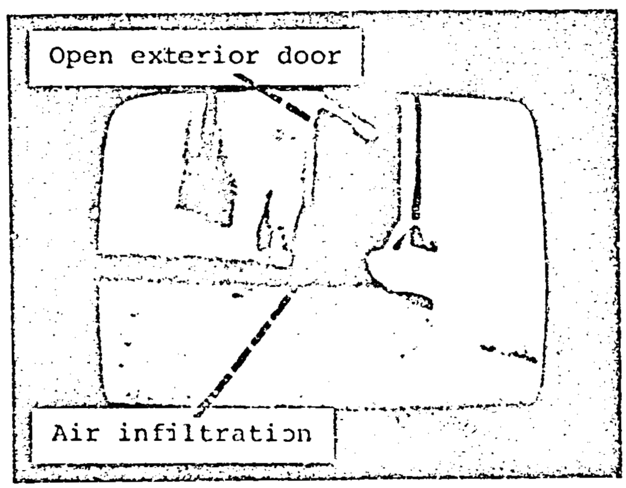

Figure 18. Board room interior

INTEGRATION OF FISH AND WILDLIFE DATA WITH REMOTELY SENSED LAND USE/LAND COVER DATA -- AND DEMONSTRATION USING SITES IN PENNSYLVANIA

by

Charles T. Cushwa, Germain LaRoche and Calvin DuBrock

ABSTRACT

The U.S. Fish and Wildlife Service in cooperation with the Pennsylvania Game Commission developed a statewide fish and wildlife data base. The data basae includes 125 categories of information on each of the 544 species of animals which are resident or common migrants to the State. The animal data will be combined with remotely sensed land use/land cover data from two sites in Pennsylvania. One site is an energy development project; the other is a high energy use area. Analyses using the combined data bases will be demonstrated for a variety of land use/land cover types at both sites. Changes in land use/land cover will be interpreted to assess potential development impacts on aquatic and terrestrial vertebrate fauna. Time and cost information for the analyses will also be presented. The animal data base will also be demonstrated during the Poster Session.

THE NUCLEAR REGULATORY COMMISSION EMERGENCY PLANNING MAPPING PROGRAM

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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555, U.S.A.

Since the accident at the Three Mile Island nuclear power plant near Harrisburg, Pennsylvania over three years ago, the staff of the U.S. Nuclear Regulatory Commission has begun making more intensive use of remotely sensed data. This, together with data from more conventional sources, combine to develop maps that can be used to provide vital information, as well as insight, to management as an aid to decision making in the event of an emergency.

Although map information proved useful during the TMI accident, the NRC mapping program has now been upgraded to include more remotely sensed data. The principal form of this data utilized by NRC is aerial reconaissance, both intermediate altitude (about 20 - 25,000 ft.) and high altitude (about 60,000 ft.).

The above information is used in conjunction with other data sources to present a complete and detailed overview of a particular site. The information acquired includes: local and regional topography, generally acquired from most recent USGS mapping information; local and regional demography, acquired from 1980 Census data and revised for site specific considerations; road networks, acquired from local maps and verified via remote sensing techniques; and general site characteristics such as land use and hydrology, usually verified by remote sensing data.

The NRC emergency planning mapping program is continuously being upgraded as new data becomes available. The presentation of maps depicting the Duane Arnold site (in Iowa) provides an insight to the current methods and types of information available to NRC.

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GLOSSARY OF SOME COMMON REMOTE SENSING TERMS

Following are some of the most commonly used remote sensing terms, including those used in the accompanying article.

ALTITUDE. Height of spacecraft above a specified datum, usually above mean sea level.

BAND. Set of adjacent wavelengths in the electromagnetic spectrum which has a common characteristic, such as the visable band.

CHANGE DETECTION. Process by which two images may be compared, resolution cell by resolution cell, and an output generated whenever corresponding resolution cells have different enough grey tones.

CHANNEL. There are six channels (scan line detectors), per MSS spectral bands 4, 5, 6, and 7. Thus the MSS is a 24 channel scanner on LANDSAT 1.

CLUSTER. Homogeneous group of units which are very much "like" one another. Likeness is usually determined by the association of similarity or distance between the measurement patterns the units give rise to.

CLUSTER ASSIGNMENT. Function which assigns each observed unit to a cluster on the basis of measurement patterns in the data sequence.

CLUSTER IDENTIFICATION. Process in which the cluster assignment function is applied to the sequence of observed units, thereby yielding a cluster identification sequence.

COLOR COMPOSITE IMAGE. A color negative, transparency or print produced from bulk or precision black and white triplet sets (usually using MSS bands 4, 5, and 7). The resulting colors are arbitrarily derived, thus the expression "false color".

DIGITAL ANALYSIS. Machine aided (computer) analysis of digital remote sensing data. In this case, Landsat digital data.

DIGITAL IMAGE. Obtained by partitioning the area of an image into a finite two dimensional array of small, uniformly shaped, mutually exclusive regions called "resolution cells" and by assigning a representative grey tone to each region.

ENHANCEMENT. Various processes and techniques designed to render optical densities on imagery more susceptible to interpretation.

FALSE COLOR. See color composite image.

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GEOGRAPHIC COORDINATES. The latitude and longitude used to locate any given point on the earth's surface.

GROUND TRUTH. Information concerning the actual state of ground conditions at the time of a remote sensing overflight.

IMAGE/FRAME. Data from the one spectral band of one sensor for a nominal framing area of the earth's surface.

IMAGERY. Representation or reproduction of objects recorded on photographic emulsion; visual representation of energy recorded by remote sensing instruments.

MOSAIC. An assembly of several aerial photographs, usually overlapping, onto one picture. A controlled mosaic is one made up of photographs restituted to confirm with predetermined ground survey data.

MULTISPECTRAL. Designates imagery formed, usually simultaneously, in more than one spectral region and analyzed jointly. The simultaneous use of two or more sensors to obtain imagery from different portions of the electromagnetic spectrum.

MULTISTAGE ANALYSIS. A statistically driven analysis technique using both manual and digital analysis of remote sensing data acquired at several altitudes, and verified by ground sampling techniques.

REMOTE SENSING. Imaging or recording of physical phenomena at a distance by detecting the radiant energy which the phenomena either reflect or emit.

RESOLUTION. Ability of a remote sensing system to render a sharply defined image, and including the three following terms.

GROUND RESOLUTION. The minimum distance between two or more adjacent features of the minimum size of a features which can be detected, usually measured in conventional distance units such as feet or inches.

IMAGE RESOLUTION. Resolution expressed in terms of lines per millimeter, for a given photographic emulsion under specified situations.

THERMAL RESOLUTION. Image resolution expressed as a function of the minimum temperature difference between two objects of phenomena.

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Energy-Efficient Planning: An Annotated Bibliography, Efraim Gil

Energy-Efficient Land Use, Duncan Erley, David Mosena, and Efraim Gil

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Introduction to Remote Sensing of the Environment, Richason

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Mr. Anderson is a geologist with the Office of Surface Mining. He received his degree from the City University of New York in 1961, has had various graduate studies in geology and remote sensing and has been associated with field geological application, and the evaluation of remote sensing data from various platforms. Since graduation, he has worked for Autometric Co., Defense Mapping Agency, Corps of Engineers, NASA, and with the Office of Surface Mining since 1978. As their geologist and remote sensing coordinator, Mr. Anderson works in the special studies area of technical assistance. and provides the evaluation of the numerous surface mining regulation areas, reclamation evaluation, inspection programs, overburden analysis studies, and assists in improving the capability to utilize aerial data for inspection, enforcement and identifying the surface effects for mine problem delineation. Mr. Anderson also has over 60 publications on aerial and digital image processing, geologic and surface mining projects throughout the Appalachian and Western coal fields.

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Mr. Arend received his Bachelor of Science in Civil Engineering for Purdue University and took his graduate studies in Earth Sciences at Dartmouth College. He has been concerned with the engineering applications of aerial photography since 1962. His work has included the identification of soils, regional analysis, highway construction, terrain analysis, and the engineering uses of geologic materials in arctic, high mountain, temperate, and tropic areas. He has directed the acquisition of aerial photography for projects in the U.S., Canada, and Thailand; organized and directed landuse mapping projects throughout the Midwest and Northeast; and participated in over 50 erosion studies, environmental analysis, and site location projects throughout the United States. He is a member of the American Society of Photogrammetry, the National Society of Professional Engineers, the New Hampshire Society of Professional Engineers, and is a registered Professional Engineer in the State of New Hampshire.

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Ronald L. Ballard earned a degree in Geology in 1960. He attended graduate school at the University of Washington, where he received a Master of Science degree in Oceanography in 1963. His first assignment was with the Environmental Safety Branch of the Atomic Energy Commission at their Nevada Operations Office, developing a Public Safety Program in support of atmospheric weapons tests. This program resulted in the formation of the "Overseas Safety Group," to which he was assigned as Safety Officer. In early 1970 he was transferred to the Office of Effects Evaluation of the Nevada Operations Office as Technical Program Coordinator. His principal activities involved managing a program for evaluating and documenting environmental effects associated with weapons test activities at Amchitka Island. In May 1971 he joined the Washington Regulatory Office of the AEC as a Senior Project Manager. In 1972 he accepted a position of Chief of the newly formed Environmental Specialists Branch and in June 1978 he was assigned as Chief of the Environmental Projects Branch of the Nuclear Regulatory Commission, which was created in 1975 by the Energy Reorganization Act of 1974. In this capacity he was responsible for preparing Environmental Impact Statements for proposed nuclear power plants. In May 1980 he was assigned to the newly organized Environmental Engineering Branch of NRR, where he is currently responsible for technical management of non-radiological environmental matters related to the nuclear regulatory program.

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John S. Banta is Director of Planning at the New York State Adirondack Park Agency. He graduated in 1969 from Hiram College with a B.A. in mathematics, and in 1972 from Harvard Law School. He has been involved in resource policy analysis at The Conservation Foundation (1974-79), dealing with coastal resources, and development management approaches in a number of foreign countries. The Adirondack Park Agency is currently undertaking a systematic review and evaluation of its statutory plans and policies using, in part, computer assisted planning techniques.

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Joseph Berry is an Associate Professor of Forestry and the Assistant Dean at the School of Forestry and Environmental Studies, Yale University. His current teaching and research interests involve the application of computer-assisted map analysis techniques to natural resource planning. Formerly, he was a Research Associate at Colorado State University where he served as a lead staff scientist for studies in spectral variability in remote sensed data. He holds a Bachelor's degree in Forestry from the University of California, a Master's Degree in Business

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Jim Brumfield is the Co-chairperson of this 1982 Conference on Energy Resource Management and served as the Technical Advisor and Chairman of the Abstract and Paper Review Committee. He is also a Regional Meetings Secretary for the U.S. Section of the Remote Sensing Society. Currently, Jim is a remote sensing technical advisor for ERRSAC at NASA/Goddard Space Flight Center and served as a

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Daniel Cooper received his training at the Remote Sensing and Spatial Analysis Laboratory of Hunter College, City University of New York. Here he received a B.A. in Environmental Science. His work at the Laboratory included the study of desertification indicators and processes from remote sensing sources. He has continued in this research at his employer, Greenhorne & O'Mara, Inc. Presently he is developing computer techniques that utilize remote sensing data to locate groundwater in arid climates. In addition to this research, he has completed such projects as a computer based analysis of Landsat data for mineral exploration in the Patagonian desert of Argentina, as well as a timber inventory assessment in Virginia.

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Mr. Cotter is presently the Director of the User Affairs Division, National Earth Satellite Service, NOAA. Since joining the Satellite Service in 1973, he has been involved in system development projects, program planning and implementation, and activities to extend the use of satellite remotely sensed earth data in application areas. Mr. Cotter is a former U.S. Air Force weather officer, having received his B.S. and M.S. degrees in mathematics and meteorology from the Florida State University. For some years, he was an instructor in mathematics at the University of Maryland. Mr. Cotter has been directly associated with satellite remote sensing programs since 1965.

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Calvin DuBrock is a Research Biometrician for the Pennsylvania Game Commission. He has also worked as an Ecologist for the Fish and Wildlife Service at the Department of the Interior and as a Statistician for the Department of Energy. In the areas of research and publications, he has authored and co-authored approximately 15 technical documents. His principal research interest and areas of expertise are in developing wildlife species data bases to enhance environmental assessments (from the fish and wildlife perspective) and wildlife planning and management. Calvin is involved in initiating fish and wildlife data bases in eight states. He holds a B.S. in Wildlife Biology and Ecology from Michigan State University and an M.S. in Wildlife Management from Virginia Polytechnic Institute and State University. He has received additional training in data base management and the design of automated data bases.

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METLAND system for landscape assessment and planning; has been awarded numerous research grants. He taught at the University of Melbourne, Australia, and has travelled widely as both a lecturer and consultant. He is the author of numerous articles, research bulletins and books including his latest, Planning The Total Landscape, Westview Press, 1979.

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Jack D. Fellows is currently a faculty research associate at the University of Maryland, Department of Civil Engineering, College Park, MD. He is conducting research in the use of geographical information systems, image processing, and data base management for use in computer-based mathematical model parameter definition. He has worked extensively on merging remotely sensed digital data and ancillary data for forecasting in water resources and environmental planning. He plans to finish his Ph.D. during the fall of 1982.

HERBERT J. FIVEHOUSE

Herbert Fivehouse serves as the Energy Coordinator for the City of Baltimore. He provides executive leadership to energy issues on a City-wide basis and assures the implementation of energy management, energy assistance to needy citizens, and research involving alternate fuels, cogeneration and energy methodology. Mr. Fivehouse has managed research development programming for the U.S. Air Force and most recently concluded a 19-year career with National Aeronautics and Space Agency (NASA) where he was Associate Director of Management at the NASA/Goddard Space Flight Center. He was appointed to his present position on the Mayor's Cabinet in July 1979. He is Baltimore's representative to the Urban Consortium and a member of the Consortium's Energy Task Force.

SUSAN BALOG FREEMAN

Susan B. Freeman received her B.S. in Geology from the University of Wyoming in 1975, where she studied remote sensing. After four years in the Air Force, Susan came to Los Alamos to pursue her primary interests of data integration and display techniques and uses of the information from integrated data sets. She has been instrumental in developing the Data Integration/Remote Sensing program at Los Alamos. Susan has been employed at the Los Alamos National Laboratory since 1979 and is currently in the Geochemistry Group.

PETER FRENCH

Dr. French, cofounder and President of Resources Planning Associates, received his Ph.D. degree in Water Resource Systems Analysis from Cornell University in 1980. Before coming to Cornell, Dr. French spent three years as a Water Quality Specialist in one of North Carolina's regional planning agencies. Since 1976 Dr. French has been involved in the application of interactive computer graphic techniques to systems analysis and resource management planning.

JANETTE C. GERVIN

Ms. Gervin is a Program Coordinator in the Eastern Regional Remote Sensing Applications Center. She initiates, plans, develops, directs and conducts remote sensing research and applications projects with federal, state and local government agencies and other organizations. She also serves as the technical manager of the joint NASA/Corps of Engineers Program, a five-year research program to evaluate the capabilities of Landsat-D Thematic Mapper and other advanced remote sensors for hydrological and environmental management functions. The program also examines integration of remotely sensed data into a geographic information system accessed by hydrological, environmental and economic models. The first study has included remote sensing applications in floodplain resource mapping, historical trends and optimal dredged material disposal siting. Regional Remote Sensing Applications Coordinator for Delaware and Virginia, with successfully completed technology transfer programs in both states. Coordinated the efforts of civil service, state and contractor personnel to accomplish ten-state demonstration projects in applications ranging from agricultural land conversion and forest hydrocarbon emission to watershed erosion and wetland mapping. Performed image analysis and directed civil service and contractor personnel on the ESL Interactive Digital Image Manipulation System (IDIMS). Ms. Gervin received her M.S. in Physics from the University of Florida at Gainesville in 1971 and her A.B. in Physics from Bucknell University, Lewisburg, PA, in 1969.

FRED GUNTHER

Dr. Gunther provides on-site computing and analysis services for the Eastern Regional Remote Sensing Applications Center (ERRSAC) at NASA/Goddard Space Flight Center. Educated in classical subjects and trained in the sciences and in statistics, he has earned degrees in philosophy (B.A., University of San Diego), geology (B.S., San Diego State University; M.S., University of Minnesota), and geological oceanography (Ph.D., Oregon State University). He has authored various ERRSAC and company documents, and has published in the fields of computer data processing, remote sensing, geology, and micropaleontology. He has designed the Apple-II Image Processing Educator (AIPE) system for remote-sensing technology transfer using a microcomputer. Dr. Gunther is a member of the International Association for Mathematical Geology, the American Association for the Advancement of Science, the American Society of Photogrammetry, the Institute of Electrical and Electronic Engineers Computer Society, and the Washington Apple Pi Computer Club.

LYNDA HALL

Ms. Hall is a staff scientist and remote sensing specialist with EarthSat's Environmental Applications Division. Since joining the firm in March, 1981, she has performed extensive field investigations, aerial photointerpretation, mapping, and quality control editing of problem areas associated with abandoned coal mines in Pennsylvania. These responsibilities include the training and management of a photointerpretation team. Field description is integrated with information from aerial photographs to arrive at an overall site analysis. Sites are assigned priorities and grouped into reclamation planning units for inclusion in the state-wide reclamation program. Other projects include a comparison and evaluation of Landsat and Seasat images of coastal North Carolina in which a Level-1 land cover classification and analysis was performed. Ms. Hall graduated Summa Cum Laude from the University of Delaware in December, 1980, with a Bachelor of Arts in Geography. Academic emphasis was in biogeography and environmental science.

WAYNE HALLADA

Mr. Hallada is currently a member of the technical staff of Computer Sciences Corporation's System Sciences Division, supporting Landsat and Multispectral Linear Array (MLA) investigations under a NASA contract with the Eastern Regional Remote Sensing Applications Center. His current activities are directed toward information extraction from high spatial resolution multispectral imagery in digital form. He received a Bachelor of Science degree in Geography and Mathematics from Carroll College, Waukesha, WI in 1977. He received an MA degree in Geography from the University of California at Santa Barbara in 1980. From June 1979 to October 1980, he worked as a research associate for the Geography Remote Sensing Unit (GRSU) at UCSB on applications of remote sensing and geographic information systems. He is a member of the American Society of Photogrammetry and the IEEE Computer Society.

KENNETH HANSEN

Kenneth Hansen is currently project manager with Dames & Moore. In addition to overall management of jobs, his responsibilities include spatial data analysis, land capability studies, remote sensing data integration, and enhancement of a geographic information system. Previously, he has worked as Landsat Project Coordinator for Oregon in administering the transfer of satellite remote sensing technology to state and local agencies. In addition, he has conducted land capability studies, analyzed natural resource information, and aided development of a computerized geographic information system for South Dakota. He possesses an M.S. in Physical Geography with a Mathematics minor from the University of Illinois in Urbana, and has written papers relating to siting studies, remote sensing applications, land suitability, and freezing action in soils.

KINGSLEY E. HAYNES

Kingsley E. Haynes is a professor of Public and Encironmental Affiars and of Geography, and Director of the Center for Urban and Regional Analysis at Indiana University. After receiving his Ph.D. in Geography and Environmental Engineering at Johns Hopkins University in Baltimore, he later was director of the Ford Foundation's Office of Resources and Environment in the Middle East. A prolific writer on environmental resource management, he has been involved in energy, resources, and environmental management in northern Indiana and the Nile River Basin in Africa.

ROD HELLER

Mr. Heller has directed or managed more than 50 major energy-related studies involving the siting and assessment of thermal and hydroelectric power plants, multi-state transmission lines and pipelines, as well as transportation systems, mines and reservoirs. Central plant studies which Mr. Heller directed or managed include a recently completed statewide siting study for a new coal-fired power plant in Arizona; the assessment and preparation of FERC exhibits for a pumped storage project in New Mexico and siting and assessment studies for two major pumped storage hydroelectric projects in Arizona; and land use and visual assessments for the Coronado Generating Station in Arizona, the Harry Allen Generating Station in Nevada, and the Kaiparowits Project in Utah. Mr. Heller has testified as an expert witness at more than a dozen Federal and state administrative hearings. He has a Master of Landscape Architecture degree, with minors in urban planning and sociology, and is an Adjunct Professor in the School of Renewable Natural Resources, University of Arizona. He is Executive Vice President and Director of Environmental Planning Services for Wirth Associates.

JOHN M. HILL

John M. Hill holds a B.S. degree from Towson State University, a M.S. degree from the American University, and a Ph.D. in Biology from Texas A & M University. He is presently an assistant professor of Civil Engineering at Louisiana State University and is active in applied research programs within LSU's Remote Sensing and Image Processing Laboratory. His present areas of interest are pollution monitoring, water resources, and coastal zone management. He is a member of the following professional societies: American Society of Limnology and Oceanography, American Society of Photogrammetry, and the American Society of Civil Engineers.

JOHN HOSHAL

John Hoshal is currently employed as a research analyst for the Land Management Information Center. Hoshal's primary duties include working with the Minnesota Land Management Information System (MLMIS) in performing environmental analysis for public and private clients. Hoshal has his undergraduate degrees in Geography and in Urban Studies from the University of Minnesota.

RICHARD IRISH

Richard Irish holds a B.S. from Colorado State University in Range-Forest Management and an M.S. from Pennsylvania State University in Forest Resources. He currently works as an Image Analyst and Cartographer for the National Park Service. He served as a Forestry Consultant for the Army Corps of Engineers. Richard's career interests include computer analysis of remotely sensed data, geographic information systems processing and computer graphics.

TONY JACKMAN

Tony Jackman is a New Zealander completing a Ph.D. in Landscape Ecological Planning at Amherst. He came to the U.S.A. in 1980 with an accumulated 12-year academic and practical experience in landscape and regional planning throughout Australasia and the South Pacific. Particular emphasis of his research is to project wider use of GIS's in determining the relationships between landscape ecological planning and management so that positive, rather than the more traditional negative or exclusionary approaches to environmental policy formulation are afforded.

RENEE JOHNSON

Renee Johnson is currently employed as the staff geographer and cartographer for the Minnesota Peat Inventory Project of the Department of Natural Resources. The emphasis of her work is the mapping products of the project--the Peat Resources map series which illustrates the results of the project's survey work; and the encoding and use of these data in the MLMIS for management decisions. Johnson is also a graduate student in geography at the University of Minnesota.

GEORGE L. JONES

Mr. Jones is the President and Chief Executive Officer of Princess Coals, Inc. of Huntington, WV, where his principal activities include development of coal lands, real estate, quarrying, docks and industrial complexes. Prior to assuming his current duties, Mr. Jones spent over 14 years in public service for the Commonwealth of Virginia serving as State Coordinator for Emergency and Energy Services and Director of Emergency Planning; Assistant Coordinator for Administration, Virginia State Office of Emergency Services. He was the principal advisor to the Governor on energy and disaster preparedness and response. He is a past president of National Association of State Directors for Disaster Preparedness. He is a member of the Advisory Board, University of Colorado, Natural Hazards Institute; Honorary Faculty Member, Defense Civil Preparedness Staff College, Administrator, University of Northern Colorado Extension Public Administration Master's Degree Program; Administrator American Institute of Architects, University Consortium to Develop Public Service Curriculum; and an Advisory Board Member of the National Community Energy Management Center.

HANS KLUNDER

Mr. Klunder is the Chief Planner and Owner of Hans Klunder Associates of Hanover, NH. Prior to forming his own firm he was employed by the State of Maine as a special consultant for Federal/State coordination between the Department of Housing and Urban Development and the Maine Department of Economic Development. Mr. Klunder received his M.S. degree in City and Regional Planning from the Harvard University Graduate School of Design. He received his B.S. degree in Landscape Design with an Agriculture major from the University of New Hampshire. His B.S. degree was awarded cum laude. He attended the University of New Hampshire on a Fulbright Scholarship.

RUSSELL KOFFLER

Mr. Russell Koffler, Director of the Office of Data Services, National Earth Satellite Service (NESS), is responsible for managing the data processing and distribution of products from the operational environmental satellites as well as managing the operation of the Landsat spacecraft. Mr. Koffler previosuly held the position of Chief, Landsat Operations. He joined NESS in 1962 as a research meteorologist.

RICHARD F. KOTT

Dr. Richard F. Kott is a senior staff member (geographer) in the Office of International Security Affairs (OISA), Office of the Assistant Secretary for Defense Programs, U.S. Department of Energy (DOE). His responsibilities involve program management, respresentation of DOE in interagency committees, strategic evaluation of foreign nuclear and other energy capabilities, and surveys relevant to the Department's role in international affairs, with special reference to national security issues. Dr. Kott has been a member of the teaching staff of the University of Maryland, Department of Geography, College Park, MD since 1974. Dr. Kott received a Ph.D. degree in 1967 from the University of Poitiers (France), an M.A. degree in 1959 from Oklahoma University, and an A.B. degree from Indiana University in 1953. All degrees were in geography. His doctoral dissertation, Brasilia dans sa Region, is an urban and regional study in human geography. Active in his professional fields of geography and international studies, Dr. Kott is a member of a number of societies and organizations. He has authored several specialized studies and reports on international, aviation/transportation, intelligence, nuclear, geographic, energy-related, and national security/defense topics. Dr. Kott has also received a number of awards, honors, and service decorations.

K. PETER LADE

Dr. K. Peter Lade is a Professor of Sociology and Anthropology at Salisbury State College. His area of specialization is the application of Remote Sensing to archaeological site location, monitoring, and cultural resource management.

GERMAIN LAROUCHE

Dr. LaRouche is a Land Use Analyst in the Terrestrial Resources Section of the Environmental Engineering Branch of the Division of Engineering, USNRC. He is involved in the evaluation of the potential environmental impact on terrestrial ecosystems and land use. Prior to being employed by the NRC, he was director of Terrestrial Ecology for a private consulting firm. In this capacity he directed and conducted baseline studies of proposed nuclear or fossil fuel power plants, and large urban and recreational developments. He has conducted forest and range management research with the U.S. Forest Service in Florida for 2 years. Dr. LaRouche received the Ph.D. degree in Botany-Plant Ecology from the University of Massachusetts at Amherst in 1969, the M.S. in the same areas from the Catholic University of America in Washington, D.C. in 1958, and the B.A. in Biology from the Catholic University of America in 1957. In 1950 he graduated from the Stockbridge School of Agriculture of the University of Massachusetts as a Floriculture major. He was elected to the Society of Sigma Xi in 1958 and has been a member of the Ecological Society of America since 1957, member of the Society of American Foresters since 1972 and a member of the Torrey Botanical Club since 1980.

BRIAN R. LENZ

Major Brian Lenz has a Master of Arts degree in Chemistry from the University of Southern California. He is currently serving as the Energy Program Manager at Headquarters United States Air Force. Prior to this, he was assigned as a quality assurance officer at the Defense Fuel Supply Center where among other duties he was the gasohol project officer. He has served as a staff fuels officer at Headquarters United States Air Forces in Europe being responsible for energy conservation, petroleum [illegible]tions and tankage allocation. He has served as a base fuels officer in Vietnam and Thailand and a staff fuels officer for missile fuels.

NORMAN H. MACLEOD

Dr. Macleod is the chairman and president of American Science and Technology Corporation; a Maryland corporation engaged in the development, management and use of the AEROS system of satellites (FOODSAT, PETROSAT, CLIMASAT), ground station and image processing technologies, and resource management information systems for resource discovery, monitoring and management. Prior to joining American Science and Technology Corp., he was a Senior Officer with the Food and Agriculture Organization of the United Nations, Remote Sensing Center, Rome, Italy. He also served as a Director for the Earth Resources Development Research Institute and as a Research Scientist at the American University. He received his Ph.D. degree in Agronomy and Plant Physiology from the University of Maryland. He received his M.S. degree in Agronomy from the University of Massachusetts and his B.A. degree in Liberal Arts from the University of Chicago. Dr. Macleod has prepared over 50 publications, principally on the interpretation and use of remote sensing data with reference to land management and rehabilitation.

MALCOLM J. MACDONALD

M. J. Macdonald was recently appointed Deputy Superintendent of Engineering and Utility Systems for Seattle City Light, one of the country's largest municipal utilities. Previously, he had been Director of Energy Resources Planning, producing the utility's 1981 Energy Resources Report and Data Base and coordinating the production of six long-range resource planning reports titled "Energy Options." Before joining City Light two years ago, Macdonald was a career officer in the U. S. Navy beginning with graduation from the U.S. Naval Academy in 1956. Before leaving the Navy in 1980 as a Captain, he served in the Civil Engineer Corps, was Commanding Officer of the Navy Public Works Center in Norfolk, VA, and Navy Mobile Construction Battalion Four, and Director of Installations and Facilities for the Assistant Secretary of the Navy. He holds a Bachelor's degree in Civil Engineering from Rensselaer Polytechnic Institute, a Master's in Civil Engineering from the University of Illinois and professional engineer licenses in the states of Washington and California.

E. BRUCE MACDOUGALL

E. Bruce MacDougall, Ph.D., is the department head of the Landscape Architecture and Regional Planning Department at the University of Massachusetts at Amherst. He is the author of several articles on geographic analysis and Computer Programming for Spatial Problems, Edward Arnold, 1976. Current research interests include: environmental inventory and evaluation for urban planning and design and the accuracy of scientific information in Regional Planning.

WUGHANGA M. MAGHENDA

Wughanga M. Maghenda obtained a Bachelor's degree from the University of Nairobi. She taught for two years in a high school in Kenya before attending Ohio University where she received an M.A. in Geography. After completing her course work in geography, she enrolled in a second Master's degree in Environmental Science. In both areas, she has concentrated in the use of remote sensing data for resource management. Her M.A. thesis was "Monitoring Kenyan Forest Changes Using Remote Sensing: A Case Study of Mau Forest." Future plans include starting a Ph.D. program in Economic Education with the desired result being a major in Environmental Economics.

MARTHA MCCLURE

Ms. McClure is the Program Manager of the Remote Sensing Program, Graduate School of Oceanography, University of Rhode Island, where she is responsible for establishment of a remote sensing facility, proposals, personnel organization, faculty interactions, and regional representation. She also serves as the Executive Secretary of the Requirements Committee for the Northeast Remote Sensing System. Prior to assuming her current duties, she was a Technical Specialist, Graduate School of Oceanography, University of Rhode Island. She developed microprocessor systems having interactions with both instruments and larger computer systems. She also designed systems in Basic and Fortran to be used on the PRIME virtual-memory computer. She has worked in private industry. Martha McClure received her B.S. degree in Ocean Engineering from the Florida Atlantic University and completed three years of study at Purdue University in Electrical Engineering. She is listed in "Who's Who in American Colleges and Universities," 1977. Ms. McClure has authored several papers on the use of Remote Sensing as a tool for Oceanography.

JOHN H. MCELROY

Dr. John H. McElroy is the Assistant Administrator for Satellites, National Oceanic and Atmospheric Administration (NOAA), Department of Commerce. In this capacity he heads the National Earth Satellite Service of NOAA. The National Earth Satellite Service is responsible for the nation's civil weather satellites (polar orbiting and geostationary) and the planning for an operational land remote sensing system. Dr. McElroy formerly served as the Deputy Director, Goddard Space Flight Center, National Aeronautics and Space Administration. He had been with NASA since 1966 and has served as Director of Communications and Information Systems Programs, Office of Space and Terrestrial Applications, NASA Headquarters. Prior to his Headquarters assignment, he led communications technology, laser, and electro-optics research and development at Goddard. Dr. McElroy is a graduate of Culver Military Academy, has a BSEE from the University of Texas at Austin and an MEE and Ph.D. from the Catholic University of America. He has been elected to Eta Kappa Nu, Tau Beta Pi, and Omicron Delta Kappa, and is a Senior Member of the Institute of Electrical and Electronics Engineers and the American Astronautical Society, and an Associate Fellow of the American Institute of Aeronautics and Astronautics. He is a Fellow of the Washington Academy of Sciences.

RON MCLEOD

Ron McLeod is currently on the staff at Caltech's Jet Propulsion Laboratory in Pasadena, CA, working in the Image Processing Laboratory. He has been a member of the Earth Resource Applications Group since 1977 and has worked extensively with Landsat digital mosiacs and their application to resource inventory and assessments. He holds degrees in Geography from San Diego State University.

DANIEL D. MORENO

Mr. Moreno is an environmental planner in the Los Angeles office of Dames & Moore. He is responsible for the application of geographic information systems to industrial site selection studies and resource assessment. Mr. Moreno received an M.A. in Economic Geography from the University of California, Los Angeles, in 1979.

LAWRENCE NIX

Lawrence Nix holds a B.S. and M.S. in Forestry from Mississippi State University and his Ph.D., also in Forestry, from the University of Georgia. His research activities have included stand growth, biomass production, silviculture, tree physiology, manipulation of biomass accretion in forest stands, multi-resource inventory of forests, availability of forest biomass for fuel, chemical stimulation of oleoresin production, and wood formation in forest trees. His publications include the subjects: biology of wood formation, chemical induction of resin soaking, chemical control of forest vegetation and multi-phase inventory of forest biomass. He is associated with the Society of American Foresters, SARRMC Wood Energy Committee, S.C. Energy Planning Committee, and U.S. Forest Service Silviculture Certification Board.

JONATHAN A. OSKI

Mr. Oski is employed by the METLAND Research Group, Department of Landscape Architecture and Regional Planning, University of Massachusetts. His work involves co-authoring a research bulletin which focuses on the application of geographic information systems in an energy planning situation. Mr. Oski received his Master's degree in Regional Planning from the University of Massachusetts in Amherst, MA, in May 1982. His area of study focused on the use of computer-aided landscape planning and systems modelling and analysis. He received his B.S. degree in Biology from Hobart College in Geneva, NY. He co-authored a paper with Timothy Aston entitled "A Land Use Plan for the Northfield Mt. Hermon School."

SIMSEK PALA

Dr. Pala obtained a Bachelor's degree at the University of Ankara, Turkey. He won a scholarship for graduate study in Germany, where he obtained a doctoral degree in geomorphology from the University of Freiburg. After immigrating to Canada in 1972, he joined the Ontario Centre for Remote Sensing at its inception. As Chief Scientist of the OCRS, Dr. Pala has developed applications of satellite imagery to geological mapping, mineral exploration, forestry, agriculture, land use planning, hydrology and environmental monitoring. He has put a practical digital image analysis system into operation at the OCRS, and has developed a computerized mapping technique to produce digital analysis results in a useable format. He is mapping the surficial geology of Northern Ontario from aerial photography and extensive field sampling, with the aid of Landsat imagery; and is also mapping the wetlands of the Hudson Bay-James Bay Lowland by digital Landsat analysis. He initiated programs to map land use/land cover across the province and to map forest types north of latitude 52°N. Dr. Pala is also responsible for the training and technology transfer programs of the Centre.

RICHARD F. PASCUCCI

Richard Pascucci is the Manager, Earth Sciences Applications, Autometric, Inc., Falls Church, VA. He received a B.S. in geology in 1952 from the University of Connecticut and pursued graduate studies as a Higgins Fellow at Columbia University and as a Fulbright Scholar at the International Institute for Aerial Survey and Earth Sciences in Delft, the Netherlands. He has had 21 years of experience in evaluating the capabilities and limitations of remote sensors. During this time he has participated in the design, implementation, and management of more than 50 projects dealing with oil and mineral exploration, environmental impact analysis, and nuclear power plant siting, and has published 25 papers on these subjects. He is currently involved in the resource-related applications of a geographic information system and in the computer analysis of satellite digital data. He is a member of Phi Beta Kappa, Sigma Xi, and Phi Kappa Phi.

MICHAEL G. PAVLIDES

Michael Pavlides received his Civil Engineering degree from Lehigh University in 1971. From 1971 to 1974 he was a consultant at Ebasco Services, Inc., a utility industry consulting firm, where he performed hydrologic investigations for power plant site feasibility studies and related environmental reports for Nuclear Power Plants. From 1974 to the present he has been employed by Greenhorne & O'Mara, Inc. In 1976 he received his Master's of Science, Civil Engineering degree from George Washington University. He is the Director for the Earth Sciences Division. Under his direction he has developed various disciplines which include applications of computer science, remote sensing, photogrammetry, geography, geology, and geographic information systems.

ROBERT RAGAN

Dr. Robert Ragan is the Director of the Remote Sensing Systems Laboratory and a Professor of Civil Engineering. His area of specialization is the application of remote sensing to hydrologic modeling.

JAMES KARL SAILOR

James Karl Sailor is presently a Systems Consultant for Resource Mapping Applications at Intergraph Corporation. Prior to joining Intergraph in April, he has served as a consultant in forest industry applications of Geographic Information Systems in Oregon, as well as a natural resources planner for the New England River Basins Commission. Mr. Sailor holds a Master's degree from Yale University of Forestry, specializing in Spatial Information Systems, and a B.A. in Biology from Amherst College. He has published papers on computer mapping applications in forestry, hydrology and land planning.

CHARLES E. SASSER

Mr. Sasser holds a B.A. degree in history and an M.S. degree in Marine Sciences from Louisiana State University. He is presently a research associate at the Center for Wetland Resources, LSU. His interests are coastal wetland ecology, and wetland management. He is a member of the following professional societies: Botanical Society of America and Estuarine Research Federation.

YALE M. SCHIFFMAN

Yale M. Schiffman is the principal of Schiffman Energy Services, Inc. He is responsible for design and management of all technical projects including the National Conference on Energy Resource Management 1982 and 1983; the Technology Assessment of Solar Energy Systems; Energy Resource Management at Naval Facilities. Prior to forming Schiffman Energy Services, he was responsible for directing the MITRE Corporation's Community and Renewable Applications Groups. He has designed a large scale system dynamics model CEIM, the Community Energy Impact Model (copyright, 1982) for use in estimating energy use at the community level and for forecasting the impacts of installing alternative energy systems including energy conservation options. His paper on CEIM was awarded the International Congress of Applied Systems Research Meritorious Award for 1982. He has recently authored two books on energy resources. The first is entitled "Solar Energy Systems--An Alternative Perspective," published by Lexington Books. The second book is called "Energy Resource Management--A Reference Notebook for Energy Resource Planners and Managers." Mr. Schiffman is the President of the American Planning Association's Energy Planning Division, is a member of the Editorial Board of Comtex Scientific Corporation and has been listed in Who's Who in the South, Distinguished Americans, and Men of Distinction. He received his Bachelor's and Master's degrees in Urban Planning from Boston University. He served as a Teaching Fellow at Boston University and Harvard University's Graduate School of Design.

WILLEM S. SCHOONHOVEN

Willem S. Schoonhoven is a Community Planning Consultant for the Pennsylvania Power and Light Company. His experience includes the coordination of efforts to establish a computerized data base for use in company facility siting and technical assistance to public agencies. Willem holds a degree in Geography from the University of Toronto.

NICHOLAS M. SHORT

Dr. Nicholas M. Short is currently engaged in research within the Geophysics Branch at NASA/Goddard Space Flight Center. During 1977-1981, he was the program scientist and Director of Training for the Eastern Regional Remote Sensing Application Center (ERRSAC) at Goddard. From 1972 through mid-1977 Dr. Short was the Geology Discipline Leader in NASA's Earth Resources Program, with responsibilities for implementation of more than 80 domestic and foreign investigations in mineral resources, geologic structures analysis, and landforms surveys within the Landsat (ERTS) program and for coordination among NASA Centers of research into applications of geologic remote sensing for mineral and energy exploration. Dr. Short received his B.S. in Geology from St. Louis University (1951) and an M.A. in this field from Washington University and obtained his Ph.D. in Geology from Massachusetts Institute of Technology (1958). Dr. Short has written or co-authored more than 75 papers in several subfields of geology and remote sensing. He has co-edited the standard reference book on Shock Metamorphism of Natural Materials, has co-authored a pictorial atlas of volcanic landforms, and has completed the first basic textbook on Planetary Geology. He is senior author of the widely known NASA Special Publication 360 entitled Mission to Earth--Landsat Views the World.

FREDERIC SIEGEL

Frederic R. Siegel received the B.A. degree from Harvard University (1954). He earned the M.S. degree (1958) and the Ph.D. degree (1961) from the University of Kansas. He then taught and did research in Argentina for two years at The Instituto Miguel Lillo (Universidad Nacional de Tucuman) before joining the State

Geological Survey of Kansas as Head of the Geochemistry Division. In 1965, he became Associate Professor of Geochemistry at the George Washington University and in 1969 was made Professor of Geochemistry. In 1976, Dr. Siegel became Chairman of the Department of Geology of the George Washington University. He has held an appointment as Research Associate with the U.S. National Museum (Smithsonian Institution) since 1967. He was an associate editor for the Journal of Exploration from 1972-76 and is presently editor for the volume "Review of Research on Modern Problems in Geochemistry" published by UNESCO. Dr. Siegel has received funding for research projects from the NSF, the Smithsonian Institution, the University Committee on Research, the NIH, and private industry. His teaching fields and areas of expertise include various aspects of geochemistry (marine, exploration, environmental) and environmental geology (including geological hazards in land-use planning).

RAM N. SINGH

Dr. Ram N. Singh received an M.Sc. degree in Agronomy from Banaras Hindu University, India, in 1964 and a Ph.D. in Sociology with specialization in Demography and Human Ecology, and Research Methodology and Statistics from the University of Georgia in 1970. Between 1969 and 1980, he taught courses in Demography, Human Ecology, Research Methodology, Social Statistics, and Community Health at both undergraduate and graduate levels at Marshall University, Huntington, WV. During his tenure at Marshall University, he directed several research projects including those related to energy resources for the U.S. Army Corps of Engineers. In addition, he has been involved with studies dealing with population estimates, trends, and distribution in the Appalachain Region. He has been an active member of the Marshall University Remote Sensing Group (an interdisciplinary group) since it was organized in 1979 and has attended several workshops on Remote Sensing at NASA/Goddard Space Flight Center in Greenbelt, MD. During 1980-81 academic year, he was selected as an American Council on Education Governmental Fellow from the faculty members from the universities and colleges throughout the United States. He joined the Data and Demography Division of the Office of Revenue Sharing, U.S. Department of the Treasury as a Program Analyst Demographer in June 1980.

ANTON A. SINISGALLI

Anton A. Sinisgalli has been with the U.S. Nuclear Regulatory Commission (NRC) since 1974. His current duties include the identification and evaluation of hazards to the safe operation of nuclear power plants due to man-related accidents external to those plants and site characterization (demography, topography, land use, etc.). Prior to joining the NRC, Mr. Sinisgalli was actively engaged in various remote sensing programs. He holds a B.S. from Davis and Elkins College and an M.S. from West Virginia University. He is a member of the Society of Sigma Xi and the American Society for Testing and Materials. Mr. Sinisgalli is the recipient of several international awards.

ALAN F. SMITH

Mr. Smith is the SEARCH-PAK Manager, Autometric, Inc. He holds a B.S. in geology from the University of North Carolina and a B.S. in geography (1977) from the University of Maryland. He has had 14 years of experience in the applications of remote sensing to the earth sciences, especially as related to exploration geology and terrain studies, and has participated in evaluating the results of NASA's Landsat, HCMM, and Magsat programs. Currently, he is involved in the development of an exploration product for the exploration community. This product uses a computer-assisted geographic information system to quantify and synthesize interpretation results from side-looking radar and Landsat MSS imagery. He is a member of the American Society of Photogrammetry.

BARRY D. SOLOMON

Barry D. Solomon is a doctoral candidate in Regional Analysis and Planning at Indiana University. An active member of the APA Energy Planning Division, his previous work includes publications on energy facility siting, coal distribution planning modeling, energy resource development impact analysis, alcohol fuels, and energy policy. As Chairperson of the Environmental Quality and Conservation Commission of the City of Bloomington, Indiana, he also has an active role in monitoring local energy and environmental issues.

STEPHEN L. SPERRY

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END

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