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Regional Studies Program Annual Report

JANUARY 1 through DECEMBER 31, 1976

R. M. Davis
D. C. Parzyck
D. J. Bjornstad
R. B. Honea
A. S. Loebel
E. Peelle

**ORNL
REGIONAL
STUDIES
PROGRAM**

Energy Division
Environmental Sciences Division

OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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**REGIONAL STUDIES PROGRAM ANNUAL REPORT
JANUARY 1 THROUGH DECEMBER 31, 1976**

R. M. Davis
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Energy Division
Environmental Sciences Division

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Regional Studies Program Annual Report January 1 through December 31, 1976

R. M. Davis	R. B. Honea
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ABSTRACT

In 1976 the Regional Studies Program, sponsored by the Energy Research and Development Administration (ERDA) at Oak Ridge National Laboratory, focused its attention on the analysis of national and regional effects of energy development and use. This annual report describes the work accomplished principally in the Energy Division and the Environmental Sciences Division. The major goal of this work has been to carry out comprehensive regional assessments to identify and evaluate potential environmental, social, and economic effects of energy resource development and use, including the effects of alternative energy technologies. This report presents the results of the assessments completed or underway in 1976, including a discussion of the environmental, social, and economic techniques and methods under development for use in future regional assessments. The report is organized and presented by the four research groups that participate in the Regional Studies Program.

1. INTRODUCTION

R. M. Davis D. C. Parzyck

The Regional Studies Program (RSP) of the Oak Ridge National Laboratory (ORNL) is a joint effort conducted principally by the Energy Division and the Environmental Sciences Division. The program is funded through the Division of Technology Overview (DTO), Energy Research and Development Administration (ERDA).

This report summarizes the results of work accomplished under the Regional Studies Program in 1976. The report is organized and presented according to the four principal research groups that participate in the Regional Studies Program—the Regional Economic Analysis, Resource Analysis, and Social Impact Analysis groups in the Energy Division, and the Regional Environmental Resources Analysis and Planning Program in the Environmental Sciences Division. The activities of each of these groups is reported in Chapters 2–5, respectively, in this report.

In the Regional Studies Program, we are pursuing two paths: (1) to conduct assessments with the methodologies presently available, and (2) to develop new assessment methodologies and data where existing procedures are inadequate or absent. Because each area enriches the other, we deliberately attempt to maintain a balance in the Program between our efforts of research and application, although the emphasis during 1976 shifted somewhat from methodology development to application.

A key objective of the program is to conduct regional integrated assessments that can be used to help balance environmental, social, and economic goals with energy development goals. As an example, during the second half of 1976 ORNL, together with several of the other national laboratories, initiated a major national and regional assessment of increased coal development and use. Particular emphasis in the assessment is given to new technologies and to the identification and analysis of any significant problems that should be solved before widespread use of these new technologies will be acceptable.

The National Coal Utilization Assessment is an example of the type of regional integrated assessment performed by interdivisional teams involved in the Regional Studies Program at ORNL. Our general approach to these assessments is shown in Fig. 1.1. We begin by selecting representative national energy scenarios and disaggregating these forecasts of future energy need to large regions (several states) as well as smaller regions [generally Bureau of Economic Analysis (BEA) areas]. A plausible mix of technologies adequate to meet future regional energy requirements is selected. Social, economic, and environmental criteria are identified and applied to the regional resource base to identify candidate areas and plausible spatial patterns for future energy facility locations. These patterns are then used to evaluate the potential social, economic, and environmental effects from the proposed facilities which are integrated into comprehensive regional assessments. Where significant regional impacts are identified, the siting criteria, technology mix, or both may be modified to minimize the effects on these regional systems. A more detailed discussion of the ORNL approach to regional integrated assessments and the role played in these assessments by each participating research group is provided in this report.

The ORNL portion of the current National Coal Utilization Assessment focuses on the South; other national laboratories are focusing on their respective regions of the country. Argonne National Laboratory (ANL) is serving as program manager for this program. The Coal Assessment, which was initiated formally in December, is designed to provide key information to ERDA administrators on the potential side effects of the development of coal resources and related technologies on a regional basis. The Assessment will also provide useful information to state and regional decision makers and industries. Although our current assessment focuses on coal, we expect future national and regional assessments to focus on nuclear, solar, geothermal, and other fuel types.

In addition to the National Coal Utilization Assessment there are several related DTO funded projects currently underway. For example, an energy profile of the southern 14 states was developed for 1972 that provides a description of typical energy production, consumption, and transportation patterns for each state in the region. Also, an assessment is being made of Appalachian coal in terms of reserves and the potential environmental impact of developing these coal resources. A third project is aimed at identifying the local as well as regional social impacts of constructing, operating, and maintaining nuclear and coal power plants. Another continuing program is aimed at developing and evaluating criteria for assessing the potential environmental impact of regional energy developments.

In addition to the work sponsored through DTO, ORNL is engaged in a number of related programs that complement our DTO-sponsored efforts. For example, a project sponsored by the Economic Development Administration (EDA) in the Department of Commerce has been directed at determining the supply and consumption pattern of various fuel types and developing related data bases at the Bureau of Economic Analysis level. In a project sponsored by the Nuclear Regulatory Commission (NRC), we developed and applied a land use screening procedure that was used to identify candidate areas for siting future power plants in northern Maryland. In a project sponsored by the Electric Power Research Institute (EPRI), a model was developed to calculate volumes of coal reserves and specific coal mining costs in Appalachia. The Water Resources Council (WRC) has sponsored an ongoing program to assess the impacts of future energy development on water throughout selected

ORNL APPROACH TO CONDUCTING REGIONAL INTEGRATED ASSESSMENTS

Fig. 1.1. ORNL approach to regional integrated assessments.

water resource regions in the eastern United States. In a related program, the Ohio River Basin Commission (ORBC) has sponsored work to assess the effect of future energy development on water availability in their basin. Several studies have been sponsored by NRC to analyze the effects of operating nuclear facilities on communities and surrounding regions, and staff members have prepared and reviewed parts of environmental impact statements and participated in several hearings as part of the NRC licensing process for nuclear power plants. Under continuing sponsorship from ERDA's Division of Transportation Energy Conservation, annual summaries of statistical information have been prepared on energy use in various transportation sectors. Through a program sponsored by the ERDA Office of Environmental Information Systems, we have maintained the Regional and Urban Studies Information Center (RUSTIC), which provides socioeconomic data to public and private agencies. Many of these regional programs provide valuable information that contributes to our work under the DTU Regional Studies Program. Consequently, we have reported these related programs in this report as well.

We invite your comments on this report and the programs discussed here, and we welcome your suggestions on future areas of research that need attention in the region. Please send your comments to:

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2.1 Introduction

The Regional Economic Analysis Group conducts research into the spatial distribution of economic activity and population and relates these distributions to energy production and consumption

-
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and to other natural resource and economic requirements for energy. Because of the importance of early planning in the development and assessment of energy technologies, much of our work follows a projection framework. Thus, the Regional Economics Analysis Group uses national projections of employment and population for target years such as 1985, 2000, and 2020 to estimate consistent projections for small functional economic regions (BEA areas). These economic estimates are then used to estimate current and future energy requirements and energy conditions for these regions.

Past work has centered on methodological development of an employment-population forecasting system for functional economic areas, a system we call MULTIREGION. When final testing and validation is complete, we anticipate that MULTIREGION will serve as a major tool of analysis.

Work conducted during the past year has centered on MULTIREGION and on constructing regional energy data bases on a spatial grid comparable to that used for MULTIREGION. We plan to use the MULTIREGION system to regionalize national energy demand aggregates and to investigate the interaction of energy and economic development by focusing on five issues.

1. How will alternative future patterns of economic activity influence the regional distribution of energy consumption?
2. How will alternative strategies in energy policy influence future patterns of regional economic activity?
3. Which national energy alternatives are most sensitive to changes in existing regional trends of economic growth and change?
4. Will regional distributions of energy production facilities and distribution networks constrain regional economic growth?
5. Will regional distributions of water, manpower, or natural resources constrain national energy alternatives?

Clearly, these issues are wide-ranging and will not be quickly nor easily answered. Nonetheless, we have attempted to incorporate sufficient flexibility into our analyses that each may be addressed in a systematic manner.

In the sections that follow, a brief description of MULTIREGION and information concerning initial validity tests will be given, followed by a discussion of our data base and work accomplished this past year for estimating regional distributions of energy commodities.⁸

2.2 Socioeconomic Projections

Over the past several years, the Regional Economic Analysis Group has undertaken a continuing series of studies into patterns of regional demography, manufacturing and other employment, and labor force participation. Empirical relationships have now been estimated for each of these components, and the emerging quantitative representations have been united into a computerized projection system that estimates future patterns of socioeconomic activity for a spatial grid of 173 BEA areas.⁹

Overview.^{10,11} MULTIREGION generates projections of population and employment across a grid of 173 BEA areas in five-year steps. In combining demographic and economic behavior,

8. The reader is also directed to Sect. 3.3, which discusses water availability for energy production and reports a portion of our past year's work.

9. BEA areas are mutually exclusive functional economic areas that include the total land area of the United States. They were defined by the Office of Business Economics (now the Bureau of Economic Analysis of the Department of Commerce) in 1969.

10. R. J. Olsen et al., *Energy Div. Annu. Prog. Rep. Dec. 31, 1975*, ORNL-5124, pp. 99-104.

11. R. J. Olsen et al., *MULTIREGION: A Simulation Forecasting Model of Population and Employment*, to be published as an ORNL/TM report.

MULTIREGION interprets each BEA region as a labor market. A cohort-component approach is used to combine the effects of births, deaths, aging, and migration into a potential labor supply. An employment analysis separates economic activity into three general categories—manufacturing, local service, and natural resources—and subsequently into components of these categories and is used to provide estimates of labor demand. Among the required inputs are national control totals for employment by type and for population by age group. MULTIREGION then calculates regional shares, which are converted to regional employment and population projections that in the aggregate add up to the national total. The major output parameters derived from MULTIREGION for each BEA are population (male, female, and total) for 16 age groups and labor demand (number of employees and national share) for 37 industry groups.

Computational sequence. Figure 2.1 identifies the major elements of a region's economy, when viewed as a labor market, and the computational steps used by MULTIREGION to prepare regional forecasts of population and employment. Because MULTIREGION operates in five-year steps (1970, 1975, 1980, etc.), some labor supply and demand components are assumed to adjust to regional socioeconomic conditions immediately. Thus, a two-stage computation is followed: (1) Trial values of some explanatory variables are used to produce first-stage estimates of regional labor supply and demand; (2) the first-stage labor market conditions are then used to recompute final regional estimates. At both stages, regional aggregates of employment, population, and labor supply are balanced to predetermined national totals, interregional migration balances are met, and regional labor market boundaries are imposed. Computations for a BEA economic area proceed as follows: (1) Trial population values are computed (population of this period is assumed to equal that of last period plus births minus deaths plus in-migrants minus out-migrants); (2) trial labor supply values are computed by multiplying the estimated population by labor participation rates; (3) trial labor demand values are computed as the sum of (a) forecasted agricultural and mining employment, (b) region's share of forecasted national manufacturing employment, and (c) local service employment; (4) trial labor market conditions are computed by bringing together trial labor supply and demand values; and (5) final labor market conditions are computed by repeating steps (1) through (4) in view of the trial labor market conditions of step (4).

Uses of MULTIREGION. MULTIREGION may be used to provide baseline forecasts of regional employment and population patterns consistent with the national forecast model chosen as the control. When the national forecasts are updated to reflect recent changes in the economic environment, MULTIREGION can be easily updated as well to provide regional forecasts that will reflect these national changes.

In addition, three characteristics of MULTIREGION make it ideally suited for examining the differing regional impacts of alternative national economic (energy) policies: (1) the detailed structure of the population model which relates migration to both the age structure and regional economic conditions, (2) the interaction of the economic activity of neighboring regions, and (3) the use of a national input-output model for determining the level of national activity. MULTIREGION can estimate, for a particular scenario, the direct and indirect employment effects on industrial activity, the consequent direct and indirect changes in the spatial pattern of that employment, and the potential changes in regional migration and population growth as employment patterns respond to the national level of economic activity.

We intend to use MULTIREGION to assess the regional impact of alternative national energy scenarios to better understand potential employment and growth constraints to differing regional demands on energy resource extraction and supply patterns. For example, for the National Coal Utilization Assessment, we will trace the implications of increased total and regional employment for

Fig. 2.1. ORNL-MULTIREGION approach to regional analysis.

expanding coal extraction and consider the indirect employment and population implications of alternative extraction sites.

Model validation and tuning. MULTIREGION is currently being subjected to a rigorous validation and tuning process prior to full-scale use of the model's outputs. This process is an important and necessary step in the development of any regional model for several reasons. First, there is currently only an imperfect theory of how and why regions develop. MULTIREGION is designed around a structural framework and computational sequence that approximate actual regional relationships. Testing is therefore necessary to ascertain how individual components of the model, which appear individually appropriate, perform when combined through the simulation framework. Second, only limited data are available on how regional relationships change over time. Thus, the dynamic validity of the model should be verified. Third, certain regions will always appear as exceptions. In tuning the model for projection purposes, these exceptions must be taken into account and the model adjusted to account for these unusual regional differences.

A two-step validation procedure has been adopted to validate and tune the MULTIREGION model. These steps include operating the model over two time frames, 1960-1970 and 1970-1985. Model estimates of population, employment, and other regional economic and demographic indicators are compared with the 1970 actual data (census), 1975 estimated data (census), and 1985 projected data (OBERS). It should be stressed that the MULTIREGION projections presented are unconditioned by judgment and are intended to compare different scenarios rather than to accurately predict the behavior of any single region. Thus, the exercise is an experiment in the purest sense, and one that will only partially reflect the final accuracy of MULTIREGION projection series when model adjustments take into account the difficulties discussed above. Although we conducted similar exercises for all model outputs, BEA population totals will be discussed since our comparisons have progressed the furthest in this area.

Differences between MULTIREGION projected population totals and the three benchmark data points discussed above are compared using the average percentage deviation. This statistic is calculated by computing the absolute value of percent differences for all BEAs between MULTIREGION total population values and the total population values of each test series and taking the arithmetic mean of the resultant differences. As shown in Table 2.1, there was an average deviation of roughly 7% between 1970 actual population and the population projected by MULTIREGION. Similarly, the average deviation was 4.42% for 1975 and 8.02% for 1985.¹²

Evaluating these statistics is somewhat difficult; nonetheless, two simple comparisons should prove useful. In an earlier study, ORNL calculated similar statistics comparing three recognized projection series¹³—the National Planning Association, OBERS, and Bureau of the Census. The average absolute deviation between these projections ranged between 3.1 and 5.1% when 1980 state level projections were compared. A similar analysis was performed by the Bureau of the Census to test the accuracy of their county population estimates program.¹⁴ In this case, the bureau-calculated population estimates were controlled by an estimated state total. Estimated projection deviations were then calculated from actual county census numbers on a county-by-county basis. When this procedure was carried out using several estimating techniques, average deviations ranged from 4.6 to 7.4%.

In general, we expect projection at the BEA level to be more difficult than at the state level and somewhat easier than at the county level. Similarly, we expect projecting a finer breakdown of population and employment to be more difficult than projecting aggregated totals. Given the above results, it appears that MULTIREGION is capable of making reasonably accurate population projections. However, a more severe test will come when components of population and employment are similarly analyzed.

Further testing and validation of MULTIREGION are currently under way; Figs. 2.2–2.4 illustrate the results of the model's validation tests to date. Figure 2.2 indicates that Florida, portions of the

12. U.S. Water Resources Council, *1972 OBERS Projections: Regional Economic Activity in the U.S.*, vol. 1, Series E Population, U.S. Government Printing Office, Washington, D.C., April 1974.

13. D. J. Bjornstad et al., *State Population Projections: A Comparative Review of National Series and Their Practical Usefulness*, ORNL/UR-120 (February 1975).

14. U.S. Bureau of the Census, *Federal-State Cooperative Program for Local Population Estimates: Test Results—April 1, 1970*, Series P-26, No. 21, U.S. Government Printing Office, Washington, D.C. (April 1973).

Table 2.1. Comparison of MULTIREGION projected BEA population with 1970 census population, 1975 estimated population,^a and 1985 OBERS population^b

	MULTIREGION 1970 vs census 1970	MULTIREGION 1975 vs Coop Program 1975	MULTIREGION 1985 vs OBERS 1985
Mean absolute percent deviation ^c	6.95	4.42	8.02
Standard deviation	6.76	3.88	6.38
Smallest error	0	0	0
Largest overestimate, %	33	9	30
Largest underestimate, %	31	21	29

^aData obtained from the Federal-State Cooperative Program for Local Population Estimates.

^bU.S. Water Resources Council, *1972 OBERS Projections, Vol. 2, BEA Economic Areas*, April 1974.

^cMean absolute percent deviation = $\frac{1}{173} \sum \left(\frac{\text{MULTIREGION} - \text{benchmark}}{\text{benchmark}} \right) \times 100$.

Fig. 2.2. Comparison of 1975 MULTIREGION and OBERS projections.

Fig. 2.3. Comparison of 1970 MULTIREGION and census projections.

Fig. 2.4. Comparison of 1985 MULTIREGION and OBERS projections.

Southwest, the Denver area, the Dallas-Fort Worth area, and the Houston area grew at a faster rate during the estimating period than was projected by MULTIREGION. Figure 2.3 illustrates that this growth continued into 1975 in Florida and in portions of the Southwest, but that surprisingly few groups of deviations are present. In fact, it appears that increasing the projected growth rate in a small number of BEAs would have led to an extremely close approximation of actual population trends since error in underestimating population was minimal and probably exacerbated by the fact that total population was controlled.

A mixed pattern is present in Fig. 2.4, in which OBERS and MULTIREGION population figures are compared. OBERS anticipates more growth in Florida and the Southwest than did MULTIREGION, but few other patterns are evident. With minor adjustments, it appears that MULTIREGION and OBERS population numbers are largely interchangeable. We are in the final stages of evaluating MULTIREGION and are planning to use the model in a number of energy planning and analysis assessments currently under way in the RUS section. MULTIREGION will continue to be improved as we gain more experience with the model during these assessments.

2.3 Energy and Socioeconomic Patterns

The first step toward analyzing energy use and production, as they relate to regional employment and demographic distributions, is to compile regional energy data bases. Historically, energy data have been collected by a diverse set of spatial grids (e.g., petroleum administration districts, electric reliability areas, and coal production areas) that are frequently incompatible. Fortunately, the Bureau of Mines has collected most of this data at the state level. Below the state level, statistics on energy production are available by extracting information from numerous state agencies when gaps in federally collected data exist. As for energy use, virtually no substate data exist. We have thus chosen to synthesize substate energy use statistics through an allocation procedure based on the levels and composition of economic activity and population.

Energy conditions in the South.¹⁵ The ERDA-DTO-RSP has encouraged the national laboratories to examine their respective regions carefully and to ascertain special conditions that affect energy. As a preliminary step, an energy profile of the South¹⁶ was compiled to provide a description of typical energy production, consumption, and transportation patterns relative to those of other regions. The year 1972 was deemed most suitable for a baseline analysis because of the relatively stable energy prices characterizing the economy prior to the Arab oil embargo and subsequent energy shortage. A later update should indicate in what areas the patterns have changed.

The fourteen states making up the region of study represented less than 29% of the U.S. population, but accounted for over 73% of all domestic energy production in 1972. Primarily as a consequence of this energy-producing activity, particularly in Louisiana and Texas, southern per-capita energy usage was 12% higher than the national average. As is true throughout the United States, the industrial sector used the largest share of total energy. The residential sector accounted for the smallest share, partly, perhaps, because per-capita income was 20% lower in the region than elsewhere. All consuming sectors exhibited greater than average dependence upon natural gas, which is relatively cheap within the region.

15. P. L. Rice, *Energy Conditions in the South*, ORNL/TM-5568 (December 1976).

16. The South is here defined to include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. The exact boundaries of the southern region may vary slightly for other research programs, depending on the geographic divisions of the particular problem under study.

The South is a net exporter of crude oil, natural gas, natural gas liquids, refined petroleum products, and coal. Table 2.2 indicates the production, consumption, receipts, and shipments of crude oil and natural gas in the South in 1972. The region has played a pivotal role in determining historical energy patterns and will probably continue to do so since it holds 72% of the remaining proven reserves of natural gas and 49% of the remaining proven reserves of oil. However, the southern role in coal production should decline in the future: Although the South accounted for 53% of 1972 coal production, it contains only 13% of the remaining coal reserves, the majority of which contain high amounts of sulfur.

Hydroelectric activity is currently centered in Tennessee and Alabama. Although less than 45% of the total potential hydroelectric capacity in the South has been developed, the balance is not likely to be developed in the foreseeable future.¹⁷ Only 1% of the electricity in the region was generated at nuclear facilities in 1972, but most observers expect this figure to grow rapidly over the next ten years. In 1972 utilities relied primarily on coal and natural gas, but it appears that coal will be extensively substituted for natural gas in the near future. Thus, the importance of coal and nuclear energy will likely increase in the future as the South follows the national trend away from the use of petroleum products in electricity generation.

17. Science and Public Policy Program, *Energy Alternatives: A Comparative Analysis*, University of Oklahoma, Norman, Oklahoma (May 1975), p. 9-5.

Table 2.2. Natural gas and crude oil patterns in the South, 1972

	Natural gas		Crude oil	
	Amount (10 ⁹ ft ³)	Source and distribution (%)	Amount (10 ⁶ bbl)	Source and distribution (%)
Production	19,008		2,520	
Receipts	297	99.9, from Ohio 0.1, from New Mexico	132	45.6, from New Mexico 36.6, from foreign sources 7.8, from Indiana, Illinois, and Michigan 2.6, from Kansas 2.4, from Pennsylvania and New York 2.1, from Utah 2.1, from Ohio 0.6, from Colorado and Utah
Shipments	8,552	25.4, to Kansas 15.6, to Ohio 13.0, to Indiana 10.2, to New Mexico 10.1, to Maryland 9.2, to Pennsylvania 9.2, to Missouri 5.9, to Illinois 1.2, to Colorado 0.2, to D.C. 0.1, to Mexico	641	34.3, to Illinois 19.7, to Ohio 16.3, to Indiana 11.4, to Pennsylvania 5.7, to New Jersey 5.6, to Kansas 3.6, to Missouri 2.9, to Michigan 0.6, to Delaware and Maryland 0.1, to California
Miscellaneous losses	228		10	
Usage	10,525		2,001	

With its 605 processing plants and 100 refineries, the South accounted for 81% of all natural gas processed and 47% of all crude oil refined in 1972. As previously noted, the South was a net exporter of refined petroleum products, including gasoline, distillates, jet fuel, and liquified petroleum gas (LPG). Although this processing activity provides the bulk of the nation's requirement for petroleum products, it also requires the use of substantial quantities of energy. The amount of natural gas per employee used by the industrial sector of the South is twice as great as that used by the industrial sector in other regions.

The employment mix within the industrial sector is important to the determination of fuel mix as well as to the regional share of energy usage by the sector. Both petroleum and chemical manufacturing, for example, require substantial amounts of energy per employee, but the apparel and leather goods industries require relatively little energy. An index of energy use by the manufacturing sector (which accounts for 25% of the region's employment) was created for the South and each of its states, as well as for the other regions, to reflect the impact of variations in employment mix upon total energy demand. Relative energy usage for each three-digit standard industrial classification (SIC) in the nation as a whole was determined and used as a measure of energy intensiveness. The employment mix of energy state was then weighted by this measure of energy intensiveness. As shown in Table 2.3, the South had the highest index of any region in 1972, and West Virginia was the most energy-intensive state. West Virginia is the fifth largest per-capita energy user in the nation.

Table 2.3. Industrial energy indices
in the South, 1972

State or region	Index ^a
Alabama	1.476
Arkansas	0.872
Florida	0.776
Georgia	0.684
Kentucky	1.254
Louisiana	2.759
Mississippi	0.658
North Carolina	0.549
Oklahoma	1.041
South Carolina	0.908
Tennessee	1.310
Texas	1.858
Virginia	0.826
West Virginia	4.116
South	1.197
Northeast	1.070
Rocky Mountain	1.122
West Coast	0.840
Midwest	1.133
United States	1.101

$$^a \text{Index}_j = \sum_i \left(\frac{E_i}{\sum_i E_i} \right) \left(\frac{L_{ij}}{L_j} \right),$$

where

- j = state or region,
- E = total energy consumed yearly in equivalent kilowatt-hours,
- i = 3-digit SIC industry,
- L = employment.

An underlying assumption of these indices is that similar industries use similar input mixes despite regional location; for example, all chemical manufacturers use the same amount of energy per worker. Such an assumption overlooks possible variations in energy use which arise from differing availabilities of energy, labor, capital, and other raw materials. Subsequent analysis of each individual state indicated that not only do states differ in terms of industrial mix, but industries also differ in terms of overall input mix. Where energy is abundant, energy usage tends to be higher relative to labor and capital usage.

An assessment of socioeconomic impacts of alternative energy futures involves minor as well as major consuming sectors. For the South, a disproportionate number of households were found to rely upon electricity for space and water heating, and the housing stock was found to be atypically characterized by a large percentage of mobile homes, which are notably inefficient in energy use. Thus, the residential sector of the South is more greatly dependent upon both electricity and LPG than are other regions. Electricity prices are lower than those prevailing in the rest of the United States, but LPG prices are slightly higher. With 47% fewer mean heating degree-days, this sector uses less energy for space heating, but twice as much energy for air conditioning, as do other regions of the country. The commercial sector, which accounts for about 60% of the employment, relies less on oil and gas and more on electricity than do commercial sectors in other regions, but pays less for all three energy forms than do other parts of the nation. With the exception of its heavy reliance on natural gas for pipeline transportation of fuels, the transportation sector of the region exhibits no unusual patterns.

We intend to conduct subsequent analyses of the South that will update these findings and provide a method for evaluating the impact of future changes in supply conditions, given the changing patterns of production, consumption, and transportation that occurred in 1974 following the first interruption of foreign oil supply. Such detailed analyses by sector and fuel should provide a portion of the information necessary to federal and state policy makers dealing with subnational energy issues.

Development of regional energy data bases. The Regional Economic Analysis Group has maintained an ongoing effort sponsored by the Economic Development Administration to develop a detailed energy data base at the BEA level for 1972 and subsequent years. A BEA-level data base is somewhat unique; only the county energy data developed by Brookhaven National Laboratory (BNL) is comparable.¹⁸ The BNL data do not reflect the energy production and consumption patterns of any given year, but are an annual compilation of statistics for 1970, 1971, 1972, and 1973. While the BNL data base is sufficient for the analysis of certain pollution effects, it is not satisfactory for socioeconomic analysis because it does not include important time and space characteristics. Thus, a data series was specifically designed to support our social and economic research programs.

Production data. The Bureau of Mines published annual coal production by county in the *Minerals Yearbook* from the detailed reports on production and mine operation prepared by coal producers. We aggregated these county data by BEAs for consistency of the data base. The BEA production of uranium was determined by disaggregating state production figures on the basis of employment and number of uranium mines. In most cases production was concentrated in a single BEA so that errors were minimal.

State publications of oil production by county (or field) are available for the major oil-producing states. We identified fields and located them within counties in order to construct BEA data bases from county groups. Where oil fields overlapped county, BEA, or state lines, the dominant BEA was credited with the total production of the field. Specific information was available, therefore, for 98% of total

18. F. R. Drysdale and C. E. Calef, *Energetics of the United States: An Atlas*, Brookhaven National Laboratory, 1975 (computer tape).

crude production in 1972. The remaining 2% of production was allocated on the basis of known locations of oil wells within the other producing states.

State publications of gas production by county or field are also available for the major gas-producing states. These reports, along with the Bureau of Mines data, provided information for 96% of U.S. gas production. The remaining 4% was estimated on the basis of footage drilled, the number of exploratory and proven oil and gas wells, the percentage of oil produced from associated and nonassociated wells, and the success ratio associated with each type of drilling.

The Bureau of Mines also publishes statistics on refinery location and capacity by township. We aggregated these township statistics by BEAs for use in allocating state production totals of refined petroleum products, such as gasoline and distillates, to those BEAs. Similarly, the *Oil and Gas Journal* publishes statistics on processing plant location and capacity by county. The 1974 output of LPG, butane, ethane, etc., by county was used to allocate the 1972 state totals because an extensive survey was not published in that year.

Hydroelectric and nuclear capacity and associated electricity generation by BEA were determined on the basis of the 1967 and 1975 data files of the Federal Power Commission and annual issues of *Steam Electric Plant Factors*. Production and capacity estimates were included in the data set in terms of the source of generation rather than place of ownership. The 1975 information on new plants was used to augment the 1967 data after adjustment for plant retirements between 1967 and 1972.

Consumption data. Since detailed statistics on energy use are generally not kept below the state level, it was necessary to develop an approach for allocating control statistics for states to substate areas. The creation of this regional data base not only provided useful information on the production and consumption of fuels by type and sector, but more importantly, it provided a methodology for determining energy patterns at the BEA level in subsequent years. Moreover, knowledge acquired in the process of developing the data was critical to the establishment of methodologically sound bases for forecasting regional energy production and consumption in the future.

Although our approach for allocating energy control totals to substrate areas is relatively simple, it possesses three characteristics that make it particularly useful for our work: (1) It is general, permitting disaggregation from several high levels of aggregation to several smaller ones; (2) it makes use of available data without detailed statistical manipulations (in most cases, detailed regional energy information is simply deficient and must undergo significant manipulation); (3) it permits ease of update. We have been impressed that new data sources, many of which were previously unused, are rapidly becoming available. We have thus chosen a simple but general approach that we intend to improve, primarily by acquiring better data. Perhaps most important, however, the approach is operational.

The basic form of this allocation procedure can be represented by

$$D_{fir} = US_{fi} \cdot Index_{fi}^s \cdot SPEC_{fir} \cdot ACT_{ir}, \quad (1)$$

where

D_{fir} = estimated demand for fuel f , sector i , and region r ,

US_{fi} = average United States use of fuel f in sector i per unit of activity (e.g., fuel used per primary metal worker),

$Index_{fi}^s$ = relative use of fuel f in the sector i and state s compared with the U.S. average for that fuel and sector,

$SPEC_{fir}$ = special adjustment for fuel f in sector i and subregion r (e.g., $SPEC = 0$ if fuel f is not available),

ACT_{ir} = activity levels in sector i and subregion r corresponding to definition of US_{fi} (e.g., number of primary metal workers).

Each of the projects in which we have used this scheme has considered different fuels (f), sectors (i), and regions (r). Consequently, the computed values of the indices have been collected from a variety of sources. As we gain experience, we will create a data base of activity variables and indices at a level as detailed as possible given the existing data. This data base will allow the use of the same data for a variety of different applications and permit more resources to be devoted to refining and analyzing the historic indices.

The indices are computed from historical data for 1971 or 1972 for the residential, commercial, industrial, and transportation sectors. The industrial sector has additional detail corresponding to the level of disaggregation in MULTIREGION and OBERS projections. The year used and limitations on the ability to define all indices for all sectors are determined by the data. The use of such historical indices for forecasting can involve restrictive assumptions, which vary according to the particular application. In general, using historical indices implies that the state patterns and sectoral differences in energy use forecasts are proportional to those in the base year from which the data are drawn.

As additional data become available, we intend to test this proportionality assumption, as well as to analyze how the state patterns and national-level indices are related to the underlying regional determinants of energy choice (e.g., regional fuel price differentials and availabilities) and other regional characteristics (e.g., regional income and heating and cooling demands).

3. RESOURCE ANALYSIS GROUP

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3.1 Introduction

The central research focus of the Resource Analysis Group is to delineate and analyze human and natural resources and to specify the interactions of these resources in meeting future national and regional energy needs. Our present emphasis in resource allocation is on energy development. To pursue this task, we have melded the objectives of six separate research projects into a central theme of resource analysis and energy development while still fulfilling the specific requirements of each project; the cumulative benefits to each project are greater than if each project were pursued independently.

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In connection with ERDA's National Coal Utilization Assessment, we are engaged in a study to identify future plausible energy facility siting patterns for the southern United States and to determine the attendant resource developments that will be required. Presentation of our research accomplishments during 1976 is organized according to the necessary steps for performing resource analyses and delineating suitable energy facility siting patterns to meet future energy needs.

The six research projects presently funded in our group are

1. ERDA-DTO-Sponsored Energy Facilities Siting: A National-Regional Assessment Project. The objective is to develop possible energy facility siting distributions for the southern United States by using several different energy demand and development assumptions and to specify associated impacts. This project is part of the National Coal Utilization Assessment.
2. NRC-Sponsored Maryland Regional Siting Factors Study. The objective is to develop and implement a land use screening procedure capable of identifying candidate areas for power plants in northern Maryland. This project is drawing to a conclusion.
3. ERDA-DTO-Sponsored Coal Mining Impacts: An Environmental Assessment in Appalachia Study. The objective is to assess the availability of Appalachian coal resources in terms of the reserves and the environmental impacts that might be associated with development. This study is also part of the National Coal Utilization Assessment.
4. EPRI-Sponsored Computer System for Assessment of Coal Reserves Study. The objective is to develop a model to calculate volumes of coal reserves and specific mining cost variables suitable for use by mine operators.
5. WRC-Sponsored Water for Energy Assessment Project. The objective is to assess the impacts of future nonnuclear energy development on water throughout selected water resource regions in the eastern United States.
6. ORBC-Sponsored Ohio River Basin Energy Facility Siting Study. The objective is to assess the effect of future energy development on water availability and water quality in the Ohio River Basin.

3.2 General Approach to Resource Analysis and Energy Facility Siting

To prepare for future siting applications, members of our group have completed a thorough review and analysis of various siting methodologies currently in use throughout the United States. This effort culminated in a report drawing conclusions from both literature and experience and recommending optimal combinations of techniques that should be employed in regional and site-specific energy facility siting studies.²⁵

As a result of past experience in regional modeling at ORNL²⁶ and extensive review, we concluded that a two-phase site selection procedure capable of multiple analyses under different constraints is best suited to determine feasible energy facility siting patterns and to perform the necessary resource analyses. The two-phase procedure involves (1) eliminating areas unsuited for

25. B. F. Hobbs and A. H. Voelker, *Analytical Power Plant Siting Methodologies: A Theoretical Discussion and Survey of Current Practice*, to be published as an ORNL/TM report.

26. For documentation of the ORNL-NSF regional modeling work, see C. W. Craven, Jr., et al., *Reflections on Regional Environmental Systems Analysis*, ORNL/RUS-26 (to be published), which provides a history of the ORNL experience and a guide to additional documentation.

energy facilities because of lack of resources (i.e., water or transportation facilities) or economic, environmental, or institutional constraints and (2) evaluating or ranking remaining areas in terms of siting potential based on the combination of characteristics sought in an ideal site.

Because some components of the site selection process are not amenable to computer procedures, parts of the site allocation process must be handled subjectively and manually. Also, we note that the procedure should accommodate a hierarchical scaling of analyses, stepping down spatially from large regional scales (e.g., census regions) to subregional scales (multiples of counties) and ultimately to site-specific levels, when environmental impact statements are required. We do not intend to recommend particular sites since this function is more properly the responsibility of utilities or state planning agencies, but our procedures should be useful for this purpose.

Figure 3.1 is a flowchart summarizing how we perform the analysis to identify energy development patterns. National energy demand scenarios are exogenously provided (by FEA or ERDA) as a beginning point for our analysis. The Regional Economic Analysis Group disaggregate these energy demand forecasts for the southern United States to subregional units (BEAs) that we consider to be load centers. Energy demands by BEAs are then mapped to determine the spatial distribution of demand and future differential growth patterns that may be expected.

For each BEA, technology mixes to meet future demands are developed from our knowledge of (1) energy technology characteristics, (2) time horizons for new technologies, and (3) the technology mixes projected for each census region (provided exogenously by the national scenarios). Also, information covering utility plans for future plant types (when available) and the general availability of suitable sites within each BEA will be used in determining the technology mixes needed to satisfy demand.

Parallel to these analyses, technology characterizations in terms of resource needs and unit facility siting requirements (water consumption, land requirements, transportation needs, and pollutants) are generated. Siting criteria for various technologies in terms of resource needs, potential environmental effects, and social and legal limitations are determined, and the relative importance of each siting criterion is then developed. Knowledge of siting criteria and resource requirements also permits the determination of resource data and siting information that must be compiled in our spatial-temporal information system.

In the energy facility screening and siting process, the above information is used to test the resource requirements of new energy development against the resources available. This task, however, requires the development of site factor models which describe resource availability in terms of the siting requirements of various energy technologies. These site factor models are collectively called the Oak Ridge Spatial Analysis Model (ORSAM). Each site factor model is designed to spatially describe a specific siting criterion for the type of energy facility (e.g., nuclear, fossil, or other power plants or coal conversion plant) to be sited. For example, simple knowledge of stream flow volume is not sufficient to determine whether adequate cooling water is available without first determining potential low flows and maximum water consumption situations. In essence, the siting factor models replicate the siting criteria considerations.

Ultimately, candidate energy facility siting and resource utilization patterns emerge from the site-screening process. These distributions provide input to the social, economic, and environmental impact analyses described in Sects. 2 and 4. The following subsections describe in more detail the components of the resource allocation and siting process and the application of these ideas to our six research projects.

Need for energy. The disaggregation and allocation of national energy projections to BEA regions is performed by the Regional Economic Analysis Group. The projections used in our

Fig. 3.1. Siting analysis approach used at ORNL.

analysis were derived by BNL and are essentially the same projections used by ERDA; near-term projections are identical to those used by FEA. In the Ohio River Basin study, the projections are provided at the state level by ANL and are then disaggregated further to BEA and state BEA portions by the Regional Economic Analysis Group.

Projections of increased electrical energy demand by the years 1985 and 2000 have been mapped for the entire United States (Figs. 3.2 and 3.3). These maps illustrate the proportionate increase in electrical demand beyond 1972 by year, the amount to be provided to meet future needs, and the areas in which additional conservation might be emphasized.

Planned and installed electrical capacity. Projection of 1985 energy facility siting patterns is based on data provided by the Federal Power Commission (FPC).²⁷ The FPC data provide

27. These data are provided by the Federal Power Commission, Officer of Public Information; the data set is called the "Generating Unit Reference File."

ORNL-DWG 77-5960

Fig. 3.2. Proportionate increase in electrical energy demand by BEA region for the year 1985 (base year 1972).

ORNL-DWG 77-5961

Fig. 3.3. Proportionate increase in electrical energy demand by BEA region for the year 2000 (base year 1972).

information on the location of proposed power plants and the generating capabilities of each plant. The 1985 planned and existing generating capacity (in megawatts) is illustrated in Fig. 3.4; capacity to be added or retired (negative numbers indicate retired units) between 1975 and 1985 is shown in Fig. 3.5. Finally, the differential between the planned and existing capacity and the needed electrical capacity in 1985, as projected by the Regional Economic Analysis Group, is presented in Fig. 3.6.

Siting criteria. One of the first steps in developing a siting methodology is the careful identification of those factors that must be considered by the utilities and state agencies in locating acceptable energy facility sites. To accomplish this important step in a systematic manner, we have adapted group processing techniques to the problem of factor identification. This year we conducted two sessions of a particular technique called the nominal group process technique (NGT) with experts familiar with nuclear power plant siting.

The nominal group process technique is a highly structured, interactive approach that has gained wide acceptance in health, social service, education, industry, and government.²⁸ The process consists of four basic steps: (1) nominal (silent and independent) generation of ideas in writing by a panel of participants; (2) round-robin listing of ideas generated by participants on a flip chart in a serial discussion; (3) discussion of each recorded idea by the group for clarification and evaluation; and (4) independent voting on priority ideas with group decision determined by mathematical rank ordering. The strengths of the technique lie in enhanced participation of group members, the step-by-step movement toward the goal, and cross-education of participants.

The output of our sessions consisted of lists of weighted factors which have since become the basis for the factor models used in our siting methodology. The factors identified by one of our NGT panels for site level are shown in Table 3.1.

Our experience with NGT is described in detail in a report now in press.²⁹ We plan to conduct more group processing sessions in the future to identify factors pertinent to coal-fired power plants and other types of energy facilities. In addition, we plan to experiment with various types of group process techniques in accomplishing this goal.

Site factor models. The ERDA National Coal Utilization Assessment will use a candidate site-screening procedure to locate potential areas suitable for energy facilities across the southern United States on the county level. Siting patterns derived from this analysis include sites for nuclear and fossil-fired power plants and coal conversion plants. Distributions will be developed for each of the four National Coal Utilization Assessment scenarios by year (1985, 2000, and 2020).

Calculation of suitability will depend upon the ORSAM factor models, which are constructed to replicate as well as possible the considerations given by agencies making siting decisions using various criteria such as water availability, seismic risk, air quality, coal availability, and others.

Proximity to load centers. A simple gravity-potential model³⁰ is being used to map accessibility potential of any given county relative to the economic costs of transmitting power to surrounding

28. A. L. Delbecq et al., *Group Technique for Program Planning: A Guide to Nominal Group and Delphi Process*, Scott Foresman, Glenview, Ill., 1975.

29. A. H. Voelker, *Power Plant Siting: An Application of the Nominal Group Technique*, ORNL/NUREG/TM-82 (to be published).

30. The potential of each county for satisfying projected demand is computed with a gravity model in the form

$$P_i = (\text{BEA demand})_i d_i^{-1.5}$$

applied between the centroid of each county and all BEA centers; P_i is the calculated accessibility potential for county i , and d is the distance in miles between the county centroid and each BEA center. The distance exponent, 1.5, was empirically derived to reflect the increased cost of delivering power over increased distance and to reflect a maximum 241-km (150-mile) transmission limit to a load center.

Fig. 14. Planned generating capacity in megawatts for the year 1985 by county (based on FPC data).

ORNL-DWG 77-5963

Fig. 3.5. Generating capacity in megawatts to be added between 1975 and 1985 by county (based on FPC data).

Fig. 3.6. Net surplus or deficit in capacity in megawatts needed by BEA region for 1985 (based on FPC data and ORNL disaggregation of ERDA projections).

Table 3.1. Site factors identified in NGT session

Importance weight	Factor	Defining term or statement
97	Adequate foundation	Licensibility, concern with liquefaction and solution channels
94	Minimum proximity to geologic faults	Capable faults avoided, cost to investigate ancient faults
90	Maximum availability of suitable surface water supply	Both quantity and quality of intake water; cost of taking and cleaning water — only considered in sufficient low flow
90	Acceptable air diffusion characteristics	Radiological diffusion; high cost to overcome poor characteristics
90	Minimum conflict with existing and potential land use	Present use of site; loss of opportunity costs
89	Minimum impact on aquatic biota	Sensitive life stages of important species
89	Minimum adverse impact on endangered species or habitat	
87	Minimum total economic costs	Differential costs of plant, transmission system, water, and relocation of people
87	Minimum susceptibility to maximum hydrological–meteorological events	NRC guidelines are maximum limit for this factor Impact on water quality from radiological, thermal, and chemical output
86	Minimum proximity to undesirable population distribution	
86	Minimum impact on water quality	
83	Minimum impact on unique cultural, historical, or archaeological sites	Includes hospital, school, and other social impact
79	Minimum adverse impact on local institutions	
79	Maximum availability of ground water	Availability without affecting offsite users
78	Minimum construction problems	Stem from roughness of terrain and presence of ground water
76	Minimum impact on terrestrial biota	Habitat destruction
75	Minimum adverse impact on local economy	Danger to plant from hazardous industrial processes in surrounding area
75	Minimum proximity to industrial hazards	
70	Availability of land parcels of sufficient size	Ability to aggregate site from individual parcels with minimum cost and delay
69	Maximum compatibility with local government attitudes	Attitude of local government toward development
68	Maximum G value for DBE	Calculation of potential acceleration caused by seismic activity
66	Minimum aesthetic impact	Includes both visual compatibility and noise
65	Minimum distance to acceptable transportation systems	Construction costs to get to rail, barge, and highway
64	Minimum adverse impact on recreation	Proximity to incompatible recreation use such as national wildlife refuge
63	Minimum adverse impact on regional economy	Potential for local opposition Affects system reliability, costs, and stability
56	Unfavorable attitude of local population	
51	Maximum proximity to load	

Table 3.1. (continued)

Importance weight	Factor	Defining term or statement
48	Maximum beneficial multiuse	Recreation, education, developmental
43	Unfavorable attitude of regional population	Potential for organized regional opposition
42	Minimum distance to transmission grid	Line construction costs and environmental impact
41	Maximum reliability of offsite power	Power to run plant, a safety concern

load centers. Transmission is limited to about 240 km (150 miles) and is based upon present technology in transmitting power along ac lines.

Calculation of 1985 accessibility to demand for the United States is presented in Fig. 3.7; accessibility to surrounding load center is shown for each country. Note that accessibility is highest at the central county of each BEA and decreases to the point at which counties located more than 240 km (150 miles) from any major load center are rated low. The demand figures for each BEA used in the calculations reflect the added electrical generating capacity beyond 1985 that must be sited to meet demand in the year 2000. The planned or installed capacity, as projected by the FPC data, has been subtracted from values for each BEA.

Water availability. We expect water availability to be the prime locational determinant in energy facility siting even in the water-abundant eastern United States. Water requirements for a given facility may be calculated readily, but evaluating the availability of a dependable water supply to meet those requirements is much more difficult. Furthermore, we must account for all existing and planned facilities for a given river system. Water supplies are unevenly distributed among and within the several regions of the nation having substantial annual and seasonal variation. We saw the need, therefore, to develop computerized tools to assess water availability from a regional perspective down to specific site evaluation. The water availability system (WAS) analysis procedure for the Maryland Power Plant Siting Project is based on historical stream flow data and aids such availability analyses.³¹

The WAS enables the user to select, retrieve, and analyze the historical stream flow information from the U.S. Geological Survey (USGS) daily-value water tapes, which contain data for all USGS stream gauging stations in the United States. The WAS package is divided into four distinct subsystems, operating in sequential fashion, that enable the user to (1) delimit any region of the United States by state, county, size of drainage area, or latitude-longitude frame; (2) recall daily flow values from the USGS water tapes for all gauging stations within the study region; (3) compute low flow recurrence frequencies and apply theoretical probability distributions; and (4) predict the reservoir drawdown capacity that would be necessary to maintain any given rate of stream flow at any specified rate of consumption. Separating the parts of the model allows the first and third phases to be conducted on an interactive mode computer which facilitates frequent user decisions. The intermediate phase of data

31. J. S. Jalbert and A. D. Shepherd, *A System for Regional Analysis of Water Availability*, ORNL/NUREG/TM-82 (December 1976).

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Fig. 3.7. Potential accessibility to 1985 unsatisfied electricity demand by county [based on 1985 surplus-deficit in capacity and a gravity model: potential (P) = BEA demand/ $d^{1.5}$].

retrieval, however, uses a batch mode computing system and usually does not require user interaction.

The study area for the definition and selection process may be delineated by latitude-longitude frame, state(s), county(ies), or drainage area size specifications. Data retrieved for each station include (1) USGS code number and name of the station; (2) latitude and longitude; (3) size of the drainage area served; (4) state and county Federal Information Processing System (FIPS) code; (5) monthly average flows by water-year (only for months yielding complete sets of daily flow records); (6) number of days of record for each year; (7) yearly average flow; (8) yearly maximum and minimum flows; (9) overall average, maximum, and minimum flows for the entire period of station record; (10) the 1-day, 7-day, and 14-day low flows calculated for each season of record in the data; (11) the recurrence fractions for the volume flows equaled or exceeded at that station 99, 95, 92, 90, 85, 80, 75, 70, and 50% of the time; (12) the number of output tape records used; and (13) a continuous record of data representing the actual daily measurements of the historical flows of each station. Current capabilities of the analysis subsystem are (a) determination of stations' historical low flows; (b) computation of low flow recurrence frequencies and application of theoretical probability distributions; and (c) modeling of reservoir capacity requirements to support a given consumptive level while maintaining specified minimum stream flow standards. Addition of other models or analyses is permitted with relative ease by modular design of the subsystems and the computer-compatible format of the data generated by the programs.

The WAS package is also well suited to investigating a broader range of water resource questions, including evaluations of water availability to meet projected energy demands. The application of the WAS program to the Maryland Power Plant Siting Project is described in ref. 32.

In performing our energy facility siting analysis for the southern United States, we entered low flow information generated by WAS for gauging stations into our geographic data information system. Figure 3.8 presents 7-day, 10-year low flows for selected streams in the Ohio River Basin region that were used in our energy facility siting analyses for the ORBC. Low flow values are shown for each county bordering on the main stem of the Ohio River or on tributary streams having sufficient flow to support at least one energy facility. Values for counties having gauging stations were calculated and allocated to intervening counties through visual interpolation. Note that values used for the main stem represent modified low flow calculations reflecting the effect of reservoir regulation. These calculations were provided by the U.S. Army Corps of Engineers.³³

Coal availability. Under contract with EPRI, our research group is developing a model incorporating geologic and mine engineering factors to calculate volumes of coal reserves and specific mining cost variables. Drill core data and coal outcrop measurements for such variables as geographic location of drill hole, coal seam thickness, overburden type and thickness, and coal quality collected by TVA field geologists (using the 1:24,000 block quad in East Tennessee as a test case) are being digitized and stored in a computer. Contour lines indicating the coal seam thickness and the thickness of overburden are drawn by a computer routine by interpolating between the drill core locations (Figs. 3.9 and 3.10). In addition, calculation of measured and inferred reserves can be made on the basis of standard criteria used by TVA and USGS (Fig. 3.11).

32. J. E. Dobson, *The Maryland Power Plant Siting Project: An Application of the ORNL-Land Use Screening Procedure*, ORNL/NUREG/TM-79 (October 1976).

33. Water flow numbers for the main stem of the Ohio River were generated by the U.S. Army Engineer Division; see U.S. Army Engineer Division, Ohio River, Cincinnati, Ohio, 1970 (1968 system, less Rowlesburg, 7-day duration, 10-year frequency low flows, main stem Ohio River).

Fig. 3.8. Low flow calculations for counties along the Ohio River and major tributaries (based on 7-day, 10-year low flow calculations at selected gauging stations).

Fig. 3.9. Coal seam thicknesses for red ash seam in the 1:24,000 block quadrangle of East Tennessee (based on data provided by TVA, Fossil Energy Branch).

Fig. 3.10. Thicknesses of coal seam overburden for red ash seam in the block quadrangle of East Tennessee (based on TVA Fossil Energy Branch data and ORNL digital elevation data).

Fig. 3.11. Interpretation of measured, indicated, and inferred coal reserves for the red ash coal seam (based on TVA Fossil Energy Branch data).

A variety of more sophisticated and comprehensive coal reserve models similar to our effort are being developed around the country, and we expect to incorporate characteristics of these models into our work. We have established a working arrangement with the USGS to use their National Coal Data Base System called PACER. What makes the ORNL-EPRI model unique, however, is that the program is geared toward immediate use by coal mine operators because it incorporates existing field data collected by traditional methods.

As part of the National Coal Utilization Assessment, we are inventorying coal reserves by county in the Appalachian region in terms of the f.o.b. price. Coal reserves are assessed from an economic perspective which accounts for variables such as coal seam thickness, coal quality, mining and reclamation costs, and overburden thickness. The feasibility of coal-fired generating plants in a given demand area can be determined when f.o.b. coal price at the mines is combined with a transportation cost model. The ultimate result is a systematic ordering of the areas in which coal is likely to be mined. By coupling this result with a transport model, one can determine the delivered cost for coal at various points throughout our southeastern region.

In addition to calculating the distribution and availability of coal reserves, we will determine certain environmental limitations for the use of coal from the Appalachian region. For example, significant coal reserves may lie in areas of high recreation potential, areas of critical wildlife habitat, and/or areas of low or sensitive water quality; any one of these factors might be seriously diminished or destroyed by mining of coal resources. An accurate assessment of coal reserves should flag these environmentally sensitive areas, and any decisions regarding potential mining sites should necessarily recognize and respect these caveats.

Recreation limitations. The outdoor recreation potential of the coal-bearing counties in the Appalachian region is being determined with respect to how well a hypothetical park built in a given county ranks in (1) its ability to satisfy the predicted recreation demand within a region bounded by a 2-hr driving time from the given county and (2) the absolute number of people within this bounded region who could be expected to visit such a park (a state-park-size facility is assumed).

A gravity model is used to predict the number of recreation participants within the given region who could be expected to travel to the hypothetical park. Gravity models are based on the concept that approximate bodies are drawn toward each other as functions of spatial distance and individual attractiveness. The recreation participation values represent both an absolute number and a percentage of the total potential recreating population. Essentially, these numbers are a function of (1) certain characteristics of the given region's population size, income and age distribution, and related socio-economic factors; (2) certain characteristics of the hypothetical park such as the total available acreage, water acreage, and shoreline miles; and (3) spatial separation between originating populations and the park, as measured by travel time. Simply, then, the number of potential visitors is a function of the recreation character of the given region's population base and a function of the accessibility and attractiveness of the park relative to other competing options.

Because the model can generate a county recreation potential ranking based on the ability to satisfy predicted regional demand for recreation, all coal counties in Appalachia can be viewed in terms of their criticality to their respective regions. If only absolute numbers of potential recreators were calculated, as is the case with most recreational models, the resulting rankings would be skewed toward those counties nearest the large urban centers. To date, the coal-bearing counties in East Tennessee have been identified and a 2-hr driving time boundary around each county has been manually calculated. The system is in the process of being automated, and when complete, its utility and feasibility will be greatly extended.

*Wildlife limitations.*³⁴ Limitations due to critical wildlife habitat areas have been shown to be identifiable in a process which employs a combination of topographic, social, and environmental variables. The method provides a reasonably accurate assessment of habitat quality in a specific geographic area prior to surface mining activity and should be able to project changes in quality both during mining and after reclamation. Figure 3.12 consists of two maps comparing the habitat before mining with that after mining and showing reclamation habitat with respect to white-tailed deer in the 1:24,000 Duncan Flats quad of East Tennessee. Further research on wildlife impacts is continuing in the Environmental Sciences Division.

*Water quality limitations.*³⁵ The first step in assessing water quality limitations to coal mining activity involves the establishment of baseline estimates of natural water quality conditions. A model can then be run to simulate the cumulative water quality impacts expected from mining the calculated reserves. Areas are thus identified where these cumulative impacts are likely to approach or exceed established standards for water quality. In the past year seven parameters of water quality have been checked in selected drainage basins in Appalachia against USGS water quality data; results have been clouded by anomalies believed to derive from groundwater seepage from underground mines. As a result, baseline estimates, to be useful, must be drawn from simulations based on natural watershed characteristics such as forest cover, geologic data, and topography.

Air resources limitations. Since air quality is an important consideration in siting coal-consuming energy facilities, we have investigated the applicability of various air quality models for measuring the spatial distribution of air pollutants. The usefulness of current models for very large regions such as the Southeast has not yet been demonstrated, although we are continuing our efforts in this regard. We are currently using Air Quality Maintenance Areas (AQMAs) designated by the Environmental Protection Agency as a surrogate measure for air quality standards. The AQMAs are regions defined by combinations of counties in which future air quality degradation will be carefully monitored by regulatory agencies; therefore, AQMAs represent areas somewhat less suitable for siting coal-using facilities. To date, the AQMAs for the southern United States have been identified and entered into our county-level information system.

Transportation limitations. Tentative agreement has been reached with the Federal Rail Administration to use its National Rail Network Model to calculate rail transport accessibility at the county level for the United States. Rail accessibility information will then be merged with existing data concerning water transportation to produce transportation accessibility measures at the county level in terms of energy facility siting constraints.

Population distribution limitations. Population density in terms of constraints to the siting of energy facilities (particularly in the case of nuclear facilities) has been mapped for the United States (Fig. 3.13). Several options in calculating site restrictions based on NRC siting regulations have been developed. Eventually, these options will be available in map form, depending on the technology being considered and the site constraint option desired.

Social-institutional limitations. The NGT panels which guided our selection of siting factors listed a number of factors relating to impact on social systems; we have pursued the quantification of these factors during the year. To date, we have adapted a generalized social impact assessment methodology for siting and have begun the task of quantifying four major areas of impact—cultural, institutional, local service, and local economic impact. This has proven to be our most difficult

34. This work was conducted by H. E. Keegan of ORNL's Environmental Sciences Division and reported in an unpublished manuscript, "Contour Strip Mining, Its Environmental Effects, and a Technique for Wildlife Habitat Assessment."

35. This work was conducted by J. R. Hyndman of ORNL's Environmental Sciences Division.

Fig. 3.12. Comparison of white-tailed deer habitat before strip mining with that after mining and reclamation for the 1:24,000 Duncan Flat quadrangle of East Tennessee. Habitat after mining is based on full reclamation.

Fig. 3.13. Population density as a function of limiting nuclear power plant siting for the United States (based on an unofficial 500 persons/sq mile density constraint).

factor model built to date, and in developing it, we are using input from the Social Impact Assessment Group. Of necessity, much of our quantification will consist of verbal descriptions created by interpreting diverse sources of information such as survey input. The local service impact measure is being developed in close cooperation with TVA, and we intend to use TVA experience as input to the construction of the model.

3.3 Development of the Oak Ridge Regional Model Information System

The geographical data system being used in the resource analysis and energy facility siting work of the Resource Analysis Group and the data input and analysis components currently being interfaced with the Oak Ridge Regional Model Information System (ORRMIS) are being developed in the Computer Sciences Division through support from the Energy Division. This work is discussed in more detail in ref. 36.

Input data, both raw (e.g., maps and aerial photography) and machine-readable (e.g., satellite and census tapes), are stored in one of several different types of data bases. Data are organized according to the most efficient method of information representation (e.g., cell and polygon data), as determined by the users, and may be retrieved for a number of different purposes. Figure 3.14 illustrates how data are stored, retrieved, and analyzed and how results are displayed in a variety of forms. The data bases may be accessed for editing, updating, transformation (e.g., interpolating from random points to a grid system), and simple display.

Each step—input, storage—retrieval, analysis, and display—represents complex processes ranging from interactive digitization systems for input to three-dimensional surface contour plots for display (Fig. 3.15). The software for performing these functions has been developed as individual generalized modules or packages because many of the routines used in one step are also used in other steps (e.g., the map projection routines are used for input data rectification as well as output map display). Due to the complexity of the data structures and the analyses or models being built, no single giant software command system has been developed to house and supervise all the individual modules. Instead, each user problem is solved by picking available modules “off the shelf” (or by developing new ones as required) and linking them in the most efficient manner to solve the user problem.

The software for the data system has been developed on a user-need basis. This approach tends to point out quickly the shortcomings and needed improvements, as well as the computer science expertise needed in each area.

Many different types of information must be manipulated by the data system. Figure 3.16 presents the major types of data and corresponding software systems that are being developed. All of these components (e.g., water availability models, site-population constraint models, and land availability models) feed into ORSAM, which in turn provides output that may be used to determine candidate areas for the siting of energy facilities.

In each step (input, storage, analysis, and display), there are about twelve major developmental efforts currently under way; the following subsections describe one example from each step.

Data input requirements: An interactive semiautomated digitization system. The purpose of an interactive semiautomated digitization system is to allow information from maps, photographs, etc.,

36. R. C. Durfee and R. G. Edwards, *Geographical Data Systems: Overview and Concepts*, ORNL/RUS-27 (to be published).

Fig. 3.14. Simplified diagram of the ORRMIS data system.

Fig. 3.15. Contour lines superimposed on topography for allocation dam area [10-m grid, 6.1-m (20-ft) contours].

Fig. 3.16. Major types of data information.

to be digitized by an operator aided by an on-line computer system (Fig. 3.17). A tremendous amount of information (e.g., on transportation systems, river systems, power transmission networks, and seismicity) is available on base maps which, when digitized in machine-readable form, may be used for sophisticated resource analyses such as determining transportation accessibility, water availability, and population distribution. The current system shown includes (1) a digitizing station for operator map input, (2) a CRT graphics terminal with a hard copy unit for local map display, (3) a "floppy" disk for local storage of digitized data, and (4) a phone line interface into the host time-sharing computer for data processing (ORNL uses a PDP-10 time-sharing system).

The basic digitization process requires an operator to move the cursor over the map features to be digitized. A continuous stream of integer x - y coordinates is sent from the tablet to the CRT terminal for display. The data may then be stored on the floppy disk or sent on to ORNL's PDP-10 computer for processing. Processing involves converting integer coordinates into latitude-longitude, checking and editing simple errors, and displaying maps onto the CRT terminal for interactive editing.

The present system is a significant improvement over previous manual data acquisition techniques, especially considering the low cost of the equipment (about \$25,000). However, because of the heavy time-sharing load on the PDP-10, the slow phone-line speed, and the inability to quickly overlay digitized data on the source map for comparison, this system is not well suited for high-volume production work. Additional equipment, including an on-line minicomputer and a video projection system, is needed to significantly improve (by a factor of 10 or more) the process, from initial data input to final corrected hard copy output. Most of the equipment is presently being purchased although a few pieces are still needed.

Much of the software developed for the system is also used in other areas of the geographical information system. For example, an algorithm to filter out x - y coordinates not needed to properly represent the curvature of a line (e.g., a highway) can be used in both data input (to reduce the number of unnecessary points) and map output as a function of map scale (to reduce plotter time).

Data base storage-retrieval: County level data base system. As mentioned previously, a number of different types of data bases are being developed and stored in data structures according to user need. For example, the U.S. Bureau of Census population data is stored as point data (population counts by enumeration district centroids), referenced by latitude-longitude; the Department of Defense topographic elevation data base (TOPOCOM) is stored in 0.4047-ha (1-acre) grid cells (elevation at centroid of each cell), referenced first by a latitude-longitude rectangle of an area and then by row and column number of each cell; and the coal seam data base is created and stored as polygonal data (boundary around coal seam outcrops), referenced by coal seam number or a latitude-longitude rectangle of the area. Although these data are stored and retrieved in various forms for general accessibility, often several data base types must be transformed into one so that variables may be simultaneously analyzed in the same coordinate system and the same data structure. For example, the population data stored by enumeration centroids must be interpolated to a grid system of cells to compute population density before it can be combined with other gridded data. When gridded population density is compared with polygonal data (e.g., polygonal county outlines), contours must be constructed from the gridded data and stored in polygonal form. Figure 3.18 shows examples of different types of data structure transformations for which software has been developed. (Some software packages are still not generalized.)

The primary purpose of this section is to briefly describe one of the data bases that is being developed for the regional power plant siting analysis. The basic storage unit for this data base is the county. A number of different variables are being collected for each county across the southern

Fig. 3.17. Interactive semiautomated digitization system.

Fig. 3.18. Geographical data structure transformations.

United States. Using a direct access file for storage and retrieval, the data area is referenced either by county FIPS code, latitude-longitude of a point within the county (e.g., county centroid), state and county name, or a latitude-longitude window (rectangle) including multiple counties. Examples of the variables include seismicity class, presence of rail lines, water flow, energy demand, barge channel depths, presence of endangered species, population accessibility, public lands, wildlife monitoring stations, and geology.

The data base actually consists of two types of files: (1) the cartographic file containing the polygonal outlines in latitude-longitude defining the county boundaries and (2) the thematic file containing the data values associated with each county. To analyze or map the data, both files will normally be accessed. For example, part of the siting process is to determine the proximity of each area in the South to future energy demand. This information allows a determination of the accessibility potential of each county in relation to the economic costs of transmitting energy to surrounding high-demand areas. In this case the cartographic file would be accessed to determine adjacency, and the thematic file would be accessed to obtain the actual energy demand values for each county.

Since the data base is being stored as a direct access file, it is possible to retrieve the county information in any order desired. Thus, the user is allowed to cross state boundaries at will during an analysis, rather than being required to process sequentially all the counties within a given state.

As new data are collected, they are converted, when possible, into a form that may be stored in the county data base. Some data, such as LANDSAT or TOPOCOM data available on a 0.4047-ha (1-acre) cell grid, are being studied to determine the feasibility of aggregating such detailed data up to the county level. At this point, there is a possibility that topographic data can be aggregated by slope classes and terrain roughness up to a county level (or at least to a 7.5-min quad level).

Analysis: TOPOCOM topographical analysis system. There are many different types of analyses that are performed in solving any one of the tasks assigned to the Resource Analysis Group. Some analyses, such as the calculation of transportation accessibility or the calculation of background air pollution over a large region, are preparatory to the actual modeling itself. Other analyses are actually part of the synergistic modeling effort, in which previous analysis results are combined simultaneously with other data variables to determine the optimal location of a power plant facility. These modeling and forecasting efforts usually require software that allows user interaction so that researchers may iteratively search for a solution subject to changing criteria. For example, economists and environmentalists would use different criteria to site a power plant.

Since several modeling analyses have already been discussed, this section will describe one of the preparatory analyses that are required to provide topographic information (e.g., slope aspect, ridge line), watershed information, and drainage pattern data. This information is useful not only in the energy facility siting and the coal reserve studies but also in assessing the environmental impact of strip mining upon water systems, an assessment which is part of the Appalachian coal study.³⁷

The basic source of information in this system is the TOPOCOM data base of elevations, digitized by the Defense Mapping Agency (DMA) from the 1:250,000 quad sheets. The DMA data base for the continental United States has been purchased by the Computer Sciences Division at ORNL. By extracting the crude contour data from the TOPOCOM tapes, rectifying it to latitude-longitude, and applying a sophisticated least-squares interpolation (using 16 neighboring data points from the

37. R. B. Honea et al., *Energy Div. Annu. Prog. Rep. Dec. 31, 1975*, ORNL-5124, pp. 125-31.

nearest two contour levels), a gridded set of elevation data can be calculated for any area in the county. From these elevations new refined contours may be mapped as shown in Fig. 3.19. The accuracy of the interpolated elevations depends on the accuracy and contour spacing of the original data, but is generally within 40 ft of true elevation.

Once gridded elevations are calculated, it is possible to calculate several important parameters useful in the resource analysis tasks: (1) slope by degrees or percent, (2) aspect in degrees from north, (3) ridge lines, (4) watershed boundaries, (5) drainage patterns, and (6) possible floodplain areas. Figure 3.20 shows the watersheds and their boundaries (green) for a complete 7.5-min quad in East Tennessee. Shown in blue are those potential streams that would drain each watershed. The red cells represent the point at which all the water leaves a particular watershed. The large blue areas that are several cells wide show areas where flooding might occur due to very flat topography.

The techniques used to compute this information are quite complex because of (1) the large number of 0.4047-ha (1-acre) cells that make up a 1:24,000 quad and (2) the desire to achieve high efficiency and low machine costs. Because of their complexity, the computer algorithms will not be described.

This type of topographical information is valuable, especially on a regional level, where digitizing costs and time prevent the collection of detailed data. The DMA digitizing and processing effort, which required a number of years to develop, represents an excellent data resource.

It is possible to combine variables such as slope, strip-mined areas, soil conditions, watershed basins, rainfall, and runoff to evaluate the effect of open strip mines on surface water.³⁸ Topography and slope are also valuable for selecting sites for power facilities and determining visibility of the cooling towers and stacks to the surrounding population.

Display: Polygon mapping system. A wide variety of software tools are being developed or are currently available to graphically display spatial data. Rather than describing each of the different plotting programs, this section describes typical output from the polygon mapping system. Figure 3.21 is a typical polygon map of the United States showing the 1975 generating capacity (in thousands of megawatts) at existing power plants by county. Each county is shaded according to generation capacity, and within each shading pattern an integer has been plotted (legible only at original scale of 1:5,000,000) showing the actual numerical capacity. Note also that the county and state polygons have been drawn and that a legend is attached. A variety of map projections (e.g., Alber's equal area) are available, and the map scale is specified by the user.

Although the map looks relatively simple, the software to create it is quite complicated. For example, each line making up a shading pattern must be intersected with the county boundary to determine starting and stopping points. The computer automatically plots the optimal location for the integers, rather than requiring the user to input the location of each integer. The state and county polygons are structured so that common boundaries, whether state or county, are plotted once. State lines can be dashes rather than solid. Aggregations of counties (such as BEA regions) could be plotted if desired. Symbols could be used instead of integers, and alphanumeric labels attached.

In summary, a wide variety of user options are available for presenting data effectively in geographical map form. The ability to perform the techniques efficiently is due to the underlying polygonal data structure used. The importance of graphical display is two-fold: (1) to present data

38. R. B. Honea et al., "Regional Scaled Methodologies for Environmental Assessment: A Case Study of Appalachian Coal Extraction," accepted for publication in *Journal of Environmental Systems*.

Fig. 3.19. Shaded contours form interpolated TOPOCOM elevation data for 7.5-min quadrangle.

Fig. 3.20. Watersheds and drainage patterns for 7.5-min quadrangle.

Fig. 3.21. Electrical generating capacity in megawatts for 1975 by county (based on FPC data).

to a viewing audience and (2) to serve as a valuable tool to researchers by revealing previously hidden relationships and suggesting new ideas and strategies to be attempted in future models and analyses.

3.4 Siting Analyses

Two applications of our resource analysis capabilities are described in the following subsections. The first involves the calculation and mapping of power plant suitability for the State of Maryland using varying technologies and constraints; the second involves an analysis of water availability to meet future energy production needs in the ORBC region.

Maryland Power Plant Siting Project. Since 1974 the Resource Analysis Group has been engaged in developing a procedure for regional and local siting analyses known as the ORNL Land Use Screening Procedure (LUSP).³⁹⁻⁴² The Maryland Power Plant Siting Project (MPPSP), in which the ORNL-LUSP was used to identify candidate areas for power plant sites in northern Maryland, was completed in October 1976. The objectives of the study were (1) to test the usefulness of the ORNL-LUSP in candidate area selection, (2) to test the applicability of the Maryland automated geographic information (MAGI) system to siting issues, (3) to examine the effects of alternative siting policies, and (4) to determine the sensitivity of the ORNL-LUSP to variations in siting criteria for different types of facilities characterized by fuel and cooling system options.

The project employs a geographic information system containing 52 variables, 27 of which were obtained from MAGI, for each 37.15-ha (91.8-acre) cell in the northern eight counties of Maryland. Each variable is characterized by discrete categories or absolute values on a continuous scale; for example, "scrub oak" is a discrete category of the variable "forest type," and "30 to 40 people per square mile" is a range of values of the continuous variable "population density."

The siting priorities and opinions of four different groups of siting specialists have been expressed as criteria matrices consisting of an importance weight⁴³ for each variable and a compatibility index⁴⁴ for each category or range of values. Twenty-two separate matrices have been applied to the data base in a cell-by-cell calculation of the form

$$S_i = \sum_{V=1}^N C_{Vi} I_V / \sum_{V=1}^N I_V \quad (2)$$

39. J. E. Dobson, *The Maryland Power Plant Siting Project: An Application of the ORNL Land Use Screening Procedure*, ORNL NUREG TM-79 (to be published).

40. J. S. Jalbert and A. D. Shepherd, *A System for Regional Analysis of Water Availability*, ORNL/NUREG/TM-82 (to be published).

41. J. S. Jalbert and J. E. Dobson, *A Cell-Based Land Use Screening Procedure for Regional Siting Analysis*, ORNL NUREG TM-80 (to be published).

42. A. H. Voelker, *Power Plant Siting: An Application of the Nominal Group Technique*, ORNL/NUREG/TM-81 (to be published).

43. This is a value from zero through ten indicating the relative importance of a given variable in the siting decision; highly important variables are assigned a value of ten.

44. This is a value from minus one through ten indicating the positive or negative contribution a specified characteristic would make to the ability of a cell to host the specified facility. Highly compatible classes of a variable may be assigned a value of ten; a minus one indicates that the cell is excluded from consideration regardless of how attractive other characteristics may appear.

where

- S_i = suitability score for cell i ,
- V = variable (e.g., land use or proximity to stream flow),
- N = total number of variables,
- C_{vi} = compatibility index for value of variable V occurring in cell i ,
- I_v = importance weight of variable V .

Clusters of cells scoring one or more standard deviations above the mean are defined as candidate areas. Figures 3.22-3.25 illustrate the spatial distribution of candidate areas in northern Maryland obtained from various criteria matrices for fossil-fired and nuclear plants. The figures indicate that it is possible to distinguish among different siting objectives and among different facilities characterized by fuel type and cooling option.

We found that considerable differences sometimes exist between the criteria matrices and the resultant distributions defined by different respondent groups. Because of the low-cost repeatability of the software, the ORNL-LUSP has been proven a useful tool for simulating the effects of various siting alternatives in candidate area selection and for identifying potential conflicts.

A major component in the success of our study was the availability of a digital geographical data base, MAGI. Without such data, development of the siting analysis capability would be impractical because of the initial costs of acquiring the geographical data base. Besides being useful in the analysis, the MAGI data base was necessary to add supplemental variables and perform additional modeling to obtain factors identified by siting specialists. One conclusion was that additional research was needed to develop procedures to rapidly construct a digital geographical data base, perhaps using ERTS, TOPOCOM, and EPA or USGS data.

The results of the MPPSP suggest that

1. The ORNL-LUSP is a useful tool for regional screening of geographic information systems even when the systems are not designed for the specific problem of power plant siting. The State of Maryland is presently implementing the ORNL-LUSP software for future use.
2. The ORNL-LUSP can serve as a means of simulating alternative siting policies to anticipate potential conflicts before they become matters of public concern.
3. Since the construction of a geographic information system is the greatest potential constraint to the development of an automated screening procedure, the data base should be designed to serve diverse uses. The shared cost can be minimized by considering the needs of potential users during system development and by including only those variables which receive high importance weights on numerous criteria matrices.
4. Siting factors must be viewed in the context of a spatial hierarchy of physical, economic, and social phenomena. Each factor should be examined at the appropriate level of spatial resolution and stored in a multiscale data base.
5. The greatest limitation to the interpretation of the candidate area maps in this study is that most siting factors are represented by raw variables rather than by indices derived from factor models.

Ohio River Basin Study. In January 1976, ANL and ORNL were requested by ERDA to assist the ORBC in determining the impacts of future energy development on water availability and quality in its region. Representatives from ANL and ORNL attended several ORBC meetings to formulate a research plan. Figure 3.26 presents the procedure to be used in our analysis.

Electricity demand figures (developed by ANL) for each state in the ORBC were provided to ORNL's Regional Economic Analysis Group for spatial disaggregation to BEAs and state portions

LEGEND

CANDIDATE AREAS

LOW & MEDIUM SCORES

Fig. 3.22. Candidate areas for a fossil-fired power plant with cooling tower in northern Maryland, 1976. Siting objective: Minimization of adverse socioeconomic impact; respondent: Maryland Power Plant Siting Program; number of variables in calculation: 27.

LEGEND

CANDIDATE AREAS

LOW & MEDIUM SCORES

Fig. 3.23, Candidate areas for a fossil-fired power plant with cooling tower in northern Maryland, 1976. Siting objective: Minimization of adverse ecologic impact; respondent: Maryland Power Plant Siting Program; number of variables in calculation: 27.

LEGEND

CANDIDATE AREAS

LOW & MEDIUM SCORES

0 25 50
KILOMETERS

Fig. 3.24. Candidate areas for a fossil-fired power plant with cooling tower in northern Maryland, 1976. Siting objective: Composite of all objectives; respondent: Maryland Power Plant Siting Program; number of variables in calculation: 27.

LEGEND

CANDIDATE AREAS

LOW & MEDIUM SCORES

Fig. 3.25. Candidate areas for a nuclear power plant with cooling tower in northern Maryland, 1976. Siting objective: Composite of all objectives; respondent: Maryland Power Plant Siting Program; number of variables in calculation: 27.

Fig. 3.26. Analysis procedure.

of BEAs (Sect. 2). Electricity demand values for the state BEA portions were converted to water consumption estimates under the assumption of a peak load situation and were mapped for the ORBC region. These values represent a worst-case situation in electricity demand. Embedded in the calculations are estimates of technology mixes by states (also provided by ANL) and estimates of water consumption (evaporation only) according to the type of power plant (with a cooling tower option). For a 1000-MW(e) plant, this translates into an average consumptive use of $0.7 \text{ m}^3/\text{sec}$ ($25 \text{ ft}^3/\text{sec}$) for nuclear and $0.5 \text{ m}^3/\text{sec}$ ($18 \text{ ft}^3/\text{sec}$) for fossil-fired plants.⁴⁵

Parallel to the peak-load analysis, calculations of low stream flow for the Ohio River and its major tributaries were developed by using the WAS model (Sect. 3.2). The values were adjusted along the main stem of the Ohio River to reflect the augmentation by reservoirs as calculated by the U.S. Army Corps of Engineers. These flows do not necessarily reflect the actual present flows along the main channel, but rather what is theoretically possible if regulation conditions are ideal and if all proposed reservoirs in the basin are constructed.

For our analysis ORBC designated that only 10% of the 7-day, 10-year low flow should be considered available for energy production. Consequently, 10% of the low flow calculated by the WAS model is shown in Fig. 3.8.

Finally, using the information on demand and water availability, members of our group employed a spatial analysis approach to allocate water to satisfy electricity demand for each forecast year (1985, 2000, and 2020). Counties in which plants would be difficult to site were eliminated from the allocation process. For example, if a county were in a seismic III risk zone⁴⁶ (which would restrict nuclear plants) and/or if EPA had designated a county as an AQMA (which would inhibit the siting of fossil-fired plants), the counties affected would be avoided in siting consideration. Only streams capable of sustaining at least one 1000-MW(e) fossil-fired plant [$0.5 \text{ m}^3/\text{sec}$ ($18 \text{ ft}^3/\text{sec}$)] were considered; reservoir construction to augment flow was not considered.

Starting with the tributaries in the Upper Ohio River Watershed (the Allegheny and Monongehela Rivers), we allocated water to surrounding demand centers (the centers of each state BEA portion), using four different power transmission constraints. The ORBC requested that we examine the possibility of satisfying surrounding demand out to 80.5 (50), 160 (100), 240 (150), and 320 km (200 miles) from the main stem and major tributaries.

Table 3.2 is a sample of the running account system used to keep track of water allocated to satisfy demand. No allocation was made if (1) the running account of available water (base water minus the running total of water consumed) was not sufficient to satisfy the consumptive needs of one plant (of at least $0.5 \text{ m}^3/\text{sec}$); (2) the county was excluded from consideration because of seismicity or air quality; or (3) all demand within the transmission distance (i.e., 80.5, 160, 240, or 320 km) was previously satisfied. When available water dropped below the minimum amount needed or when all the surrounding demand areas could not be satisfied, areas were identified as unsatisfied and the corresponding counties on the tributaries were designated as problem areas. Figure 3.27 indicates those counties that, on the basis of our analysis, may experience water availability problems during low flow, assuming that the generating capacity proposed to be on line in 1985 is built and the ORBC adheres to an allocation of 10% of low flow for energy generation.

45. The consumptive rates for various types of power plants were calculated by Garland Samuels of ORNL; see Garland Samuels, *Assessment of Water Resources for Nuclear Energy Centers*, ORNL-5097 (September 1976).

46. Seismic risk is defined according to NRC as an area for which "costs and time" make it impractical to consider siting a nuclear plant.

Table 3.2. Water allocation—m³/sec (ft³/sec)—using running account system to satisfy 1985 demand, 50-mile radius of county, Ohio River

River ^a and county	Base water	Water available	Water allocated	Running total of consumed amount	By state BEA	
					Portion served	Amount used
Allegheny and Monongahela Rivers			2.66 (93.81)	2.66 (93.81)		
Allegheny (AQMA and population) ^b	15.80 (558)	13.15 (464.19)	0	2.66 (93.81)		
Beaver (AQMA and population) ^b	16.71 (590)	13.77 (486.19)	0	2.66 (93.81)		
Columbiana	16.99 (600)	14.34 (506.19)	4.72 (166.66)	7.38 (260.47)	PA-66	4.34 (153.35)
Jefferson	17.28 (610)	9.90 (349.53)	0	7.38 (260.47)	PA-67	0.38 (13.31)
Belmont	18.41 (650)	11.03 (389.53)	0	7.38 (260.47)		
Mcroe	18.97 (670)	11.60 (409.53)	0.14 (4.9)	7.52 (265.37)	WV-64	0.14 (4.9)
Washington	19.54 (690)	12.16 (429.53)	0	7.52 (265.37)		
Muskingum River			0	7.52 (265.37)		
Washington	21.30 (752)	13.78 (486.63)	0	7.52 (265.37)		
Athens	21.49 (759)	13.98 (493.67)	0	7.52 (265.37)		
Meigs	22.09 (780)	14.57 (514.63)	0.21 (7.4)	7.72 (272.77)	OH-52	0.21 (7.4)

^aNote that each tributary is kept on a separate sheet.

^bReason for excluding county.

WATER AVAILABILITY PROBLEMS WILL BE CREATED WITH

> 1985 CAP + 1000 MW
 1985 CAP + 1000 MW
 1985 CAP + 500 MW
 PROPOSED 1985 CAP

Fig. 3.27. Unsatisfied demand for 1985 for ORBC region using 80-km (50-mile) transmission constraint.

Several caveats should be attached to this analysis. First, peak-load demand coinciding with a low water flow situation does not occur often or even uniformly over the entire area considered in the analysis. Also, it is our opinion that it would be more realistic to perform the ORBC analysis using a worst-week peak electricity demand and a worst-week water flow situation instead of a worst-day situation. This analysis is now being performed.

On the other hand, our analysis used water consumption figures easily achieved by present technology; even with a 20% error, the water availability situation will progressively worsen. Countermeasures such as better reservoir regulation, more reservoir construction (an increasingly less feasible option), or more water conservation are indicated. It would appear that the "free lunch," as far as water is concerned, is about over in the eastern United States.

4. SOCIAL IMPACT ANALYSIS

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4.1 Approach to Community Assessment

Our approach to social impact analysis is a pragmatic one, combining applied research with direct applications in licensing or regulatory procedures for the NRC and ERDA. Both our research and applications functions derive from the new requirements and policy directions specified in the National Environmental Policy Act of 1969. Sections 1A, 1B, and 1D of Title 1, Section 102, require that we "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences . . . in decision making . . ." (1A); "identify and develop methods and procedures . . . which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decision making along with economic and technical considerations" (1B); and "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves *unresolved conflicts* concerning alternative uses of available resources" (1D).

Our two applied research projects seek to develop both qualitative and quantitative knowledge at different levels of analysis. These two projects are the ERDA-DTO work on social effects of alternative energy generating technologies and the NRC postlicensing studies of effects on host communities of operating nuclear power reactors. Work is now in progress at the individual, group, and community levels, and efforts are under way to identify and analyze variables for regional social impact assessment. A third project is applications work, which this year has involved preparation and review of environmental impact statements with the Environmental Impact Section. A major expansion of our applications effort occurred this year as a result of formalizing our previously ad hoc participation in

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NRC impact statements. In addition to nuclear plant assessments, we are involved in assessments of two operating coal-fired generating plants in the Ohio River basin (Clifty Creek and Kyger) as part of the Portsmouth project and assessments of proposed demonstration plants for ERDA-FE.

The dual goals of the group are (1) to develop a broad understanding of the social effects of large energy facilities through practical, exploratory work in which we ask questions in a variety of settings, develop an inclusive list of variables, and specify their relationships and (2) to advance the state of the art by developing methodological tools in our research projects that will lead to continuing improvements in direct applications.

A major focus is the siting of large energy facilities. We approach the problem on many different levels—individual, group, community, and regional—to identify for each level (1) characteristics of acceptable sites and (2) courses of action that minimize adverse social impacts. Mitigation of, or compensation for, externalized social costs at facility sites is a continuing interest and is being developed further in comparisons of mitigation plans at four facility sites (three nuclear and one coal). A principal goal of the NRC studies is to develop siting guidelines for minimizing adverse social impacts.

The Social Impact Assessment Group is also developing the capability for comparing the social impacts of alternative fuels at each stage of the fuel cycle, beginning with generating facilities. To date, the emphasis has been on the nuclear fuel cycle; work on both preconstruction and postconstruction effects of nuclear generating facilities is in progress. Case studies of Plymouth and Waterford (NRC) examine construction and operating effects; the Hartsville project (DTO) examines preconstruction effects. Through the ERDA-DTO work, the group will be broadening its approach by looking at the coal fuel cycle, beginning with coal generation plants and undertaking parts of the National Coal Utilization Assessment for the southern region.

Much of the research and applications expertise developed by the Social Impacts Analysis Group has been used by the Socio-political Resource Group, Risk-Impact Panel, Committee on Nuclear and Alternative Energy Systems (CONAES), National Research Council. Elizabeth Peelle is a member of the Resource Group and has drafted the community impact and response sections of the CONAES report.

4.2 Social Assessment Research

Postlicensing case studies. Under a grant from the NRC Office of Regulatory Research, the Social Impact Assessment Group completed its first postlicensing case study of two nuclear power plant host communities—Plymouth, Massachusetts, and Waterford, Connecticut. The purpose of this comparative assessment was to analyze the social, economic, and political impacts associated with the construction and early operation of these plants. As the first of its kind, this study provided a unique opportunity to verify the range of impacts that occurred in the two host communities, in contrast to impact statements, which forecast expected impacts. Comparisons and characteristics of the two communities and reactors, along with additional information about the study, were given in last year's report.⁵¹

Various primary and secondary data were collected and analyzed during the study. These data included open-ended interviews, local and state records, census data, and attitude surveys. Within each community, about 35 open-ended interviews were conducted with local officials, utility personnel, and

51. Elizabeth Peelle et al., *Energy Div. Annu. Prog. Rep. Dec. 31, 1975*, ORNL-5124, pp. 132-45.

concerned citizens. In addition, information on the particular nuclear plant, community socioeconomic and political characteristics, and regional demographic and economic trends was also used. Finally, attitude surveys were taken in both communities to determine citizens' (1) attitudes toward the plants and plant effects, (2) satisfaction with their community, and (3) perceptions of the future of their community.⁵²

A social impact assessment model (Fig. 4.1) was developed to classify the data for analysis and to structure observed empirical relationships. This conceptual model⁵³ has three distinct components—inputs, community structure, and impacts. Inputs are defined as those factors introduced into a host community solely as a result of siting a nuclear plant there; that is, they would not exist without the plant. Four such factors are distinguishable: (1) facility characteristics, (2) the licensing and regulatory process, (3) generated revenue, and (4) human resources. Although all these factors are present when siting any nuclear power plant, the relative importance of each varies from case to case.

Facility characteristics refer to the physical plant, the land it occupies, its transmission lines and corridors, cooling system, discharge canals, and ancillary facilities (e.g., a visitor's center). Typically, these characteristics will have some effect on the land use patterns, aesthetic appearance, and natural and human ecology of a host community and the surrounding area. Our assessment of Plymouth and Waterford, however, indicated that this input was of minor significance in these two cases.

Similarly, we did not devote special attention to the second input category, the licensing and regulatory process, which includes all the legal requirements, procedures, and related nonformal activities associated with licensing a nuclear plant. Foremost among these activities are the preparation of an environmental report by the utility, preparation of an environmental impact statement and a safety and radiological analysis by the NRC, and licensing hearings before the Atomic Safety and Licensing Board.⁵⁴ The licensing and regulatory process provides the framework within which supporters and opponents of a nuclear plant have the opportunity to argue their competing claims. In both Plymouth and Waterford, this process was essentially routine and did not prove to be significant in explaining the impacts that occurred.

The last two inputs—generated revenue and human resources—were significant and occupied the bulk of our attention. Generated revenue refers to the direct and indirect flow of money into the host community as a result of siting a plant there—property taxes on the plant,⁵⁵ local plant-related purchases of goods and services, and growth in employment. In both Plymouth and Waterford, the key economic impact was the enhancement of the community's tax base.

Human resources refer to the in-migrating and commuting populations associated with construction and operation of the plant. The relative proportions of commuters and in-migrants are crucial in determining the type and degree of impacts which a host community experiences. Since both Plymouth and Waterford were located within sizable labor markets, there were very few in-migrants, but substantial numbers of commuting workers.

The second component of the model, community structure, refers to the social, economic, and political structure and service capacity of the host community. Changes in these variables constitute the

52. The questionnaire used in the attitude survey was adapted from C. R. Schuller et al., *Citizens' Views on the Proposed Hartsville Nuclear Power Plant: A Preliminary Report of Potential Social Impacts*, ORNL/RUS-3 (May 1975).

53. Note that this is not a mathematical model, but entirely a conceptual model useful for organizing and classifying data and relationships. The relationships between inputs, community structure, and impacts have not been quantified.

54. Steven Ebbins and Raphael Kasper, *Citizen Groups and the Nuclear Power Controversy*, MIT Press, Cambridge, Mass., 1974.

55. Or, in the case of publicly owned utilities, in-lieu-of-tax payments.

Fig. 4.1. Social impact assessment model.

impacts of the plant and arise from the interaction between the inputs and community structure. We distinguish primary and secondary impacts according to their temporal sequence: thus, a primary impact such as an increased property tax base may lead to a lowering of the existing tax rate, a secondary impact. In this way, impacts may "feed back" on community structure to produce other impacts; hence, the model includes a feedback "loop."

Findings. Construction phase impacts in both Plymouth and Waterford were minor. The only impact of any magnitude identified retrospectively was construction worker traffic. Most workers commuted to the sites from homes in the metropolitan areas, rather than relocating nearer the sites or moving to the host communities. This pattern appears to be typical of "nonremote" sites (i.e., those located within a major labor market). There was little interaction between construction workers and local residents, except for incidental contact in bars, grocery stores, restaurants, and other places of business. Thus, although some construction worker dollars were spent in the host communities, neither plant stimulated significant local commercial activity during construction.

In both Plymouth and Waterford, it is clear that the major impact has been the enormous increases in their tax bases provided by the operating reactors. By 1975 this amounted to about 50% of Plymouth's property tax base and 60% of Waterford's. Both communities have consequently chosen to lower or stabilize existing property tax rates and invest the additional revenue in new public services and facilities. This additional income has enabled the communities to further professionalize public services by hiring new staff and creating new positions in the local government. Both communities created new departments of public works, and town planners have been hired to develop more detailed comprehensive plans.

The relationships of the host communities to neighboring communities have also been affected by the presence of the plants, principally because of the augmented tax base. Neighboring towns have, to varying degrees, resented the favorable tax situations of the two host communities. Efforts have been initiated in both states to redistribute utility tax payments so that a larger proportion will go to other jurisdictions and/or to the states. This sense of distributive injustice has been exacerbated by the transportation of reactor wastes through neighboring communities, a matter now under legal challenge.

The sudden population growth that has occurred in Plymouth since 1968 (the start of plant construction) has been further stimulated by the favorable property tax rate made possible by the plant. Regional growth rates were also increasing at the same time, and Plymouth would certainly have experienced population increases if the plant had not been built. However, it appears that the favorable tax rate in Plymouth made the community a more attractive place to live, a judgment supported by building contractors, citizens, and officials. Waterford, on the other hand, had a history of effective zoning ordinances prior to plant construction which appear to have prevented significant increases in its rate of population growth. Town officials, however, have felt pressure from some local residents to rezone to encourage more rapid growth by making land and housing available to the less affluent.

Finally, attitude surveys and interviews with local officials indicate high levels of support for the nuclear plants in both communities. There were few intervenors in either community; residents expressed little concern over potential environmental and safety hazards; and relations between the communities and utilities are considered mutually beneficial. In view of the substantial economic benefits to both the utilities and the communities, this conclusion comes as no surprise.

The conclusions of the study are based on just 2 of the 61 communities presently (1976) hosting nuclear reactors. There are no comparable published data on these other cases which would enable us to make valid comparisons. These constraints severely restrict the generalizability of this study to other cases.

Nevertheless, we can attempt to place the particular impacts and responses of these two communities in some perspective with the following observations. By cross-classifying the two key input variables (incoming people and generated tax revenues) in a two-by-two table, we see that Plymouth and Waterford fall in cell 2, where generated tax revenues are high and the number of incoming people is low.

		Amount of tax revenue	
		Low	High
Number of incoming people	Low	1	2
	High	3	4

As seen in this study, one result of this input mix of high benefits and low costs, or low amount of disturbance, is a relatively high rate of public acceptance. We expect that no other input combination will produce similar levels of public acceptance since in no other case is the relative benefit-cost ratio as favorable. In cell 1, both are low; in cell 3, benefits are low and costs are high; and in cell 4, both are high. The types of impacts, as well as their magnitudes, vary from cell to cell. We also suspect that local levels of support would vary too, primarily as a function of perceived benefits and costs. Communities falling

into cell 3 are prime candidates for mitigation plans which attempt to alter an unfavorable benefit-cost ratio.

A final report on the Plymouth-Waterford study will be issued early in 1977.

Hartsville II. As part of our plan to approach community impact analysis on different levels and with different research designs, the longitudinal Hartsville case study, which began during the planning stage prior to licensing, examines community effects throughout the life cycle of the nuclear facility.

TVA's four-unit Hartsville nuclear power plant is presently under construction near Dixon Springs and Hartsville, Tennessee. Two surveys have been administered and analyzed. The first (Hartsville I) was administered in January 1975 before any work had begun at the site.⁵¹ The second survey (Hartsville II) was administered in August 1975 immediately before limited hearings opened on the final environmental statement (FES). Since a limited work authorization was not granted until April 1976, the first two surveys will serve as an extended benchmark against which future comparisons can be measured.

This year's Hartsville effort focused primarily on the analysis and evaluation of the second Hartsville survey and on comparison of changes between the first and second surveys. The two attitude surveys are part of a continuing multifaceted assessment, funded by ERDA-DTO, of community impacts on energy-related facilities. To date, major emphasis has been placed on attitude research, correlates of support and opposition, and expectations regarding the facility.

The first two surveys asked two major questions: (1) What are the correlates of support and opposition to the nuclear power plant? and (2) How do residents perceive the quality of their lives? Respondents to the Hartsville I survey were reinterviewed for Hartsville II. Of the original 350 respondents, 288 (88%) participated in the Hartsville II survey. This "panel" of 288 respondents was used in comparative analysis of the two surveys. The questionnaire was composed of items which provided information on (1) background characteristics of respondents; (2) measures of perceived quality of life; (3) information level regarding the facility; (4) expectations of changes in the community, including estimates of the likelihood and desirability of events; and (5) support or opposition to the plant.

Support and opposition. A comparison of the level of support and opposition in the two surveys is presented in Table 4.1. Both support and opposition rose slightly in the August survey when "don't know" was not an option: 68% supported the nuclear plant, and 31% opposed it. These responses may be compared with the Harris survey⁵⁶ of a national sample in March 1975, in which 63% supported nuclear plant construction, 19% opposed it, and 18% were not sure (see Table 4.1). The proportions remain very similar for three nuclear communities surveyed by Harris, with a slight increase to 23% in those opposed. These results are in general agreement with those from six nuclear referenda held in the fall of 1976 on somewhat different issues, in which the ratio of support to opposition was about 2 to 1.

Looking closer at the levels of support and opposition in Table 4.2, one can compare the answers of specific categories of supporters and opposers from one survey to the next. As can be seen in the diagonal, almost 60% of the panel, 163 individuals, gave the same response in both surveys. Excluding the "no response-don't know" category, we found that almost the exact proportions of support and opposition held in both surveys: 70% indicated some level of support in Hartsville I compared with 69% in Hartsville II; the opposition proportions for the two surveys were 30 and 31% respectively.

56. Louis Harris and Associates, Inc., *A Survey of Public and Leadership Attitudes Toward Nuclear Power Development in the United States*, conducted for Ebasco Services, Inc., New York, August 1975.

Table 4.1. Support and opposition (%)
to nuclear power plant construction

Survey	Support	Oppose	Not sure
Harris survey^a			
National sample	63	19	18
Composite of three nuclear communities	63	23	14
Hartsville panel sample^b			
Hartsville I (January 1975)	59	26	15
Hartsville II (August 1975) ^c	68	31	1

^aLouis Harris and Associates, Inc., *A Survey of Public and Leadership Attitudes Toward Nuclear Power Development in the United States*, conducted for Ebasco Services, Inc., New York, August 1975, pp. 76-102.

^bSample included 288 respondents.

^cForced choice.

Table 4.2. Analysis of responses to Hartsville II survey question: "If it were
up to you, would you permit construction of the TVA Power Plant near Hartsville?"

Response in January	Response in August					Percent of responses in January (N = 288) ^a
	"Definitely yes" (N = 109)	"Probably yes" (N = 87)	No answer (N = 3)	"Probably no" (N = 37)	"Definitely no" (N = 52)	
"Definitely yes" (N = 116)	85 ^b	25	0	4	2	40
"Probably yes" (N = 55)	15	30	0	7	3	19
"Don't know" or no answer ^c (N = 42)	8	22	2	6	4	15
Probably no" (N = 26)	0	4	1	12	9	9
Definitely no" (N = 49)	1	6	0	8	34	17
Percent of responses in August (N = 288) ^a	38	30	1	13	18	100

^aN = 288 (i.e., the panel of respondents who answered both the January and August surveys).

^bNumbers in italics refer to respondents whose response was the same in January and August. The total was 163, or 57% of the 288 members of the panel.

^cThe "don't know" alternative appeared only in January; 12 respondents declined to answer in January.

Coal vs nuclear. One additional item that was asked only in the second survey dealt with respondents' preference for coal vs nuclear plants. It was hypothesized that opposition to nuclear power may stem from an opposition to high-technology projects in general. Respondents were asked, "Suppose that the power plant proposed for Hartsville was going to burn coal instead of using nuclear fuel. If it were up to you, would you permit construction of this type of plant?" Results of this item are presented in Table 4.3. The largest proportion of the sample, 107 individuals (38%), would support both types of plants. Only 43 individuals (15%) are opposed to both types of plants. It is interesting to note, however, that the general level of opposition to each plant separately is almost equal (31% for nuclear vs 30% for coal). It may be that a small minority of citizens are opposed to any kind of energy development, but that enough others are opposed to specific technologies that total opposition becomes a substantial minority in any community. This interesting component of energy development opposition will be further explored in subsequent reports.

Expected events. Respondents were asked to rate the likelihood of a list of possible events ranging from "traffic congestion" to "air pollution" to "more jobs." These likelihood estimates were analyzed to ascertain commonalities among items. A factor analysis produced five factors in each survey. Although seven individual items were slightly different across surveys (20 were exactly the same), the individual dimensions represented by the factors were very similar. Likelihood groups (factors) are presented in Table 4.4 in decreasing order of explained variance.

Although the underlying dimensions of the factors did not change significantly, the order of importance of the factors has changed. Most strikingly, the social disruption factor has shifted from fourth to first between the surveys. Since these changes may be artifacts of the data (number of items in each factor, for example), further exploration into the reasons for these shifts is continuing.

Demographics. The demographic characteristics of supporters and opponents of the Hartsville plant were very similar in both surveys. Support for the plant was strongest among business and labor occupations and less pronounced among housewives. In both surveys, the only occupational group in which a majority opposed the construction was farmers. Women tended to oppose the plant more than men in both surveys. In the second survey, some evidence indicated that support for the plant increased as the respondent's place of residence became more urban.⁵⁷

Community satisfaction. Satisfaction with the quality of services available in Hartsville was a common theme in both surveys. Results are presented in Table 4.5. Scale scores ranged from 1.0 (very

57. E. D. Sundstrom et al., *Citizens' Views about the Proposed Hartsville Nuclear Power Plant: A Survey of Residents' Perceptions in August 1975*, ORNL/TM-5801 (1977), p. 42.

Table 4.3. Support of nuclear plant vs support of coal plant

Support nuclear plant	Support coal			Total	
	Yes	Don't know	No	Number	Percent
Yes	107	45	43	195	69
No	29	16	43	88	31
Total					
Number	136	61	86	283	100
Percent	48	22	30		

Table 4.4. Likelihood estimate factors

Hartsville I ^a	Hartsville II ^b
Hazards	Disruptive effects of population growth
Economic growth	Hazards to safety and environment
Community stability; lower costs	Increased business and new facilities
Social disruptions	Attention from outside the area
Community recognition	Economic benefits of growth

^aThe questionnaire used in the attitude survey was adapted from C. R. Schuller et al., *Citizens' Views on the Proposed Hartsville Nuclear Power Plant: A Preliminary Report of Potential Social Impacts*, ORNL/RUS-3 (May 1975).

^bE. D. Sundstrom et al., *Citizens' Views about the Proposed Hartsville Nuclear Power Plant: A Survey of Residents' Perceptions in August 1975*, ORNL/TM-5801 (1977).

Table 4.5. Satisfaction with local services in Hartsville, Tennessee, 1975

Type of service	Mean rating of satisfaction ^a		Correlation of January with August ^b	T-test of difference	Number of respondents
	January	August			
Public schools	2.4	2.4	0.51	0.88	275
Streets and highways	2.0	2.1	0.38	0.44	286
Police protection	2.5	2.4	0.42	0.69	280
Fire protection	2.2	2.2	0.45	0.14	275
Telephone service	2.1	2.1	0.53	0.15	284
Sewage treatment	2.6	2.6	0.47	0.13	227
Water supply	2.3	2.2	0.37	1.76	265
Zoning laws	2.8	2.8	0.35	0.88	230
Garbage pickup	2.4	2.4	0.29	0.17	239
Housing availability ^c	3.4	3.3	0.46	2.87 ^b	280
Medical care	2.6	2.5	0.41	1.44	279

^aVery satisfied = 1.0, satisfied = 2.0, not sure = 3.0, dissatisfied = 4.0, very dissatisfied = 5.0.

^b $p < 0.01$.

^cThree-digit values are 3.43 and 3.25.

Source: E. D. Sundstrom et al., *Citizens' Views about the Proposed Hartsville Nuclear Power Plant: A Survey of Residents' Perceptions in August 1975*, ORNL/TM-5801 (1977).

satisfied) to 5.0 (very dissatisfied). As can be seen from the table, Hartsville residents were generally satisfied with services, and their level of satisfaction did not change appreciably between the two surveys. Only one item showed any significant change. In the second survey, respondents were slightly less satisfied with the availability of housing. A second measure of satisfaction dealt with individuals' neighborhoods. For both surveys, respondents were asked to rate their neighborhoods on a series of seven-point semantic differential scales. Results reported in Table 4.6 show that in the first survey the respondents tended to describe their neighborhoods as private, stable, uncrowded, pleasant, quiet, safe, and pretty. The same people evaluated their neighborhoods as somewhat more noisy, crowded, unpleasant, and changing in the second survey. The number of building permits granted in Hartsville almost doubled between 1974 and 1975 and appears to have doubled again between 1975 and the present.

Summary. Comparison of the two surveys revealed some shifts in individuals' perceptions of the quality of their lives and in the expected likelihood of certain events associated with the plant. Most significantly, however, there has been virtually no change in the proportion of individuals voicing an opinion either in support of or against construction of the facility. It should be noted that no construction had begun at the time of either survey. Further examination of the interests reflected in these surveys must be extended to construction and operation phases, together with an appropriate behavior monitoring program. The evolution of attitudes and community support and opposition will be followed by future surveys, the next of which is scheduled for a few years from now during the peak of construction activity.

Table 4.6. Ratings of characteristics of neighborhoods^a in Hartsville, Tennessee, 1975

Characteristic	Mean rating		Correlation of January with August ^b	T-test of difference	Number of respondents
	January	August			
Private vs not private ^c		2.7			288
Changing vs stable	6.0	5.0	0.20	6.94 ^b	286
People similar to me vs people dissimilar to me	2.3	2.5	0.34	1.32	283
Crowded vs uncrowded	5.9	5.5	0.36	2.70 ^b	282
Close-knit vs not close-knit	3.5	3.6	0.31	0.14	278
Unsafe vs safe ^c		3.8			288
Unpleasant vs pleasant	6.5	6.1	0.23	4.63 ^b	284
Wealthy vs poor ^c		4.0			286
Noisy vs quiet	5.7	5.3	0.46	3.72 ^b	287
Pretty vs ugly ^d	2.5	2.5	0.35	0.73	286

^a Respondents were asked to make rankings on a seven-unit continuum for each pair of attributes. A score of 1.0 was given for the first member of the pair, and 7.0 for the opposite member. Responses in between were assigned appropriate intermediate scores.

^b $p < 0.01$.

^c Asked in August only.

^d Asked in January as attractive vs unattractive.

Source: E. D. Sundstrom et al., *Citizens' Views about the Proposed Hartsville Nuclear Power Plant: A Survey of Residents' Perceptions in August 1975*, ORNL/TM-5801 (1977).

Hartsville III research plan. A detailed research plan was developed for our Hartsville III work. Two significant departures from previous work are the inclusion of a parallel coal host community (Coaltown), now in final site selection stage, and a shift in focus for both communities from the attitude component to examination of community response and adaptation to perceived or real impacts resulting from the planning, construction, and operation of the particular generating facility.

Figure 4.2 presents the time-series quasi-experimental design for the study as it is currently under way. Inclusion of a coal host community brings us closer to the overall goal of the group—the capability to generalize about impacts across technologies and across stages of the fuel cycle. By adding a coal-fired generating plant to the study, we will be able to (1) examine social and economic impacts common to both technologies and (2) determine those impacts that appear to be unique to the facilities. The second departure—examining local responses to facilities—will be undertaken through a series of interrelated tasks which will establish the linkages between the licensing process, local policy responses, and changes in characteristics of the community (or changes in the relationships of those characteristics). As with the attitude component, the major research innovation of this study will remain the time-series nature of the analysis and the following impacts and responses throughout the life cycle of the facility.

Figure 4.3 lists seven areas of interest that will be examined for each community. They represent a convenient, if artificial, separation of specific tasks and indicate the types of data to be considered.

Generally, however, most of the tasks can be subsumed under two analytical categories: (1) policy formation and implementation and (2) social indicators. Work with social indicators will involve monitoring those areas anticipated to change as a result of the facilities and those areas which local administrators are particularly concerned with (as reflected in local policy decisions) and some general monitoring to pick up any unexpected impacts. Table 4.7 lists some possible indicators which may be used, as well as the general categories of indicators currently being considered. Subsequent refinements of this list will depend on data availability and the nature of the local decisions under consideration.

Policy formation and implementation will be considered under two general conditions. First will be those licensing and siting policy decisions that may affect the type and magnitude of impacts upon a community. Such licensing and design decisions can alter the sequence in which new people or direct financial benefits are introduced into the community. Concomitant with these decisions are those which

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COALTOWN – HARTSVILLE DESIGN															
	BASELINE	PRECONSTRUCTION				CONSTRUCTION				OPERATION					
	T ₀	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	T ₁₁	T ₁₂		
1. ATTITUDE SURVEY		0			0	CONSTRUCTION APPROVAL	0		0	OPERATING APPROVAL	0		0		
2. ECONOMIC DEMOGRAPHIC	0	0	0	0	0		0	0	0		0	0	0	0	
3. INSTITUTIONAL CONSTRAINTS		0			0		0		0		0		0		
4. SOCIAL/POLITICAL	0	0			0		0	0	0		0	0	0	0	
5. LABOR FORCE/HOUSING/SERVICES	0	0	0	0	0		0	0	0		0	0		0	
6. LICENSING/PERMITS		0		0	0		0		0		0	0		0	
7. MITIGATION		0			0		0	0	0		0	0	0	0	0
0 = OBSERVATION															

Fig. 4.2. Coaltown-Hartsville design.

Table 4.7. Some social indicator data for time-series analysis

Demographic characteristics
Age, sex, race distribution
Urbanization
Population density
Economic characteristics
Occupational distribution
Unemployment rates
Median family income
Retail and service receipts
Governmental revenues
Cost of living
Social structure
Voluntary organizations
Socioeconomic status distribution
Public services
Education: student-teacher ratio; per capita expenditure
Health-care delivery
Fire, police, sanitation
Social, counseling
Social-mental health
Alcoholism
Delinquency, suicide
Divorce, single-parent households
Crime statistics
Poverty levels
Attitudes and values
Population at large: satisfaction, support-oppose
Decision makers: expectations, efficacy
Governmental performance
Size, professionalization
Planning bodies, etc.
Voting: local issues, elections
Budgets: allocations
Activities: licensing, regulation
Federal money as percent of total revenue

affect the responsibility of the utility in mitigating perceived adverse impacts resulting from the introduction of the facility. This second category of policy decisions involves community-level responses to social impacts. These decisions may be made in response to real changes in the social and economic environment, or they can be made in anticipation of impacts. Policies may be designed to encourage growth or minimize changes. These types of responses will be examined in relation to the real changes in community social indicators to determine the effectiveness of policies in dealing with social impacts at the local level.

Social impact analysis model. The preceding description of proposed work presupposes an implicit model for the organization of data and the development of testable hypotheses. Work on the development of a social impact model has been continuing within the group over a period of two years. We use alternative models representing the same basic assumptions, but differing in application and in the emphasis put upon some of the elements according to the needs of specific studies. As shown earlier in Fig. 4.2 (Sect. 4.2), we are working toward a systems approach, as reflected in the input-output

nature of the model used in the postlicensing studies. The current model, which is being used in the Hartsville III project, is presented in Fig. 4.3.

Here the inputs, community context, and outputs are similar to the model presented earlier. However, since Hartsville III will concentrate on the relationship among policy decisions, the facility, and social changes, we have added two additional stages. First, extracommunity siting policy outputs are considered. Early consideration of these policy outputs is very important since they directly affect the rate at which human resources and revenues are introduced into the community. Additionally, siting policy outputs resulting from interactions between the utility and the licensing agency may result in enforced mitigation responsibilities for the utility, which in turn may have an important effect upon the magnitude and direction of impacts. Finally, we have introduced community management strategies (policies) as an intervening characteristic because the selection and implementation of particular strategies serve to modify intracommunity relationships.

Economic impacts analysis. To complement the community level fiscal impacts work done in our postlicensing studies, we are approaching economic impacts from a different angle and stage of the facility life cycle in our Hartsville project. We are beginning a major emphasis on measuring the magnitude and spatial distribution of economic impacts associated with energy facility construction. Toward that end, we have begun analysis at three spatial levels—a construction site (county), an impact region (multicounty area), and a national grid. At the site level, we are constructing a data and analysis book to record the socioeconomic impacts associated with the Hartsville, Tennessee, nuclear power plant. Objectives of the data book are to establish baselines for modeling and monitoring as many socioeconomic dimensions as possible at the site level. To date, we have completed a preliminary analysis of baselines in the retail trade and services sectors for Trousdale County, the location of Hartsville.

At the national and regional levels we have started complementary activities aimed at monitoring the macroimpacts of energy facility construction. Regional science techniques of input-output analysis, multiplier analysis, economic modeling, and spatial analysis are being employed to establish a framework for identifying (1) the level and range of socioeconomic impacts by industrial category, (2) regional and multiregional specific impacts by industry, and (3) relative spatial effects from alternative

Fig. 4.3. Social impact assessment model for local decision making.

site selection. Regional differences by industry are being measured through a procedure that may be termed a "homogeneous group-average requirements technique," in which regions are classified with respect to export or import orientation by two-digit SIC. Such measures will provide (1) a base for allocating macroeconomic impacts to internal and external destinations and (2) a background for measuring regional growth change stimulated by new construction activity.

Hartsville data analysis book: Retail trade baseline. The beginning of our analysis at the construction-site (county) level is represented by the socioeconomic data analysis book. The Hartsville impact area includes a contiguous five-county area surrounding Hartsville, Tennessee, which is located in Trousdale County, northeast of the Nashville-Davidson metropolitan area. To establish a baseline retail activity, we estimated a retail trade model. On the basis of previous experience,⁵⁸ we knew that a significant correlation exists between retail service receipts (hereafter referred to as retail receipts) and county levels of population, income, and urban orientation; in fact, these variables explain most of the observed variation in retail receipts at the county level. We have also observed that, with few exceptions, counties tend to remain in relatively constant economic position with respect to these variables. In other words, growth through time in levels of these variables is fairly uniform across all counties.⁵⁸ Using this information, we developed a projections model based on relative county positions instead of directly on socioeconomic variables. This change has greatly simplified the information needed to project baseline retail receipts for impact evaluations. Instead of requiring estimates of population, urbanization, income, and other influential variables, we can now project on the basis of relative economic position.

We first analyzed the socioeconomic characteristics of the 95 counties in Tennessee in each census year since 1950. Cluster analysis⁵⁹ revealed four main groups of counties having significantly different levels of population, urbanization, income, number of families, and number of families with income below poverty level. Through simple statistical comparisons, we determined that retail employment was significantly different among the four groups. This was an important finding, for it supported our suspicion that retail activity depends on county size as determined by the level of the economic variables (i.e., population, income, number of families, and urbanization).

To establish a baseline projection for each county in the Hartsville impact area, we first determined the cluster group membership of each impacted county. Three impact counties (Trousdale, Macon, and Smith), as well as some other Tennessee counties form group IV; Sumner and Wilson, along with some other counties, make up group II. In all cases the groupings were exclusive and exhaustive of the sample. Our baseline estimate of retail receipts per capita for each impact county is the group estimate of the unique group in which the county is a member. Thus, the first three counties have the same level of estimated and projected retail receipts since they are members of the same group. Retail receipts level by group was calculated with the estimated model:

$$\hat{RS} = 0.2697 + 1.0020 \text{ GI} + 0.5948 \text{ GII} + 0.3203 \text{ GIII} + 0.1705 T, \quad (3)$$

(7.85) (16.68) (16.57) (12.30) (12.46)

$$\bar{R}^2 = 0.6926, \quad Se = 0.1974, \quad F(4280) = 161, \quad DW = 1.82,$$

58. C. R. Kerley, *A Model of Functional Area Retail Trade Receipts*, paper presented at the Western Regional Science Meeting, San Diego, Calif., Feb. 27-29, 1976.

59. A. J. Barr et al. *A User's Guide to SAS 76*, SAS Institute Inc., Raleigh, N.C., 1976.

where

$\hat{RS}$ = estimated retail receipts (millions of dollars per 1000 population),

G_I = group I = 1.0 if group I,
= 0 if not group I,

G_{II} = group II = 1.0 if group II,
= 0 if not group II,

G_{III} = group III = 1.0 if group III,
= 0 if not group III,

T = time (1950 = 1, 1960 = 2, 1970 = 3, 1980 = 4),

$\bar{R}^2$ = coefficient of determination adjusted for degrees of freedom,⁶⁰

Se = standard error of the estimate,⁶⁰

F = F ratio,⁶⁰

DW = Durbin-Watson statistic.⁶⁰

Numbers in parentheses are t -values, which test the hypothesis that each b coefficient (number preceding variable in the model) is significantly different from zero at some level of significance (e.g., 0.05, 0.01).⁶⁰ Since all t -values in the model are significant at the 0.01 level, the cluster groups are highly significant as variables to explain the variation in retail receipts. In regression analysis the smaller the value of the t significance level, the more powerful the results and the more confidence we can place in the variables as predictors of the dependent variable (i.e., $\hat{RS}$).

Each binary variable can assume values of 1.0 or 0, depending on whether a county is a member of a given group. If the county is a member of group I, then its value will equal 1.0 for G_I and 0 for G_{II} and G_{III} . Similarly, counties that are not members of group I will have values of 0 for group I.

We have defined four groups of counties by cluster analysis, but have included only three binary variables in the model. Only three are needed to account for differences in four groups.^{60,61} The fourth group is accounted for by the intercept term. Reading from left to right in the model, we estimate retail receipts as the level of group IV (the intercept), plus some larger amount if we are referring to another group. Levels of retail receipts were estimated using adjusted data expressed on a per capita basis. This adjustment purges the data of unwanted correlation due to uniform changes in population and price levels. In Table 4.8 we change the estimates back to unweighted form and to a dollar basis by multiplying by the consumer price index (CPI) and 1000 respectively. The last column is a baseline estimate for the year 1980 in the absence of the upcoming construction activity. Implicit in the projection is the assumption that group membership would not have changed between 1970 and 1980. This assumption is based on observed regularity in group membership for each decade since 1950. As noted earlier, three impact counties are members of group IV. The baseline projection for each of those counties is \$1400 per capita in 1980. In Sumner and Wilson Counties, the baseline receipts projection is \$2300 per capita. These levels will eventually be compared with actual levels (during construction activity) to determine the longer-term impacts generated by retail receipts in each county. An additional element will be incorporated for the actual comparison; this element is the regression residual, which tells us how well the model fits a given observation unit. Since we obtained a fairly good $\bar{R}^2$, we expect the model to do well in most cases. However, should an impact county vary significantly from its group, the projection and impact measurement will be adjusted accordingly.

60. Potluri Rao and R. L. Miller, *Applied Econometrics*, Wadsworth Publ. Co. Belmont, Calif., 1971.

61. Jan Kemta, *Elements of Econometrics*, Macmillan, New York, 1971.

Table 4.8. Unweighted baseline estimates of retail service receipts (\$) per capita in the Hartsville impact area to 1980

	1950	1960	1970	1980
Group II (Sumner, Wilson, and others) ^a	755	1070	1590	2300
Group IV (Trousedale, Macon, Smith, and others) ^a	320	545	900	1400

^aOnly counties in the Hartsville impact area are listed; each group actually includes other counties from the 95-county sample. Table values apply to each county in each group. The table values are equal to those calculated with the model plus adjustments for CPI weighting and dissimilar measurement units for income (millions) and population (thousands). Thus, the table value relationship to the calculated model value in Table R = $\hat{R} \times \text{CPI} \times 1000$, where CPI equals 0.73 in 1950, 0.89 in 1960, 1.16 in 1970, and 1.50 in 1980 (estimated).

4.3 Social Assessment Applications

Coal utilization assessment. As part of the ERDA-DTO-RSP national assessment of coal utilization scenarios to 2020, we have been involved from an early stage in the development of the Coal Utilization Assessment (CUA) for the Southeast. Development of the CUA plan has been supervised by ANL. Most of our time was spent in development of the socioeconomic work statement and in meetings with socioeconomic groups from other national laboratories.

The primary output from this effort has been the detailed work plan for 1977. Four major efforts are currently under way as our primary input into the CUA; these tasks will be necessary to complete the cost-effective yet systematic assessment of potential social impacts of alternative coal technology scenarios for the Southeast. These impacts are:

1. Assessment of fuel cycle impacts. Generic social impacts associated with six stages of the coal fuel cycle (extraction, beneficiation, transport, conversion, combustion, and transmission) will be reviewed and assessed. Through systematic reviews of current and past research we expect to extract impacts common to the entire coal fuel cycle and those unique to each stage of the cycle. In this way essential background data collection and analysis will be possible for each scenario.
2. Identification of initial siting criteria. Current and evolving expertise will be used by the siting group to develop and apply socioeconomic criteria in siting choices. Provision will be made for systematic interchanges between the groups and for periodic updating and revision of criteria as more information becomes available.
3. Identification of constraints to coal development. We will identify both institutional and socioeconomic "initial states" that may act to hinder or accelerate coal development at differential rates within the CUA region. State and regional compacts and laws will be examined, together with evaluations of the constraints that may be imposed by existing social or economic conditions. Task three will draw heavily on the results of the two previous tasks.
4. Assessments of sites. To make relative local impact comparisons for alternative levels and types of coal technology development, we will conduct social assessments for the 50 to 150 sites (counties) identified by the siting group for extraction, conversion to liquid or gaseous fuels, and combustion. Sites will be characterized in terms of socioeconomic commonalities and assessed by a limited number of social indicators. Assessments of impacts, mitigation possibilities, and constraints will be based on the three other tasks.

The four major tasks, together with the evaluation of CUA scenario I (base case), are projected for completion by June 1977. Refinement of techniques and assumptions will then be made for subsequent scenarios as needed.

Environmental impact statements. Upon request, the Social Impact Assessment Group prepares and reviews parts of environmental impact statements and/or participates in licensing hearings. Over the past year, the group's involvement in such work has expanded with a growing recognition of the need for social science expertise in impact statement work. Our policy is to distribute work assignments among all members so that each is responsible for at least one environmental impact statement. The purpose of this policy is to provide opportunities for the practical application of research and to suggest further research possibilities for methodological and conceptual development of social impacts assessment at the community level. Group members assigned to a project are expected to continue with the project throughout the impact statement process.

Through October 1976, members of our group have been involved in activities related to ten separate impact statements (nine for NRC and one for ERDA). Projects continuing from last year are Wolf Creek, Sterling, and Greene County; new projects this year for NRC are Montague I and II, Jamesport I and II, Blue Hills I and II, New England I and II, Shoreham, and Fort Calhoun II; the new project for ERDA is the Clifty-Kyger coal-fired generating plants. Activities have consisted of making site visits, preparing social impact sections for the DES and FES, reviewing and commenting on impact statement documents, preparing testimony, and/or testifying. Table 4.9 lists our contributions to the various impact statement projects over the last year; dates given are the time at which major documents were docketed.

The circumstances, issues, and problems related to each of these projects vary. We mention only a few of these differences here. The Blue Hills I and II project represented the first early site review (ESR) by NRC, the purpose of which is to provide preliminary data to NRC on the suitability of the site for a nuclear power plant prior to the applicant's application for a construction permit. For the Wolf Creek, Sterling, and Jamesport I and II projects, we commented on hearing contentions related to potential socioeconomic impacts. In the cases of Sterling and Jamesport I and II, the staff testified before the Atomic Safety and Licensing Board on (1) the impacts on land use planning (Jamesport); (2) the impacts on police, fire, health, and transportation services (Sterling); and (3) the impacts of decommissioning (Sterling). The New England I and II project represents the first staff participation in an impact statement from its inception, and the Shoreham Project is our first operating license impact statement. Finally, the Clifty-Kyger project requires assessment of impacts of two coal-fired generating plants which have been operating for over 20 years. This information is an input to the Portsmouth Gaseous Diffusion add-on draft environmental statement.

In addition to participation in the formal impact statement process, we worked on the development of environmental standard review plans (ESRP) for NRC. The ESRP are to be used as guidelines for preparing impact statements. We participated in briefings given by local management and NRC on problems of impact statement work. A library of materials and data is being developed in support of our activities for the preparation of environmental impact statements.

One important sequel resulted from our participation during the Hartsville hearings reported last year. In 1975, the Social Impacts Analysis Group reviewed the statement on the proposed Hartsville Nuclear Power Plant at the request of NRC's environmental statements project and legal staff. Several significant changes were made in the FES at the suggestion of our staff representative. These changes included a provision requiring the applicant to monitor and semiannually report socioeconomic changes during the construction period to ascertain the effectiveness of the applicant's proposed plan for mitigating expected social and economic costs. In April 1976, the Atomic Safety and Licensing Board issued its ruling in which this revision was adopted officially; Section 201 of this ruling reads

17. Within six months of the beginning of construction activities on site, TVA shall develop and submit for NRC review, a program to monitor and evaluate socioeconomic impacts and

Table 4.9. Participation of Social Impacts Analysis Group in environmental impact statement preparation, 1976

Stage ^b	Statement ^a									
	Wolf Creek CP	Montague I and II CP	Sterling CP	Greene County CP	Jamesport I and II CP	Shoreham OL	Blue Hill: I and II ESR	New England I and 2 CP	Fort Calhoun II CP	Clifty-Kyger CP ^c
ER docketed	5/17/74	7/12/74	12/20/74	9/15/75	9/17/74	1/26/76	8/26/76	9/9/76	1/26/76	
Lab team comments							X	X		
Site visit				X	X		X	X		X
PDES writer						X	X		X	
DES docketed	7/3/75	11/5/75	1/5/76	3/11/76	2/13/75					
FES prepared		X	X	X						
FES docketed	10/31/75		6/18/76		10/7/75					
Response to comments			X	X						
Testimony prepared	X		X		X					
ASLB hearings			X		X					
FES issued										
CP or OL issued										

^aAbbreviations: CP – construction permit; OL – operating license; ESR – early site review.

^bAbbreviations: ER – environmental report; ASLB – Atomic Safety and Licensing Board.

^cAddendum to an existing DES for two coal-fired plants.

the effectiveness of mitigating actions. This program shall include but not be limited to an assessment of effects resulting from primary as well as secondary employment. Continuing information and evaluation shall be provided to the Staff on a semi-annual basis until the third report has been submitted following the issuance of any operating license for the last unit.

We view this as an important contribution of legal precedents requiring the internalization of social costs in direct energy production costs.

Coal conversion project. This work is in support of the Fossil Energy environmental project for ERDA's Fossil Energy Division, Major Facilities Project Management. Several types of synfuel and combustion processes are being assessed before construction of scaled-up demonstration plants. We function as part of a multidisciplinary team which is reviewing environmental reports on specific plants, developing guidelines for content and procedures for future environmental reports and environmental impact statements, and, in general, formulating the environmental assessment framework to be used before emplacement of a new operating-scale technology.

We have applied the framework and methods developed in our earlier work on nuclear plants to coal conversion facilities. We anticipate some differences in the size and ratio of construction and operating work forces; in the water, coal availability, and transportation requirements of conversion plants; and in the taxation and licensing procedures. Future work on programmatic and site-specific environmental impact statements for coal conversion plants can be expected to clarify the significance of these differences.

5. DATA MANAGEMENT AND ANALYSIS GROUP

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5.1 Overview

The Data Management and Analysis Group was established for the purpose of accumulating, evaluating, analyzing, and synthesizing information on the social and economic aspects of energy supply and demand. During the past fiscal year, the group has focused on (1) data management research and information research, (2) socioeconomic data management and analysis, and (3) energy data analysis.

The group has concentrated its effort on three related research projects during FY 1976: (1) RUSTIC: Regional and Urban Studies Information Center—a unified socioeconomic analysis and retrieval system; (2) transportation energy conservation data book; and (3) assistance to the Health Physics Division for an epidemiological study of Oak Ridge employee (a) mortality, (b) public health and demographic statistics, and (c) analytic dosimetry.

5.2 RUSTIC: Regional and Urban Studies Information Center

RUSTIC was created in 1973 to study the problems of demographic information transfer and to determine an efficient means for transferring socioeconomic data to federal, state, and local policy

62. Group leader.

63. Computer Sciences Division.

makers. This work, sponsored by the Office of Environmental Information Systems of ERDA in cooperation with the Information Center Complex of ORNL's Information Division, has become a strong link between ORNL and other federal agencies and provides assistance to state and local policy makers. RUSTIC includes in its library over 3000 reels of computer tape and computer software developed for management and analysis of socioeconomic data bases.⁶⁴ Its data collection is available to internal (ORNL) users as well as public, private, governmental, and academic users outside the laboratory through Oak Ridge Associated Universities. During 1976 RUSTIC services were provided on a cost recovery basis to about 20 outside users. Among these users were ERDA's Division of Biomedical and Environmental Research, ERDA national laboratories, HUD, Kentucky Department of Commerce, University of Missouri, University of Texas, City of Gastonia, North Carolina, and the Urban Institute.

Program design. RUSTIC focuses on development of retrieval methods for research applications. RUSTIC has fostered development of data management tools^{65,66} and improved data acquisition, maintenance, utilization, and organization with the incorporation in 1976 of 7 software packages and 22 data bases consisting of 61 data files. Data resources acquired during 1976 included files on transportation energy supply; consumption and conservation; facility location, particularly of airports and power plants; human health and vital statistics; regional economic data; socioeconomic surveys of the United States; recent federal census and related data.

The development of the RUSTIC program has (1) mobilized existing and developing information resources to meet expressed needs; (2) provided energy and environmental research and development data; (3) established a responsiveness to energy research and development needs; (4) established factual data base construction; (5) provided resources and guidance in the development, exchange, and use of methods and materials in analysis of social science data; and (6) promoted the development of information networks among ERDA's scientific and technical information services and collaboration with information networks of other federal agencies. This collaboration was accomplished, in part, through participation with the Inter-Laboratory Working Group for Data Exchange.

5.3 Transportation Energy Conservation Data Book

Energy end-use analyses by the Data Management and Analysis Group have included development, maintenance, display, and manipulation of data supportive of the program responsibilities of the ERDA Division of Transportation Energy Conservation (TEC).⁶⁷ The Data Analysis Branch of TEC contracted with ORNL in January 1976 to prepare a transportation energy conservation data book. The major purposes of this data book are to (1) draw together, under one cover, data from diverse sources, (2) eliminate data inconsistencies, and (3) produce a useful reference document.

The 263-page volume completed in October 1976 contains statistical information on the major transportation modes, overall energy use in the transportation sector, and the energy distribution among transportation modes. Data on past, present, and projected energy use and conservation in the

64. A. S. Loeb et al., *Regional Information Group Energy, Environmental and Socioeconomic Data Bases and Associated Software at Oak Ridge National Laboratory*, ORNL/TM-5600 (September 1976).

65. N. S. Malthouse, *INDEXGEN: Automated Indexing for Large Bibliographic Document Collections*, M. S. thesis, University of Tennessee, June 1976.

66. N. S. Malthouse, *INDEXGEN: Index Term Generation Heuristics Software Documentation*, ORNL EIS-104 (December 1976).

67. A. S. Loeb et al., *Transportation Energy Conservation Data Book*, ORNL-5198 (October 1976).

transportation sector are presented under six chapter groupings: (1) characteristics of transportation modes; (2) energy characteristics, including energy consumption by source, sector, and energy intensiveness; (3) conservation alternatives; (4) government impacts, including expenditures, regulations, and research; (5) energy supply, including domestic petroleum production, prices, and projections; and (6) transportation demand, including population characteristics and economic determinants.

The compilation is based on a review of past and continuing data-gathering activities of many private and public organizations. Each chapter provides a bibliography of data sources. In a more general bibliography at the end of the book, references that are particularly significant have been annotated. Time series data are presented for transportation and transportation fuel use for one or two decades prior to the oil embargo. Where available, projections of future energy use and the determinants of energy use are also given.

Future editions of the data book that will include data on energy use and conservation at the subnational level and more information on nonhighway transportation modes are planned. Four supplements are scheduled to be published by the end of FY 1977; the first of these was released in November 1976.⁶⁸

A detailed information set supports publication of this document. This set will be continuously improved by (1) review of past and ongoing data collection sources and activities, including research that will provide transportation energy use parameters; (2) collection, monitoring, and updating of data sources identified in step (1); (3) assembly of information into summary form; and (4) development and use of simple analytical tools, using the collected data identified in step (1).

5.4 Additional Program Activities

Mortality study of work health hazards to Oak Ridge employees. The FY 1976 effort has focused on an occupational mortality study constituting an epidemiological study of the causes of age-, sex-, and race-specific mortality of Oak Ridge employees at ERDA installations. The study represents a longitudinal analysis of mortality experience and compares the experience of the relevant work force with that of the general population of the United States. The immediate effort of this study has focused on total mortality and mortality from neoplasia for the population employed in the three-plant complex between 1950 and 1970.

The study draws heavily on the established biomedical and environmental research programs at ORNL and Oak Ridge Associated Universities and on the unique computerized information-handling hardware and software systems available at Oak Ridge. Specifically, we have developed the capacity to collect and document demographic-epidemiological parameters and to develop the necessary automated procedures that permit flexibility of analysis. We have coalesced that information, which is conventionally available in raw form from national and subnational sources, and are able to meld it with specific occupational personnel data into a comprehensive system.

Public health and demographic statistics. This program is functionally and administratively located within the Health Physics Division. The purpose of the program is to assess the methodology and available data sources appropriate for use in analytical studies and environmental impact statements concerning the health effects of nuclear power plants.

68. D. B. Shonka et al., *Transportation Energy Conservation Data Book: Supplement I*, ORNL-5232 (November 1976).

To accomplish this purpose, we have focused on the determination of the public health and demographic data sources of local, state, and federal origin. Received to date are data from the National Cancer Institute (NCI), National Center for Health Statistics (NCHS), and Tennessee Department of Public Health. The NCI provided cancer mortality data aggregated for 1950 to 1969 on a nationwide basis by county and also provided data from the Third National Cancer Survey.⁶⁹ NCHS provided data concerning mortality for the United States by county;⁷⁰ the State of Tennessee also provided the mortality data by county in published and machine-readable form.

Demographic data including age, sex, race, and socioeconomic structure are available to the program on a county and subcounty level in the 1950, 1960, and 1970 censuses on a nationwide bases.⁶⁴ Additional socioeconomic statistics for counties and large cities are available for selected intercensal years from the county and city data books, county business patterns, and other economic censuses of the U.S. Department of Commerce.

One specific contribution of the Data Management and Analysis Group to this program is in the area of data management and analysis. The group analysis focuses on methodology development in the areas of human ecological analysis and classical demographic analysis employing stable population theory and life table techniques. The development of methodology and location of data sources for assessment of the public health impacts of energy production are the central purposes of this interdivisional project.

Analytic dosimetry. Functionally and administratively located in the Health Physics Division, the analytic dosimetry program was established to undertake in-depth review of certain subjects selected by the staff and to serve as a focal point where technical questions could be directed to assist researchers. Organization and development of the Health Physics Information System has been a responsibility of the Data Management and Analysis Group in collaboration with the Information Center Complex of the Information Division. Collaboration between the Energy and Health Physics Divisions under this program has focused on human health effects (as discussed in the two projects above) and health standards for energy production.

The human effects research has been discussed under the heading of the mortality study of Oak Ridge workers. Our group assisted the Analytic Dosimetry Program in developing a file (within the Health Physics Information System) on health standards of energy production as a basis for review of general and applied problems in this area.

6. REGIONAL ENVIRONMENTAL RESOURCES ANALYSIS AND PLANNING

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The Regional Environmental Resources Analysis and Planning Program carries out research directed toward identification of those criteria which may serve as critical indicators of regional environmental impact and the development and application of analytical methodologies designed to

69. S. J. Cutler et al., "Third National Cancer Survey—an Overview of Available Information," *J. Nat. Cancer Inst.* 53, 1565-75 (1974).

70. National Center for Health Statistics, *Standardized Micro-Data Tape Transcripts*, DHEW Publ. No. (HRA) 74-1213 (Revised), Rockville, Md., June 1974.

examine the potential ecological impacts of energy technology development. The identification and application of regional impact criteria are used to evaluate environmental constraints to future energy resource development for locating future energy facilities. The methodologies developed for examination of ecological impact allow for evaluation of impacts upon potentially suitable sites from the standpoint of optimal siting, intensity of development, and the choice between various energy technology alternatives.

The Regional Environmental Resources Analysis and Planning Program carries out environmental assessment studies as a component of the ORNL Regional Studies Program. As part of its overall program, the Regional Environmental Resources Analysis and Planning Program carries out environmental analyses that will permit identification of siting exclusion areas within the South. Members of the Program also utilize environmental transport and ecological effects models, as well as optimization techniques, to evaluate the environmental impacts associated with the development of energy technology facilities within the region. The research currently focuses on the impacts associated with coal extraction in Appalachia and the assessment of impacts associated with the siting and operation of coal technology facilities in the southern United States.

6.1 Atmospheric Transport

Deposition of SO_2 from a pollutant plume has been studied by incorporating a model⁷¹ that calculates deposition on various kinds of ground cover into a Gaussian Plume model of atmospheric transport.⁷² Ground cover information in the Kingston, Tennessee area has been obtained from aerial photographs, and this information has been used as input in modeling deposition rates of SO_2 due to a source in the area. The area studied was a circle of 22-km radius and had ground cover in the categories of deciduous forest, coniferous forest, cropland and pasture, water, and urban. The study is aimed at acquiring representative deposition velocities for the southern United States.

The process of SO_2 deposition was modeled for the months of March, July, and October. In some instances the model yielded high values. Table 6.1. shows the maximum deposition velocities calculated for these months under daytime and nighttime conditions. However, most values of deposition velocity calculated are significantly lower than these maximum values. Table 6.2. shows the average values of deposition velocity.

The most important aspect of these results is the significantly higher nighttime values—presumably due to moist vegetation. The daylight deposition process would seem to have as its limiting factor the absorption of SO_2 on vegetative surfaces. On the other hand, because of moist surface cover during nighttime hours, the deposition process is aerodynamically limited.

Table 6.1. Maximum calculated deposition velocity, v_g (cm/s)

	March	July	October
Day	6.2	3.3	5.4
Night	12.3	8.7	13.5

Table 6.2. Area averaged values of v_g (cm/s)

	March	July	October
Day	0.4	1.2	1.0
Night	5.4	3.6	5.5

71. B. D. Murphy, *Deposition of SO_2 on ground cover*, Third Symposium on Atmospheric Turbulence, Diffusion, and Air Quality, Raleigh, North Carolina, Oct. 19–22, 1976.

72. W. M. Culkowski and M. R. Patterson, *A Comprehensive Atmospheric Transport Model*, ORNL/NSF/EATC-17 (1976).

A long range atmospheric transport model incorporating diffusion and deposition is now operational; it is based on the model of Heffter.⁷³ Data are available for two to five years which allow the calculation of actual wind trajectories. Display routines have been added to the model so that density plots of ground level concentration and deposition rate can be shown. An example of a density plot is shown in Fig. 6.1. The conversion of some SO₂ to sulfate can now be assessed, and the vertical diffusion of pollutants at great distances has been modified so as to limit all material to the troposphere. The problem of diffusion parameters in general has received attention and is still being actively investigated. Some initial results using this model have been used in siting optimization studies of power plants.

73. J. L. Heffter, A. D. Taylor, and G. J. Ferber, *A Regional-Continental Scale Transport, Diffusion, and Deposition Model*, NOAA TM ERL ARL-50 (1975).

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Fig. 6.1. Density plot showing a monthly averaged ground level SO₂ concentration due to a hypothetical source located at Oak Ridge. The different levels of shading represent powers of ten. Wind data for 30 days from August 27, 1974 were used. Depth of mixed layer was assumed to be 1800 m; a deposition velocity of 1 cm/sec was used together with a conversion rate of 0.05/hr for the SO₂ to sulfate transformation.

6.2 Hydrologic Analysis

Seven-day low-flow frequency distributions have been chosen as indices of water availability for regional energy facility siting and assessment. Since no single frequency distribution can match low-flow frequencies for all stations, we have selected four of the most widely accepted distributions for use in regional studies. When the theoretical distributions are compared to the cumulative probability plots of the observed data for a station, the best fitting method can be determined.

The four frequency distributions, and two methods of plotting cumulative probabilities, have been incorporated into an interactive analysis package, LOFLO2. LOFLO2 forms one analysis module of the ORNL Water Analysis System (WAS),⁷⁴ a series of interactive programs that can be used to select, retrieve, and analyze streamflow data from the U.S. Geological Survey DAILY-VALUE water tapes.

One underlying assumption of all theoretical methods is that the data are consistent, representing one set of conditions over the entire period. A stream that is unregulated, or one whose record has covered a period of consistent regulation practices is suitable, but a record that spans the time when one or more reservoirs were brought into operation must be considered unsuitable without adjustment. By generating plots of data and theoretical distributions, one can often spot spurious data values, such as those produced when a reservoir is being filled and flow is drastically reduced. It is also likely that spurious values will result in differences between theoretical distributions and plotted data. The plots generated by the LOFLO/WAS system serve as a guide for identifying stations where further analysis of the data is warranted. We are addressing the problem of developing consistent records for such stations, including the use of synthetic streamflow models for adjusting flow records.

6.3 Validation of a Forest Growth Model

The FORET model (a computer model of growth, birth, and death of trees in a $1/12$ -ha stand located at lower slope positions in Anderson County, Tennessee) has been described in terms of the model structure and some preliminary model results.⁷⁵ During the past year, a test of the model in an experimental context (model validation) was developed. The validity of the FORET model was examined by comparing results from the forest growth simulated under conditions that either included or excluded American chestnut (*Castanea dentata*) as an eligible species. In the simulation with chestnut included, the simulation would theoretically be that of the historical forest in Tennessee. In cases in which chestnut was deleted, the simulation results should resemble the dynamics of the present Tennessee forests (with the chestnut blight being considered an experiment of nature that eliminated the chestnut from the forest canopy). The procedure in developing and testing the model was to develop and test the model only under conditions with chestnut absent from the species mix. The model was developed to mimic present forest conditions and was tested on its ability to reproduce the conditions at present and on its ability to reproduce the conditions in the historical pre-chestnut blight forest. Because including chestnut in the model constitutes a model experiment relative to the procedure by which the model was developed, the ability of the model to simulate the historical forests in Tennessee represents an inferential test on the model's validity.

Table 6.3 is an example of the model output. Data shown in this table (columns 1 and 2) are from a sample taken in the early 1900s of an undisturbed chestnut oak forest in Anderson County, Tennessee.

74. J. S. Jalbert and A. D. Shepherd, *A System for Regional Analysis of Water Availability*, ORNL/NUREG/TM-82 (1977).

75. S. I. Auerbach, et al., *Environmental Sciences Div. Annu. Rep., Sept. 30, 1975*. ORNL-5193.

Table 6.3. Results from FORET simulation compared with data collected in Anderson County, Tennessee in 1908^a

Species	Average of 262 acres ^b		Percent ^c
	Number of trees	Percent	
Chestnut oak	7.46	16.98	10
Black oak	6.33	14.41	15
Chestnut	8.73	19.88	20
White oak	6.09	13.87	15
Shortleaf pine	0.60	1.37	1
Scrub pine	0.33	0.75	1
Hickory	3.14	7.15	5
Gums	2.37	5.40	4
White Pine	0.20	0.46	3
Yellow poplar	1.84	4.19	10
Maples	3.55	8.08	12
Hemlock	0.12	0.27	1
Basswood	0.42	0.96	1
Birch	0.24	0.55	1
Buckeye	0.13	0.29	1
Cherry	0.04	0.09	1
Reach	1.20	2.73	4
Locust	0.28	0.64	1
Other species	0.85	1.93	1
Total	43.92	100.00	

^aH. D. Foster and W. W. Ashe, *Chestnut Oak in the Southern Appalachians*, USDA For. Ser. Cir. 135, 23 p. (1908).

^bScott, Campbell, and Anderson Counties, Tenn.

^cValues derived from FORET-with chestnut.

The third column of the table also shows the percent of each species as simulated by the model. Since the actual data are from a somewhat more xeric condition (compared to model results), the similarity (validity) of the simulation output is considered adequate to permit future application of the FORET model.

6.4 Agricultural Applications

Modification of the meteorological data input section of the Terrestrial Ecosystem Hydrology Model (TEHM) has been completed for ease of handling detailed micrometeorological measurements from agricultural research studies. Irrigation algorithms have been conceptualized for inclusion in TEHM to represent both sprinkler and flood irrigation methods. This capability is needed for two of the four agricultural applications selected for study, and it will be valuable in many other agricultural assessment studies since irrigation either as a supplement or as the main crop water supply is a well-established practice.

A sensitivity test of 19 parameters representing landscape, plant, and soil characteristics in the TEHM⁷⁶ showed that the model simulations were stable to a wide range in parameter values, supporting the utility of TEHM for a range of land uses, soil types, and landscape situations. The sensitivity test of

76. R. J. Luxmoore, Janice L. Stolzy, and J. T. Holdeman, *Some Sensitivity Analyses of an Hourly Soil-Plant-Water Relations Model*, ORNL/TM-5343 (1976).

leaf area index (Fig. 6.2) showed that the water balance components were insensitive to values above four, indicating that well-vegetated surfaces behave about the same as far as water dynamics is concerned.

Soil variability is a well-known problem in conducting agricultural research, and statistical methods were originally developed for the design and analysis of agricultural field studies. An analysis

Fig. 6.2. Sensitivity of July water balance components to change in maximum leaf area index of the vegetation (ALMAX).

of soil variability using the scaling theory of soil physical properties in the TEHM model⁷⁷ showed that one average soil type gave similar water budget results as those obtained for spatially varying soil properties in the cases examined. Spatial variability had only a small effect on evapotranspiration whereas water storage in the soil profile changed so that the drainage flux beyond the root zone tended to become uniform throughout the area simulated. These findings lend support to the wider use of the TEHM model in regional agricultural applications.

Four agricultural crop systems have been selected for initial study with the agricultural version of the Terrestrial Ecosystem Hydrology Model (AGTEHM)—namely, corn in South Carolina, soybeans in Arkansas, wheat in northern Mexico, and pasture in Western Australia. The input data sets have been completed for the corn and pasture studies, and initial simulations indicate the general suitability of AGTEHM for agricultural applications.

A survey of extant agricultural models is well underway and several modelers have been contacted by letter for recent information. Many of the agricultural models reviewed to date are research models of very specific processes that do not provide a framework for an integrated assessment of an environmental impact. Nevertheless specific impacts of critical importance could be evaluated with detailed process models. Identification of the environmental impacts of energy technologies tabulated from other studies are providing the basis for evaluation of the agricultural models.

6.5 Distribution of Sensitive Species

One of the long-term goals of the Regional Program is to understand and describe the regional ecological processes that determine how the occurrence and abundance of animal populations respond to environmental changes. To fulfill this goal, information on the structure of avian and mammalian communities in the southeastern United States is being gathered and is being related to vegetation structure. The resulting data can be used for predicting the effects of habitat alterations. Figure 6.3 shows how data can be displayed.

The identification of appropriate habitat descriptors involves the determination of parameters related to the niche pattern descriptions of species. Most animal population studies that use this approach, particularly those involving avian species, generally have examined interactions of individual populations within specific vegetation types. This approach concentrates on development of specific habitat variables which correlate with specific species occurrence.^{78,79}

As an example of the application of the relationship of species and habitat, the structure of five small mammal populations on a section of Key Largo in the Florida Keys was simulated. Initially, multivariate analysis was performed on a set of habitat parameters to group variables important in describing the habitat strategies of the mammal populations. Discriminant function analysis was used to construct an n-dimensional hypervolume of niche overlap and abundance (Table 6.4). The species used in this analysis were Key Largo woodrat (group 1), Key Largo cotton mouse (group 2), Key Largo gray squirrel (group 3), Norway rat (group 4), and shorttail shrew (group 5). Information on the habitat of the

77. A. J. Peck, R. J. Luxmoore, and Janice L. Stolzy, "Effects of Spatial Variability of Soil Hydraulic Properties in Water Budget Modeling," *Water Resour. Res.* (in press).

78. H. H. Shugart, Jr. and B. C. Patten, "Niche Quantification and the Concept of Niche Pattern," pp. 284-327 in B. C. Patten (ed.), *Systems Analysis and Simulation in Ecology*, vol. 2, Academic Press, New York, 1972.

79. S. H. Anderson and H. H. Shugart, Jr., *Avian Community Analysis of Walker Branch Watershed*, ORNL/TM-4700 (1974).

ORNL DWG. 76-5173

Fig. 6.3. Computer generated distribution map of wood ibis (MYCAME), Indiana bat (MYOSOL), Ipswich sparrow (PASPRI), and burrowing owl (SPECUN), used to demonstrate the cartographic capabilities on the GEOECOLOGY data bank.

Table 6.4. Niche hypervolume and classification of five mammal species found at Key Largo, Florida

Discriminant analysis – paired squared generalized distances between groups where
 $D^2(I/J) = (\bar{x}_i - \bar{x}_j)' \text{Cov}^{-1} (\bar{x}_i - \bar{x}_j) - 2 \ln \text{prior } j$

Group	Generalized squared distance to group				
	1	2	3	4	5
1	3.2	3.5	3.3	12.6	6.0
2	4.3	3.9	4.1	14.9	7.6
3	2.9	2.9	2.7	12.0	5.3
4	13.0	14.5	12.8	3.5	6.5
5	5.9	6.8	5.6	6.1	3.1

Summary of classification performance using generalized squared distance number of observation classified into group					
1	7	3	6	0	4
2	4	3	6	0	1
3	7	3	11	0	4
4	0	0	1	12	4
5	1	0	7	5	8

first three species was taken from Brown.⁸⁰ Information on the shrew and Norway rat was taken from Hall and Kelson.⁸¹

The position of each specie's niche in this hypervolume can be measured directly in terms of interniche distances in the hyperspace. Viewing the total habitat of each species as a hypervolume of habitat variables, one can compare the distance between the different species' population centers (Table 6.4). Using the Key Largo woodrat (group 1) as an example, it is seen that the habitat hypervolume is 3.2 units. The smaller the number when the species is compared within itself, the larger the abundance of the species in its particular habitat. Other populations with similar values when compared to the woodrat select habitat hypervolumes similar to that of the woodrat population. The Key Largo cotton mouse (group 2) is 3.5 units away; the Key Largo gray squirrel (group 3) is 3.3 units; however, the shrew (group 5) was 6.0 units away, and the Norway rat (group 4) even more distant, 12.6, indicating a wide separation in the habitat needs of the first three species when compared with the latter two species.

The habitat discriminant function also can be reclassified to determine the number of individuals of a certain species that would be placed in the habitat hypervolume of the other species. The lower portion of Table 6.4 summarizes these results. The conversion of mature hammock (represented by species 1, 2, and 3) for subdivision development (represented by species 4) eliminates the occurrence of the first three species, since no member of the woodrat, cotton mouse, and gray squirrel would be expected to be found in this type. With this habitat information and related population data it will be possible to predict changes in the populations of animal species prior to landscape alteration over large regional areas. The type of data analysis demonstrated can have far-reaching effects in conservation of not only existing rare or endangered species, but more importantly, of those species which may become endangered by unknowing destruction of critical elements of their habitat.

80. L. N. Brown, "Unique Mammals Found in the Florida Keys," *Fla. Nat.* 43(4): 146 (1970).

81. R. E. Hall and K. R. Kelson, *The Mammals of North America*, vols. 1 and 2, Ronald Press Co., New York, 1959.

6.6 Impacts of Transmission Line Corridors

The land area occupied by transmission line rights-of-way is growing rapidly. By 1990, it is expected to total nearly three million hectares.⁸² In many landscapes, rights-of-way through forested terrain create strips of herbaceous-shrubby cover and forest edge. Research was conducted along several forest-bordered rights-of-way in East Tennessee to (1) determine if corridors constitute barriers to animal movement and to (2) assess the effect of habitat alteration on the presence and abundance of small mammal species.

Schreiber and Graves⁸³ showed that displaced individuals of *Peromyscus leucopus* and *Blarina brevicauda* returned to home areas after being released across a right-of-way (Table 6.5). On the average, *Blarina* individuals took longer to return and were less successful than *Peromyscus*. A

Table 6.5. Recapture success of displaced *P. leucopus* and *B. brevicauda* in right-of-way and forest habitats

Species	Location (Right-of-way)	Displacement distance (m)	Right-of-way			Forest			Fisher exact probability ^a
			Released	Recaptured		Released	Recaptured		
			(No.)	(No.)	(%)	(No.)	(No.)	(%)	
<i>P. leucopus</i>	Narrow	79.2	7	6	86	8	6	75	0.50
<i>P. leucopus</i>	Wide	128.0	7	6	86	6	5	83	0.81
<i>B. brevicauda</i>	Wide	70.1	8	6	75	7	7	100	0.27
<i>B. brevicauda</i>	Wide	128.0	11	7	64	7	7	100	0.11

^aBased on the null hypothesis that an animal released in the forest or in/across the right-of-way has an equal probability of returning to the capture site.

companion study,⁸⁴ however, showed that separate populations inhabit the corridor and adjacent forests and that individuals of these two species do not cross the right-of-way as part of their normal movement patterns.

Population analyses⁸⁴ showed that the frequency and abundance of small mammal species differed considerably among forest, edge, and right-of-way habitats (Fig. 6.4). Maintained rights-of-way create habitat for two species (*Sigmodon hispidus*, *Reithrodontomys humulis*) not present in adjacent pine or hardwood forests.

Results of diversity calculations⁸⁵ indicate that corridor and edge communities have a higher small mammal diversity ($\bar{H}$) than existed in the formerly continuous arboreal cover. The composition of the adjacent forest had little effect on small mammal diversity in wide (91 m) rights-of-way; diversity was almost identical for corridors bordered by pine plantations or native hardwood forest (Fig. 6.5).

82. Federal Power Commission, 1970 *National Power Survey*, Government Printing Office, Washington, D.C., 1971.

83. R. K. Schreiber and J. H. Graves, "Powerline Corridors as Possible Barriers to the Movements of Small Mammals," *Am. Midl. Nat.* 97: 504 (1977).

84. R. K. Schreiber, W. C. Johnson, J. D. Story, C. Wenzel, and J. T. Kitchings, "Effects of Powerline Rights-of-Way on Small, Nongame Mammal Community Structure," *Proceedings of Symposium on Environmental Concerns in Rights-of-Way Management*, Mississippi State University, Starkville, pp. 264-73 (1976).

85. W. C. Johnson, R. K. Schreiber and R. L. Burgess, "Diversity of Small Mammals in Powerline Communities," *Bull. Ecol. Soc. Am.* 57(1): 14 (1976).

Fig. 6.4. Abundance (total number of individuals caught/number of traps in trapping grid $\times 100$) of small mammal species in five habitats within and bordering a 500-kV powerline right-of-way through a pine forest in east Tennessee.

Fig. 6.5. Diversity ($\bar{H}$) of small mammals in three habitats along pine (solid line) and hardwood (dashed line) bordered powerline corridors.

6.7 Environmental Objectives in Energy Facility Siting

Incorporation of environmental planning criteria in the siting of energy facilities is a difficult problem. Typically, environmental criteria are incorporated as constraints on a siting process which minimizes cost. In some cases environmental objectives are expressed as costs through weighting factors. Often these weighting factors are a measure of the cost of abatement for various pollutants. This type of siting analysis leads to a characterization of the energy system with respect to econometric criteria. Environmental criteria are often not adequately treated.

One approach to the analysis of energy facility siting questions which treats each planning criteria is multiple objective optimization. This scheme allows the incorporation of environmental objectives through independent optimization models. The objective functions of each optimization model are related by tradeoff functions. These tradeoff functions are developed through interaction with decision makers.

The multiple objective optimization approach requires the development of optimization models for each planning criteria to be considered. To this end, an optimization model for air quality has been developed. A set of candidate sites for energy facilities is assumed. Levels of activity at each site are calculated to minimize the exposure of population or various categories of land use to air-dispersed sulfur pollutants while meeting an increase in demand. Activities at each site are constrained by the suitability of the site. Water availability is generally of primary importance in establishing this constraint level.

The air dispersion characteristics of the region of interest are incorporated in the optimization model by parameterizing the output of a trajectory pollutant transport model. The region is subdivided

into a system of cells and the pollutant contribution to each cell due to a source at each candidate site is calculated. These contributions are summed to determine the average ground level concentrations of sulfur pollutants in each cell.

An exposure index is used as an objective function rather than as a measure of the effect of pollutants. A measure of effect will generally show little change below a threshold value beyond which the effect is very pronounced. The population exposure index is formed as the sum for all cells of the product of ground level concentration of pollutants, which is proportional to activity levels at each site, and population of the cell. A land use exposure index is similarly formed by substituting acres of land in the cell in particular critical land use categories for population.

Initial implementations of this optimization model for air quality have been in the form of a linear program which can be solved using any number of standard computer packages. With sufficient data collection for calibration and verification, this optimization model can be used as a planning tool for energy system decisions. However, the most important application is in a multiple objective optimization framework. In this framework air quality and other environmental criteria are adequately considered with engineering and cost criteria.

6.8 Environmental Effects of Coal Extraction in Appalachia

Research is continuing to examine the impacts associated with strip mining of coal in Appalachia. The primary effort has been to develop methodologies related to four specific areas of interest.

A geodetic information system has been developed for regional analysis of environmental problems. The system permits interfacing regionally-scaled data sources, such as LANDSAT imagery, TOPOCOM (digital topographic elevation) tapes, and U.S. Census Bureau tapes with additional manually digitized data and stored in a 1.2-acre geodetic cell data base. Computerized techniques have been developed for the accurate identification and location of surface mining activity relative to surrounding features such as streams, roads, unmined coal seams, and rural and urban populations. Manuscript preparation documenting this research is in its final stage.

A technique has also been developed and applied for assessing the impact of strip mining on wildlife and wildlife habitat. This has been accomplished by determining a set of habitat requirements for specific game mammals and evaluating these requirements in relation to the suitability of an area (both before and after mining) for the animal of interest.

Work is now beginning which will be concerned with developing and demonstrating a methodology to locate natural areas within an area susceptible to strip mining activities. This task will evaluate a multicounty region containing strippable coal within East Tennessee, and evaluate this area for its natural ecological value. This value will be determined by locating the least disturbed areas within the region as determined by zoological, botanical, and geological features.

As a first step in constructing a hydrologic model for predicting water quality changes associated with mining, the U.S. Geological Survey water quality data for the Appalachian region were examined. Current water quality varies widely, with the differences caused in part by man's activities, including present and past coal extraction, and in part by geological differences. Prior to developing a model for predicting changes following mining, one must be able to predict the expected water quality in the absence of mining. We expect to make these baseline predictions, and the subsequent impact predictions, using a regression model and are now assembling the required geologic information for the Appalachian region.

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