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REGIONAL ISSUE IDENTIFICATION AND ASSESSMENT

STUDY METHODOLOGY
FIRST ANNUAL REPORT

JANUARY 1980

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U.S. DEPARTMENT OF ENERGY
OFFICE OF THE ASSISTANT SECRETARY FOR ENVIRONMENT
OFFICE OF TECHNOLOGY IMPACTS
REGIONAL ASSESSMENTS DIVISION

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STUDY METHODOLOGY FIRST ANNUAL REPORT

JANUARY 1980

PREPARED BY
SYSTEMS CONSULTANTS, INC.
UNDER CONTRACT NO: 31-109-38-4388
(ANL SUBCONTRACT)

FOR

U.S. DEPARTMENT OF ENERGY
OFFICE OF THE ASSISTANT SECRETARY FOR ENVIRONMENT
OFFICE OF TECHNOLOGY IMPACTS
REGIONAL ASSESSMENTS DIVISION
WASHINGTON, D.C. 20545

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FOREWORD

This report describes the overall assessment methodologies and models utilized for the first project under the Regional Issue Identification and Assessment (RIIA) program. This report includes detailed descriptions of the methodologies used by "lead laboratories" for the quantification of the impacts of an energy scenario on one or more media (e.g., air, water, land, human and ecology), and by all laboratories to assess the regional impacts on all media.

This report serves as an adjunct to the study results report which delineates major national and regional effects of implementing future energy development on the Nation's physical and human environments.

We believe this assessment to be innovative, that is, it is the first time the Federal Government has attempted to examine comprehensively and in detail the impacts of national policy at the state and sub-state level. It provides the type of insight that should make it a valuable and important tool for the formulation of energy policy at all levels of government.

The research and assessments reflected in this document were performed by the following national laboratories:

Argonne National Laboratory
Brookhaven National Laboratory
Lawrence Berkeley Laboratory
Los Alamos Scientific Laboratory
Oak Ridge National Laboratory
Pacific Northwest Laboratory

The project was managed by the Regional Assessments Division, Office of Technology Impacts, Office of Environment.

This regional assessment activity is continuing with an examination of a more recent energy supply/demand projection. Since this is the first report—a report which breaks new ground—we would appreciate your comments and suggestions on improving the assessment methodologies and analytical techniques for future RIIA programs. Comments, questions, and suggestions should be directed to Dr. Joan Hock, Director, Regional Assessments Division, Office of Environment, U.S. Department of Energy, Washington, D.C. 20545, telephone: (301) 353-4258.

S. P. Mathur
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INTRODUCTION

In April, 1977, President Carter submitted a proposal to Congress specifying energy use, conservation, and energy supply goals for the United States. This proposal, known as the National Energy Plan (NEP), was the initiation of a Federal energy planning process whereby comprehensive national energy policies and programs are formulated with the ultimate objective of reducing our Nation's dependence upon unreliable foreign sources of energy.

National energy plans impact different parts of the Nation in different ways, and without a thorough understanding of state and regional differences, subtle and often critical conflicting state and regional objectives and issues are often missed when national energy policies and programs are being formulated. The failure to identify and address issues unique to particular states and regions can therefore impose substantive constraints upon fully realizing the benefits of national energy programs.

The Regional Issue Identification and Assessment (RIIA) project was developed by the Department of Energy's Assistant Secretary for Environment (ASEV) to provide Federal energy policy-makers with an understanding of state and regional environmental and socioeconomic issues and their relative significance as they relate to alternative energy futures. Managed by the Regional Assessments Division (RAD) of the Office of Technology Impacts (OTI), RIIA utilizes DOE's national laboratory system to identify and quantitatively assess conflicts that may arise between future energy development and local human and physical environments.

The first RIIA project (RIIA I) was conducted during Fiscal Year 1978 and the early part of Fiscal Year 1979. The results of the analysis are presented in ten regional reports (one for each Federal Region) and in one national report (a compilation of the ten regional reports). The purpose of this document is to provide interested readers with a detailed description of the overall study methodology as well as in-depth analyses of the specific analytical approaches and models utilized to assess each impact category addressed in the assessment.

This report contains five chapters. Chapter 1 briefly describes the overall study methodology and introduces the technical participants. Chapter 2 is a summary of the energy policy scenario selected for the RIIA I study and Chapter 3 describes how this scenario was translated into a county-level siting pattern of energy development. The fourth chapter is a detailed description of the individual methodologies used to quantify the environmental and socioeconomic impacts of the scenario while Chapter 5 describes how these impacts were translated into comprehensive regional assessments for each Federal Region.

CHAPTER 1

STUDY METHODOLOGY - OVERVIEW

The overall analytical approach utilized in RIIA is shown in Figure 1. Essentially, the RIIA methodology involves four distinct steps:

- 1 - Selection and disaggregation of a future national energy supply and demand scenario;
- 2 - Establishment of national county-level siting patterns for utility and industrial boilers and fuel extraction facilities;
- 3 - "Lead lab" quantification of the environmental and socioeconomic impacts of the energy development sited in Step 2; and
- 4 - Regional analysis and assessment of the environmental and socioeconomic impacts identified in Step 3.

In the first step, a basic Department of Energy mid-term (through 1990) national projection (scenario) of future energy supply and demand was chosen and disaggregated to the Federal Region level. The scenario selected for RIIA I, referred to as the EIA Trendlong Series C, is one of six alternative energy futures developed by the Energy Information Administration (EIA) for the Department's Annual Report to Congress published in April, 1978*. It assumes medium energy demand and fuel supply through 1990 as projected prior to the passage of the National Energy Act (see Chapter 2).

The next step utilized the fuel mix projected by the scenario (i.e., the proportions of coal, oil, gas, geothermal, solar, etc.) to determine the spatial (county level) and temporal (1985 and 1990) location of power plants, major fuel burning industrial plants and mining facilities throughout the United States.

Each national laboratory then performed two major, distinct tasks. First, each laboratory determined the impact of the future energy development on one or more impact categories (e.g., air quality, water quality, etc.) across the Nation (Step 3 - Figure 1). This exercise was referred to as the "lead lab" impact analysis and the assignment of a laboratory to a specific analysis was made on the basis of that laboratory's demonstrated expertise.

Secondly, each laboratory reviewed the data generated in the "lead lab" analyses from a regional perspective and utilized them to support their own intensive regional assessment (Step 4 - Figure 1). The assessments focused on specific problems unique to the particular region(s) for which the laboratories were responsible (see Figure 2) and involved further impact analyses where necessary.

Each of the steps described above are discussed in detail in the remaining sections of this report. In addition, the interrelationships among the various components of the study are identified and the unique aspects of the RIIA analysis are highlighted.

*Energy Information Administration, Annual Report to Congress, 1977, DOE/EIA - 0036/2.

FIGURE 1
MAJOR STEPS IN THE RIIA METHODOLOGY

"LEAD LABORATORY" ASSIGNMENTS FOR RIIA I

Oak Ridge National Laboratory (ORNL)	- Utilities siting
BEA level industrial siting
Water availability
Brookhaven National Laboratory (BNL)	- County level industrial siting
Industrial and utility emission factors
Eastern long-range transport of air pollutants
Public and occupational health and safety
Solid waste
Argonne National Laboratory (ANL)	- Water quality
Local air quality
Ecology/land use
Local socioeconomics
Los Alamos Scientific Laboratory (LASL)	- Visibility
Pacific Northwest Laboratory (PNL)	- Western long-range transport of air pollutants
Lawrence Berkeley Laboratory (LBL)	- National economics

FIGURE 2
FEDERAL REGIONS AND LABORATORY ASSIGNMENTS

CHAPTER 2

THE EIA SERIES C TRENDLONG SCENARIO

The EIA Series C Trendlong Scenario is one of six possible energy futures developed by the Energy Information Administration for DOE's Annual Report to Congress (1977). The Series C Scenario is commonly referred to as the "MID-MID Scenario" because it represents a mid-term (i.e., 1985 to 1990) projection of energy supply and demand reflecting medium supply and medium demand. The MID-MID Scenario further assumes:

- slight increase of indigenous oil production;
- constant world oil price of \$15.32 per barrel;
- continued decline of indigenous natural gas production;
- dramatic increase in coal production for electric generation, particularly in the West;
- growth in electricity sales of 4.8 percent per year, rather than the historic rate of 7 percent;
- moderate shifts by industry to use coal rather than oil/gas.

Table 1 shows the national MID-MID Scenario projections for energy supply and demand for 1985 and 1990 as well as the status in 1975. Under this scenario, total energy flow is projected to increase from 72.6 quadrillion Btu's (quads) in 1975 to 96.9 quads in 1985 and 110.9 quads in 1990 (Figure 3). Total electricity in 1975 was 2036 billion kilowatt-hours and, under this scenario, is forecasted to increase to 3045 billion kilowatt-hours in 1985 and 3692 billion kilowatt-hours in 1990. The fuel mix for electrical generation changes with increased use of nuclear power and decreases in oil and gas.

Figure 4 compares energy supply in 1975 and 1990 by fuel type. The growth of energy derived from coal, uranium and imported oil are the most significant changes. Since the MID-MID Scenario is only projected to 1990, alternate energy sources such as synthetic fuels are not an important part of the predicted energy mix.

The data described above and in the accompanying table and figures were derived from EIA's Energy Demand and Supply Forecast Model. This model tracks, in an accounting sense, the flows of coal, oil, gas, nuclear, geothermal, hydropower and solar energy from production and processing to each of the final four demand sectors - industry, commerce, transportation and residential - and electrical generation. In doing so, the model links the energy consumption trends of the final demand sectors to key economic variables (such as GNP, worker productivity, etc.) which impact energy trends and are themselves sensitive to these trends. Thus, the scenario encompasses both economic and energy projections.

TABLE 1
1975, 1985 and 1990 Energy
Supply/Demand Balance
(Quadrillion BTU per year)

Projection Series ¹	1975	1985	1990
<u>DOMESTIC PRODUCTION</u>			
Crude Oil	17.9	19.0	18.0
MGL and Butane	2.6	2.0	1.8
Shale Oil	0.0	.1	.3
Natural Gas	19.0	17.2	16.7
Coal	14.6	23.1	27.5
Nuclear	1.8	6.2	10.3
Hydro and Geothermal	3.2	4.2	5.0
TOTAL DOMESTIC PRODUCTION	59.1	71.8	79.6
<u>IMPORTS</u>			
Crude Oil	8.7	16.5	20.9
Petroleum Products	3.8	6.7	7.8
Natural Gas	1.0	1.9	2.6
TOTAL IMPORTS	13.5	25.1	31.3
TOTAL SUPPLY	72.6	96.9	110.9
<u>DOMESTIC CONSUMPTION</u>			
Oil	32.8	43.9	48.5
Natural Gas	20.0	19.1	19.3
Coal	12.8	21.2	25.4
Nuclear	1.8	6.2	10.3
Hydro and Geothermal	3.2	4.2	5.0
TOTAL DOMESTIC CONSUMPTION	70.6	94.6	108.5
<u>EXPORTS</u>			
Coal	1.8	1.9	2.1
Refinery Loss	.2	.4	.3
TOTAL CONSUMPTION AND EXPORT	72.6	96.9	110.9
<u>DOMESTIC CONSUMPTION BY SECTOR</u>			
Residential	14.7	19.0	21.2
Commercial	11.3	13.5	15.0
Industrial	26.0	40.7	49.0
Transportation	18.6	21.4	23.3
TOTAL DOMESTIC CONSUMPTION	70.8	94.6	108.5

¹For the EIA MID-MID Scenario

FIGURE 3

TOTAL ENERGY CONSUMPTION AND EXPORT

FIGURE 4

U.S. PRIMARY ENERGY SUPPLY MID-MID SCENARIO

The model also balances the quantity and cost of producing energy supplies with the projected quantity and purchase price of energy consumed by each final demand sector in order to arrive at an equilibrium supply and demand of energy for U.S. totals (i.e., when supply equals demand).

There are two key structural aspects of the model: an accounting framework on the supply side and an econometric analysis on the demand side. The accounting framework tracks by region and by fuel type both energy flows and mark-up costs at various stages of production, transport and transformation to arrive at a final price required to support a corresponding level of supply.

The econometric analysis is a statistical analysis of past trends which quantitatively links two kinds of cause and effect relationships. First, energy growth is linked to economic growth by means of a macroeconomic model on the U.S. economy. Second, the demand response for energy of each final sector is linked to a final purchase price. An equilibrium between demand and supply is achieved when the final purchase price of energy both clears the supply market by compensating for production costs and at the same time matches the willingness of each final demand sector to pay this price. This equilibrium position is consistent with the economic scenario. Certain fundamental assumptions about oil import prices, conservation measures, monetary and fiscal policy, oil lease sales and DOE mandated conversions from oil and gas underlie the growth trends of energy demand and supply.

The Energy Demand and Supply Forecast Model performs these computations for each of the ten Federal Regions and then aggregates these results to arrive at the national scenario depicted in Table 1. The disaggregated regional supply and demand projections are summarized in Table 2. These regional energy totals are important because EIA requested that they be used as control totals when the scenario was further disaggregated to subregional levels for subsequent facility siting. Each Federal Region, therefore, was treated as a closed system and interregional transfers of power were not considered (see Chapter 3). As a result, the environmental impacts in regions where power is generated for consumption in other regions may be understated while the impacts in regions where power is imported may be overstated.

Disaggregation of the Scenario to Subregional Levels

Two integrated models (Oak Ridge National Laboratory's MULTIREGION and the Regional Energy Balance System (REBS) were used to disaggregate the national MID-MID Scenario to workable subregional levels. Brief descriptions of the two models follow.

ORNL's MULTIREGION model, which utilizes the Bureau of Economic Analysis (BEA) area as the functional regional unit, provides the regional economic and demographic base for subnational energy consumption projections. MULTIREGION is a formal econometric/simulation model for projecting regional activity based on a national forecast.

MULTIREGION incorporates a "top down" approach in which predetermined (scenario) national projections of population, labor supply and employment are allocated to the BEA level. The model views a region's economy as a labor market in which labor supply is a function of mortality, fertility, migration and labor force participation; and labor demand is a function of a region's ability to grow in these sectors including natural resources, manufacturing and services sectors as measured by employment trends.

TABLE 2

REGIONAL ENERGY CONSUMPTION*
(TRILLIONS OF BTUs PER YEAR)

SECTOR/FUEL	REGION 1			REGION 2			REGION 3			REGION 4			REGION 5		
	1975	1985	1990	1975	1985	1990	1975	1985	1990	1975	1985	1990	1975	1985	1990
RESIDENTIAL	629	793	834	1224	1476	1500	1047	1135	1162	1128	1478	1786	2796	3390	3483
COMMERCIAL	552	721	775	986	1126	1155	714	751	802	844	1002	1122	1769	1786	1801
INDUSTRIAL	276	484	572	613	950	1089	2046	2628	2951	2066	2895	3474	3950	4832	5516
TRANSPORTATION	799	955	1031	1584	1809	1893	1784	2066	2232	3200	3929	4444	3475	4034	4300
RAW MATERIAL	20	39	49	56	121	152	115	205	258	235	430	554	230	415	518
TOTAL	2276	2991	3261	4463	5482	5789	5706	6785	7405	7473	9734	11380	12220	14457	15618
ELECTRICITY	228	298	342	472	705	801	616	956	1143	1242	2313	3049	1204	1853	2216
OIL	1733	2248	2445	2940	3548	3739	2610	3164	3458	3860	4968	5750	4908	6531	7101
NATURAL GAS	309	442	471	882	1001	1005	1258	1336	1385	1915	1896	1893	4480	3880	3930
COAL	6	3	3	169	228	224	1222	1329	1419	456	557	688	1628	2193	2371
TOTAL	2276	2991	3261	4463	5482	5789	5706	6785	7406	7473	9734	11380	12220	14457	15618

SECTOR/FUEL	REGION 6			REGION 7			REGION 8			REGION 9			REGION 10		
	1975	1985	1990	1975	1985	1990	1975	1985	1990	1975	1985	1990	1975	1985	1990
RESIDENTIAL	914	1258	1343	691	852	812	348	528	596	928	805	816	287	426	451
COMMERCIAL	742	806	853	476	394	397	303	328	358	671	600	611	292	333	345
INDUSTRIAL	1041	6678	8358	672	798	961	500	769	914	1036	1443	1693	464	657	754
TRANSPORTATION	2764	2892	3206	1165	1232	1320	679	799	879	2382	2831	3064	725	832	910
RAW MATERIAL	1413	2986	3812	123	211	263	24	48	59	91	166	208	82	134	124
TOTAL	9874	14620	17572	3127	3487	3753	1854	2472	2806	5108	5845	6392	1850	2382	2584
ELECTRICITY	700	1197	1415	279	456	543	147	336	396	587	698	788	360	627	750
OIL	3257	4278	5031	1290	1585	1764	889	1128	1311	2635	3153	3426	1021	1389	1639
NATURAL GAS	5853	9029	10975	1470	1313	1232	680	704	670	1827	1888	2058	441	282	80
COAL	64	116	151	88	133	214	138	304	429	59	106	120	28	84	115
TOTAL	9874	14620	17572	3127	3487	3753	1854	2472	2806	5108	5845	6392	1850	2382	2584

*Does not include electric utility fuel consumption

MULTIREGION generates BEA area projections of male and female populations for 16 age groups. Employment is forecasted for 37 sectors categorized by basic structure. Table 3 illustrates these sectors and their corresponding categories as depicted in the MID-MID Scenario. Resource-oriented industries are projected within a shift-share framework, manufacturing industries by a regional advantage approach, while service-oriented industries are projected by a regional base model.

MULTIREGION recognizes interregional linkages through an economic potential (distance) approach, such that the projections for a given BEA area are determined by the level of activity in nearby areas. Similarly, each industry is linked spatially and structurally to other industries which are purchasers or suppliers of inputs to the industries' product. Interregional migration and labor force participants are both incorporated in the model and related to underlying changes in regional employment potential.*

REBS was designed to bridge the gap between national energy models and the specific regional detail needed for impact assessments. In bridging this gap, the REBS system was also designed to use the MULTIREGION forecasts of population and employment. However, for the REBS system to be able to provide energy projections for a variety of regions, it was necessary to increase the regional detail available from the MULTIREGION - BEA forecasts. Consequently, ORNL developed a computer algorithm which allocates the BEA area projections provided by MULTIREGION to the constituent counties of each BEA. The model retains the detailed age/sex cohort structure and employment categories used in MULTIREGION. County population projections are made using 1970** census estimates of county populations by age/sex cohort (as a base for the first forecast period) and then aging the population - similar to the procedure used in MULTIREGION. Any differences in the projected BEA total, as computed from the summation of county forecasts and the MULTIREGION forecasts, are allocated proportionate to each county share. These county projections are then used as the base for the next forecast period.

Similarly, employment projections are initialized by 1970 county/sector employment data with any growth by sector allocated proportionally to the past employment patterns by sector. If a "new" industry appears in the BEA forecast, this is allocated based on total county employment. While the procedure is somewhat simple, it does allow for differential county growth depending on which industry is growing in the BEA.

The REBS system incorporates three component modules to provide a comprehensive view of regional historic and projected energy conditions: (1) an energy consumption submodel; (2) a primary energy production submodel, and (3) an energy transformation submodel. Since the MID-MID Scenario assumes equilibrium between regional energy supply and demand (i.e., regional control totals), only the energy consumption submodel was used for the analysis.

*For more detailed information regarding MULTIREGION see Olsen, Richard, et. al., MULTIREGION: A Simulation Forecasting Model of BEA Economic Area Population and Employment, ORNL/RUS-25 (n.d.)

**For RIIA I, ORNL "fine tuned" regional population estimates to the 1975 census estimates.

TABLE 3

MULTIREGION SECTORS AND THEIR
RELATIONSHIP TO THE MID-MID SCENARIO SECTORS

Scenario Aggregated Sectors	MULTIREGION Sectors
Residential ¹	Total Population
Commercial ²	Amusement Services Business and Repair Services Communications Finance, Real Estate and Insurance Services Lodging and Personal Services Professional Services Private Household Services Retail Trade Wholesale Trade Public Administration (Federal, State, and Local Government) ² Armed Forces Utilities
Industrial	Agriculture Forestry and Fisheries Metal Mining Coal Mining Crude Oil and Gas Non-Metallic Mining Construction Food and Kindred Textiles Apparel Paper Printing and Publishing Chemicals Fabricated Metals Primary Metals Machinery (Non-Electrical) Electrical Machinery Motor Vehicles Transportation Equipment (Excluding Motor Vehicles) Other Manufacturers
Petroleum Refining ³	Petroleum Refining
Transportation	Population ⁴ Rail Trucking and Warehousing Other Transportation Services ⁵

¹Reported in tables as residential demand.

²Reported in tables as miscellaneous.

³The MID-MID Scenario includes the consumption of electricity and coal by the refining sector in the industrial total, but separately report petroleum products and natural gas demands for the sector. We follow their convention in the allocations, but report all fuels used in the refining sectors in the industrial total.

⁴Population is used to regionalize gasoline demands.

⁵Includes air and water transportation employment.

Energy consumed by final end uses in the residential, commercial, industrial, and transportation sectors was estimated using historic energy consumption patterns and regional economic activity by sector. Since substate consumption data are not available in a consistent manner for all fuels considered in the REBS system, an estimating scheme was used for developing historic data series. In the case of the historic energy consumption series, state-level consumption data developed by the Bureau of Mines were regionalized to the BEA areas using employment data from County Business Patterns.

The energy consumption submodel projects regional energy demand using base year energy use patterns and forecasted economic activity. These estimates are generated separately for each fuel considered and each of the employment sectors projected by the MULTIREGION model and a residential sector represented by total population. The regional unit utilized may be the county or any aggregate of counties. Because of the large number of fuels usually considered in any given analysis, multicounty* regions were utilized in RIIA for the unit of analysis in order to facilitate the data processing.

Using the county-level forecast of population and detailed employment provided by MULTIREGION and the county algorithm, ORNL computed a demand for a fuel using the following simple equation:

$$\text{Demand} = \left(\frac{\text{Energy}}{\text{Employment}} \right)_{\text{Base}} * \left(\text{Employment} \right)_{\text{Forecast}}$$

The forecasted employment (population) was multiplied by the per worker (capita) consumption exhibited in a base year. Energy per worker indices were computed based on 1971-1972 data using state data from a variety of sources. It was thus assumed that regional differences were represented in the historic state data, and moreover, energy consumption patterns by industry were similar within individual states.

A simple interpretation of the procedure is that the demand estimates represent the amount of an energy product required if industries maintain their historic consumption patterns but have the activity (employment) forecasted. The individual demands can then be summed to the sectoral/regional level contained in the scenario forecast. Since the scenario projections employ a change from historic consumption patterns, the sum of the demand estimates were adjusted to match the projected energy consumption in the scenario. This procedure was to simply proportionately adjust each of the component demands so that they add up to the projected total in the controlling scenario.**

Table 4 presents the fuels for which individual projections were made. Two files were developed from the MULTIREGION/REBS output - one for electricity demand and another for the industrial sector. The electricity consumption file was retained by ORNL for the electric utility siting analysis while the industrial file was transmitted to Brookhaven National Laboratory where industrial facilities were sited at the county level.

*Multicounty units are defined as the largest grouping of counties that will allow simple aggregation to the different grids required in a study.

**For more detailed information regarding the REBS system see Vogt, D.P., et. al., REBS: A Methodology for Addressing the Regional Implications of National Energy Scenarios, ORNL/TM (in draft).

TABLE 4

DEFINITION OF FUEL AGGREGATES AND THEIR
RELATIONSHIP TO MID-MID SCENARIO PROJECTED FUEL AGGREGATES*

Fuels Defined in the Regionalization Procedure	Scenario Aggregated Fuel Category	Reported Aggregates
Anthracite	Coal	Coal
Bituminous	Coal	Coal
Metalurgical Coal	Coal	Coal
Natural Gas	Natural Gas	Natural Gas
Kerosene	Distillate Oils	Otherhydro
Diesel Fuel	Distillate Oils	Distillate
Distillate Fuel Oil	Distillate Oils	Distillate
Gasoline	Gasoline	Gasoline
Asphalt	Asphalt	Otherhydro
Liquid Propane Gas	Liquid Gas	Otherhydro
Jet Fuel	Jet Fuel	Otherhydro
Liquid Refinery Gas	Liquid Gas	Otherhydro
Still Gas	Liquid Gas	Otherhydro
Naphtha	Naphtha	Otherhydro
Special Naphtha	Liquid Gas	Otherhydro
Petroleum Coke	Miscellaneous Oil Products	Otherhydro
Lubricants and Waxes	Miscellaneous Oil Products	Otherhydro
Miscellaneous Liquid Gases	Liquid Gas	Otherhydro
Miscellaneous Oil Products	Miscellaneous Oil Products	Otherhydro

*D.P. Vogt, et. al., REBS: A Methodology for Addressing Implications of National Energy Scenarios, ORNL/TM (in draft).

CHAPTER 3

FACILITY SITING METHODOLOGIES

Because the magnitude and significance of environmental and socioeconomic impacts are contingent upon the geographic and demographic settings to which energy development is introduced, effective assessment of these impacts requires that their potential sources be located as specifically as possible. As a result, the second major step in the RIIA I process was the establishment of plausible county level siting patterns for electric utilities, major industrial facilities and fuel extraction and processing facilities. As will be seen, these siting patterns formed the basis for all subsequent environmental and socioeconomic residual calculations and assessments.

A. ELECTRIC UTILITY SITING

Electric utility siting patterns for RIIA I were established by Oak Ridge National Laboratory (ORNL). ORNL has had a long history of transforming estimates of future energy demand into siting patterns of energy production.* As previously mentioned, the MID-MID National Scenario was disaggregated to multi-county forecasts of electric energy demand as well as possible technology mixes (i.e., the proportion of coal, nuclear, oil, gas, etc.) that may be used to meet the demand in 1985 and 1990. In developing utility siting patterns, ORNL attempted to match the proportionate mixes specified by the scenario as closely as possible.

ORNL's past experience in regional modeling has prompted the development of a computerized site-selection procedure capable of multiple resource analyses, using different constraints and scenarios. However, because some decisions cannot be completely simulated by the computer, the design also accommodates manual operation whenever human judgment is required. This computerized site-selection procedure is known as Oak Ridge Spatial Analysis Model (ORSAM).

ORSAM represents a concept involving a collection of models. The components of the system are illustrated in Figure 5 and further described below.

Geographic Specification of Energy Demand

Present and future energy facility siting patterns, up to 1985, are based on knowledge of existing and proposed generating capacity data unless modified by the scenario. A fundamental reference for information on existing and proposed electric generating facilities is available from the Federal Energy Regulatory Commission (FERC).** ORNL has updated and corrected the FERC data set substantially through

*See R. B. Honea, E. L. Hillsman and R. F. Mader, Oak Ridge Siting Analysis: A Baseline Assessment Focusing on the National Energy Plan, October, 1979, ORNL/TM-6816.

**The Federal Energy Regulatory Commission, Office of Public Information, Generating Unit Reference File (updated by Oak Ridge National Laboratory).

FIGURE 5

ORNL SITING ANALYSIS APPROACH

communications with utility companies, with the use of published data on plant cancellations and the assistance of other laboratories participating in the RIIA program. Using this data base, it is possible to construct a detailed picture of the supply infrastructure as viewed by the utilities at any given year up to about 1990. Included in the data file is a description of the capacity, plant type, fuel type, cooling type, and location of generating units over 10 MWe in the United States. The file also indicated the year a facility came on line, or is scheduled to come on line, and the scheduled date of retirement for some generating units.

The 1985 siting pattern is easily determined by the announced expansion plans of the utilities. Most of the existing and proposed facilities will be operating in 1990, but the location for unscheduled or replacement plants, which must come on line to meet demands beyond 1990, is uncertain. To site the capacity required to meet these increases, it is essential to know where the deficits will occur. Demand is expressed in terms of required capacity so that existing and proposed capacity can be subtracted to show net deficits or surpluses of power production by subregion. Before beginning a siting analysis, surplus power is normally redistributed to the nearest deficit region.

The disaggregation of the MID-MID Energy Scenario to ten Federal Regions provides basic information on the level of demand for which capacity must be sited and also provides the relative amounts of generating or processing capacity in each technology and fuel type that must be sited in a given federal region. The technology mixes serve as guidelines and control totals in the allocation of capacity within a given region, but do not necessarily determine the final mix sited in any given county or Bureau of Economic Analysis (BEA) area. The fuel mixes in the regional disaggregations received by ORNL were often substantially different from those planned by the utility companies in the regions. For this reason, the facility siting patterns prepared for the RIIA analysis may be quite different from those that actually develop in 1985 and 1990.

Technology Characterization and Development of Siting Criteria

One of the first steps in developing the siting methodology for RIIA was to identify the factors that must be considered by the utilities and state agencies in locating acceptable energy facility sites. To systematically accomplish this important step, ORNL adapted a group processing technique to the problem of factor identification. Two nominal group sessions were conducted to obtain expert opinion from power plant siting specialists.

The nominal group technique is a highly structured, interactive approach which has been widely accepted in health and social services, education, industry, and government.* 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 in a serial discussion; (3) discussion of each recorded idea for clarification and evaluation by the group; and (4) independent voting, with the group decision resulting in a mathematical ranking. The strengths of the technique lie in enhanced participation by group members, step-by-step movement toward a goal, and cross-education of participants.

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

ORNL's sessions resulted in lists of weighted factors that have become the basis for the factor models used in the siting method. The regional siting factors, identified by one of the nominal group technique panels, are shown in Table 5.

In a related project associated with identifying candidate siting regions for the State of Maryland, staff members of the Maryland Power Plant Siting Program provided ORNL with weighted factors for both coal and nuclear plants. The Maryland criteria weight inputs were modified to specify candidate siting regions for the RIIA analysis.

The minimum criteria to be considered in the county-level siting analysis for coal-fired electric generating facilities were specified by a DOE Siting Work session held in 1975 at Argonne National Laboratory. These criteria are:

1. Proximity to load centers. The factor to be considered is the distance to the load center or centers as an indication of the cost of transmission from each potential site.
2. Water availability. Water availability is considered in terms of the flow available 95% of the time and the 7-day/10-year low flow. The percentage of this flow actually available for energy use may vary from region to region; precise estimates cannot be obtained in most areas.
3. Coal availability. The relative availability of coal, as indicated by the magnitude of the reserves and by the transport distance, has been established at a subregional level using methods provided by the Siting Work Group. This information, relating to delivered price, is considered in selecting the location of the plant relative to the producing mine.
4. Air-quality constraints. Air-Quality Maintenance Areas (AQMAs), as defined by the Environmental Protection Agency (EPA), have been considered as exclusionary areas for coal-fired plants except in the case where other overriding constraints make use of these areas mandatory. Regulations for the prevention of significant deterioration (PSD) have not been used in the initial baseline siting patterns.
5. Seismic risk. Areas of high seismic risk (zone 3 as designated on the U.S. Geological Survey (USGS) seismic risk maps) are excluded as sites for nuclear facilities.
6. Population distribution. Population constraints exclude areas of 500 or more per square mile for siting of nuclear facilities. AQMA constraints often exclude coal-fired facilities as well.
7. Public lands. No facilities have been sited on state or federally owned lands.

TABLE 5

FACTORS AND WEIGHTS, SECOND GROUPS, REGIONAL CONTINUOUS

First Vote	Second Vote	Factor	Definition
92	98	Availability of water	Reflected in costs for acquiring water (example - reservoir), impact of getting and using water, and chance of future conflict with growing use by others
95	97	Minimum proximity to undesirable population distribution	NRC guidelines
93	94	Minimum adverse geological features	Geology and soils related to foundation cost and safety considerations of subsidence
95	89	Minimum adverse impact on regional aquatic biota	Rare and endangered species and loss of habitat
85	88	Minimum susceptibility to maximum hydrological/meteorological events	Includes such things as dam failures and floods
89	85	Minimum adverse impact on regional terrestrial biota	Rare and endangered species and loss of habitat
80	83	Minimum adverse impact on existing and potential land use	Incompatibility with perceived future or present use of site and surrounding area
75	72	Minimum value for Bureau of Economic Area Region	Calculation of potential acceleration caused by seismic activity. Tectonic province used at this scale. Determines if standard plant design can be used
71	70	Regional water quality	Impact on quality by plant and quality of input for plant
57	58	Presence of acceptable transportation systems	Could not be sufficiently defined
43	58	Land surface slope and relief	Rough terrain leads to excessive grading costs and poor accessibility
53	55	Minimum proximity to man-made hazards	Airports, military installations, etc.
46	46	Acceptable air diffusion	Poor diffusion leads to double containment and increased costs
53	43	Minimum adverse impact on historical/archaeological areas	Proximity to important sites or presence of unexplored sites as Indian mounds
45	41	Adverse impact on regional economy	Housing, services, etc.
43	38	Minimum impact on regional recreation	Affect patterns of recreation or type of recreation
31	35	Maximum proximity to load	Could not be sufficiently defined
36	29	Unfavorable attitude of regional population	Potential for local opposition
17	17	Maximum reliability of offsite power	Power to run plant, a safety concern

Source: A. H. Voelker, "Power Plant Siting: An Application of the Nominal Group Technique. ORNL/NUREG/TM081, Oak Ridge National Laboratory. Oak Ridge, Tennessee (February 1977).

Quantification of Siting Criteria

The siting analysis at ORNL used a candidate site-screening procedure to locate potential counties suitable for energy facilities across the United States. The criteria used in this procedure were prepared as described below.

Accessibility to Load Centers. Accessibility-to-load-center calculations were not directly entered into the site suitability calculations. Rather, the accessibility calculations were used at a later stage to guide the allocation process toward those highly suitable areas close to load centers. Transmission was limited to 483 km (300 miles) and was based on present technology in transmitting power along AC lines.

Water Availability. Water availability is considered a prime locational determinant in energy facility siting. 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, a cumulative account must be made of the water requirements 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, and substantial annual and seasonal variations exist. Therefore, there is a need to develop computer methods to assess water availability from a regional perspective down to specific site evaluation. The Water Analysis System (WAS) developed at ORNL aids such availability analysis.*

The WAS enables the user to select, retrieve, and analyze historical stream-flow information from the USGS daily-value water tapes, which contain data for all USGS stream-gauging stations in the United States. The system is divided into distinct modules that presently 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 a given rate of stream flow at a specified rate of consumption.

Descriptions of low-flow availability uses flow estimates were generated by WAS and information on the effects of reservoir regulation were obtained from the U.S. Army Corps of Engineers.** A detailed characterization of low-flow at the county level is not yet complete for the entire United States. However, a baseline county approximation was constructed using stream-reach data compiled in a study by the USGS.***

*J. S. Jalbert and A. D. Shepherd, A System for Regional Analysis of Water Availability, Oak Ridge National Laboratory, ORNL/NUREG/TM-82, June 1977.

**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.

***S. J. Stankowski, J. J. Limerinos and S. E. Buell, Stream Reaches in the Conterminous United States Where Dependable Flows at 300 Cubic Feet Per Second are Available or Could be Provided, U.S. Geological Survey Report 77-646, Reston, VA, 1977.

Coal Availability. An inventory of coal reserves by county for the U.S. was compiled in terms of coal production potential. Coal production potential is assessed in terms of total coal reserves, surface and deep coal seam thickness, coal quality, and past coal production. The ultimate result is a systematic quantification and mapping of the areas where coal is likely to be mined according to the production levels forecasted in the scenario. The feasibility of coal-fired generating plants in a given demand area were then determined based on proximity to supply. To do this, coal availability at the mines was combined with a transportation model. By coupling this result with a transport model, the relative availability of coal at various points throughout the Nation was determined.

Air Resource Limitations. Because air quality is an important consideration in siting coal-consuming energy facilities, ORNL 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 had not yet been demonstrated at the time of this assessment. As a result, Air Quality Maintenance Areas (AQMA) designated by the EPA were used in lieu of quantitative air-quality standards. AQMA are regions defined by combinations of counties, or portions of counties, in which future air-quality degradation will be carefully monitored by regulatory agencies; therefore, AQMA are less suitable for siting coal-using facilities than non-AQMA counties.

Transportation Limitations. For determining transportation suitability, ORNL utilized its county-level information system data on rail and barge transport availability. For RIIA I, the availability of rail transportation for a county was coded as presence or absence of a rail line. For barge transportation, the length of barge channels in a county was used as a measure of availability of barge service. 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. For future RIIAs rail accessibility information will be merged with existing data concerning water transportation to produce better transportation accessibility measures at the county level in terms of energy facility siting constraints.

Population Distribution Limitations. Population density as a constraint to the siting of energy facilities (particularly in the case of nuclear facilities) was mapped for the United States. Several options in calculating site restriction based on NRC siting regulations were developed. The RIIA analysis used the percentage of a county with a population density greater than 500 per square mile as a constraint on siting power plants.

*The suitability of each county for satisfying projected demand is computed with a gravity model in the form of $P_i = (\text{BEA demand})/d^{1.5}$ applied between the centroid of each county i and all BEA centers; P is the calculated accessibility potential for county i , and d is the distance in miles between the county and each BEA center. The distance exponent, 1.5, was empirically derived to reflect the increased cost of delivering power over an increased distance and to reflect a maximum 241-km (150-mile) transmission limit to a load center.

Seismic Activity Limitations. Siting constraints were established for nuclear facility suitability based on seismic risk zones identified by the Nuclear Regulatory Commission. NRC based the delineation of these on the degree of difficulty in establishing seismic risk for a proposed nuclear plant.* In Zone I, suitable sites would be found with little difficulty. Zone II would require site specific studies to determine geologic seismic site suitability. This zone includes areas of moderate seismicity with complex geologic structures and areas close to zones of high seismic risk. It is considered impractical to locate nuclear facilities in Zone III because of the time and cost required to investigate sites. This area is characterized by high seismicity and recent faulting. Each county in the U.S. was classified on the basis of these three zones.

Suitability Calculation

The siting criteria described above were used to specify the general suitability of counties for various types of energy facilities. Quantitative expressions of these criteria captured by ORSAM were applied to the county-level information system (Oak Ridge Regional Modeling Information System (ORRMIS)) through a screening algorithm of the form:

$$S_i = \sum_{V=1}^N C_{Vi} I_V$$

where

S_i = suitability score for county i ,

V = variable (e.g., proximity to stream flow),

N = total number of variables,

C_{Vi} = compatibility index for value of variable V occurring in county i

I_V = importance weight of variable V .

*U.S. Nuclear Regulatory Agency, Nuclear Energy Center Site Survey, 1975, Part IV, National Technical Information Service, Springfield, Virginia, NUREG-0001, January 1976.

The county-level data base presently in ORRMIS is pertinent to energy facility siting only at the regional scale. These are continuous variables which do not change greatly over the area within a county. For example, seismic activity varies from one part of the nation to another, but variations within the relatively small area of a county (usually about 300 square miles in the eastern United States) are negligible. In contrast, certain variables, such as land surface slope and land use, fluctuate so much within a small area that an aggregate figure for each county would not be useful in regional screening for energy facility sites.

As noted previously, regional siting factors have been defined. Each variable has been assigned an importance weight to indicate its relative influence in the selection of suitable candidate counties for a facility, and each category within each variable has been given a compatibility index reflecting its positive or negative influence on the siting decision when it occurs in a county. The combined importance weights and compatibility indices for a given facility type are referred to as a siting criteria matrix.

Calculation of Site Suitability for Coal-Fired Generating Facilities. Siting specialists invariably rank water availability among the most important factors in regional screening for coal-fired generating plant sites (Table 6).

A 1000-MWe coal-fired plant with a wet-cooling tower requires a total water withdrawal of 17 million gal/day (Mgd) and loses 10 Mgd through evaporation and drift. A similar plant with once-through cooling withdraws 826 Mgd and consumes 3 Mgd. In either case, the water withdrawal requirement is significant enough to require selection of a site near an ample water supply. Since current policies (enforced mainly by the EPA) favor cooling towers, ORNL assumed this to be the cooling mode for all steam-electric facilities to be constructed in the future and have judged county suitability on the basis of a consumptive rate of 20 Mgd (sufficient to support a 2000-MWe coal-fired generating plant or a 1200-MWe nuclear plant).

A second major consideration for coal-fired plants is the status of air-quality maintenance in the candidate counties. Although federal standards do not explicitly prohibit construction of new coal-fired plants in AQMAs, it was believed that the potential for environmental damage and the cost of pollution abatement would justify exclusion of counties totally designated as AQMAs.

Concern for air quality also encourages the use of low-sulfur coal to reduce emissions of sulfur dioxide without the addition of costly scrubbers. Hence, proximity to large deposits of low-sulfur coal ($\leq 1.9\%$ S) was judged a highly positive factor. Accessibility of high-sulfur coal ($> 1.9\%$ S) was a positive factor of somewhat less importance.

Barge and rail access are considered important because of the huge volumes of coal that must be moved to the plant daily. Shipment by barge is a cheaper form of transportation than movement by rail, and the cost of trucking would be prohibitive except in the case of mine-mouth plants.

Calculation of Site Suitability for Nuclear Generating Facilities. It is apparent from the criteria matrix that siting specialists consider water availability to be of prime importance in choosing candidate sites for a nuclear generating facility (Table 7). Population density is also considered to be important because of the safety hazard that might result from the accidental release of radiation in a highly popu-

TABLE 6
REGIONAL SITING CRITERIA FOR A COAL-FIRED GENERATING PLANT

Variable	Importance weight	Category or value	Compatibility index
Water availability	10	Adjacent to stream with 7-day/10-year low flow ≥ 194 Mgd	10
		Adjacent to stream which could have 7-day/10-year low-flow ≥ 194 Mgd if additional regulation were imposed	4
		Adjacent to Great Lakes	8
		Adjacent to Atlantic Ocean or Gulf of Mexico	5
		Other counties	^a
Air quality maintenance areas (AQMA)	10	Not an AQMA	10
		Partially an AQMA	5
		Entirely an AQMA	^a
Accessibility of low-sulfur coal ($\leq 1.9\%$ S)	8	Values represent calculations from gravity model using tonnage of low-sulfur coal	
		Highest value	10
		Lowest value	1
		>300 miles from low-sulfur coal reserve	0
Barge accessibility	7	Adjacent to channel of ≥ 9 ft depth	^a
Seismic activity	6	Activity level I (lowest risk)	10
		Activity level II	5
		Activity level III (highest risk)	0
Rail accessibility	6	Adjacent to medium- or heavy-duty railroad	10
		Not adjacent to medium- or heavy-duty railroad	0
Accessibility of high-sulfur coal ($> 1.9\%$ S)	4	Values represent calculations from gravity model using tonnage of high-sulfur coal	
		Highest value	10
		Lowest value	1
		>300 miles from high-sulfur coal reserve	0
Population density	3	90-100% of county has ≥ 500 inhabitants per square mile	0
		80-90%	2
		70-80%	3
		60-70%	4
		50-60%	5
		40-50%	6
		30-40%	7
		20-30%	8
		10-20%	9
		0-10%	10

^aScore equals number of miles of channel (maximum is 94.6)

^bExcluded from consideration as potential candidate counties

TABLE 7
REGIONAL SITING-CRITERIA FOR A NUCLEAR-GENERATING FACILITY

Variable	Importance weight	Category or value	Compatibility index
Water availability	10	Adjacent to stream with 7-day/10-year low flow $\geq$ 194 Mgd	10
		Adjacent to stream which could have 7-day/10-year low flow $\geq$ 194 Mgd if additional regulation were imposed	4
		Adjacent to Great Lakes	8
		Adjacent to Atlantic Ocean or Gulf of Mexico	5
		Other countries	a
Population density	10	90-100% of county has $\geq$ 500 inhabitants per square mile	a
		80-90%	2
		70-80%	3
		60-70%	4
		50-60%	5
		40-50%	6
		30-40%	7
		20-30%	8
		10-20%	9
Seismic activity	7	0-10%	10
		Activity level I (lowest risk)	10
		Activity level II	5
		Activity level III (highest risk)	a
Barge accessibility	4	Adjacent to channel of $>$ 9ft depth	b
Rail accessibility	2	Adjacent to medium- or heavy-duty railroad	10
		Not adjacent to medium- or heavy-duty railroad	0

^a Excluded from consideration as potential candidate counties

^b Score equals number of miles of channel (maximum is 94.6)

lated area. A high level of seismic activity increases the risk of accidental release and is significant enough to exclude counties from consideration regardless of other characteristics.

For a nuclear facility, transportation accessibility is important primarily during the construction phase. Barge access contributes to site suitability because of the difficulty of transporting the huge reactor vessel over land. Railroads are a less desirable alternative for transport of the vessel, but may be the mode for moving many other construction materials. Sites in counties without barge or rail access require expensive movement by highway and often involve costly measures such as raising of power lines and special routing to avoid narrow bridges or other restricted passages.

Calculations of site suitability at the county level based on the criteria matrix for nuclear facilities were made for the U.S.

Siting Allocation Process

A basic assumption in allocating generating capacity to candidate counties was that the locational pattern of supply facilities should minimize transmission distance. Transmission line loss could amount to as much as 1% of the electricity for every 10 miles of transmission. Utilities are aware of this sizable loss, but in the past they have not considered transmission distance to be a major factor in site selection. In contrast, ORNL assumed that there will be increasing concern for minimization of transmission distances in future site selections because of the following:

1. Energy is becoming more valuable both in terms of costs and public opinion. There is increasing emphasis on improved efficiency in all generation and conversion processes. It would seem unwise to spend millions of dollars in research and development to improve the efficiency of a given plant by a small percentage and then lose what was gained by unnecessarily placing the plant additional miles from its load center.
2. Many traditional supply areas in the East will have trouble finding sufficient sites to meet their own demands by 2000. Indeed, a recent survey* of state energy offices indicates that almost all states are emphasizing a goal of self-sufficiency by 2000, and exporting additional power to distant consumers is out of the question.
3. There is increasing emphasis on cogeneration to use the heat given off by generating plants. Most forms of cogeneration would require sites near load centers to use "waste" heat (e.g., steam for district heating can be piped about 40 miles).

*F. D. Boerker and R. M. Davis, Identification of Energy and Environmental Issues in the South: Views of Officials from Selected State Agencies, ORNL/TM-6280, Oak Ridge National Laboratory (November 1978).

As discussed in the previous chapters, for each multistate region, the regional supply projections were disaggregated to subregional areas by the Regional Economics Group at ORNL. Using population and employment projections for Bureau of Economic Analysis (BEA) regions, ORNL then determined each BEA's share of the multistate supply total. That share was then assigned to the most populous county in the BEA, as a load center. Allocation procedures for each generating technology within a region were as follows:

1. Identify the load center requiring the least capacity.
2. Starting with the supply planned by the utilities nearest the load center, allocate supply until the projected supply* at the center is equalled, or until all scheduled supply within 100 miles of the center is allocated.
3. Repeat steps 1 and 2 for all load centers in order of increasing capacity requirements.
4. Repeat steps 1-3 for unsatisfied load centers, using allocated scheduled capacity in 100-mile rings, out to a maximum of 300 miles.
5. Identify the load center having the largest remaining supply requirement.
6. Starting with a county having excellent suitability, locate new capacity up to a total of 4000 MWe new and utility-scheduled capacity in any county. Repeat with more distant counties until the projected supply at the center is equalled or until all excellent counties within 100 miles are filled. An excellent county has a suitability score greater than one standard deviation above the national mean.
7. Repeat steps 5 and 6 for all unsatisfied load centers, in order of decreasing unmet supply projections.
8. Repeat steps 5-7 for unsatisfied load centers, using excellent-rated counties in 100-mile rings, out to a maximum of 300 miles.
9. If any supply requirement remains unsatisfied, repeat steps 5-8 using counties having good suitability scores. A good suitability score falls between the national mean and one standard deviation above it.

*The scenario identifies the technology mixes or supply required to meet the demand as forecasted. In other words, equilibrium is assumed by the scenario implying that supply is equivalent to demand.

The procedure used to allocate the capacity in successive years is identical except that the maximum capacity may be increased to 8000 MWe if the 4000 MWe limit prevents sufficient capacity from being sited to meet demand in a region. The 4000- and 8000-MWe limitations were used to avoid the simplistic solution of placing all capacity for a load center at one or two sites. If such concentrations were necessary, they appeared as clusters of 4000- or 8000-MWe counties. The option of combining these into a single energy park was still available.

Following the completion of electric utility siting analysis, the resulting patterns were distributed to the other national laboratories to be reviewed from a regional perspective. Any changes in the patterns were then transmitted back to ORNL where the data files were adjusted and redistributed to the laboratories for subsequent impact analysis.

Limitations of the Analysis

The ORNL siting methodology is based on the recent behavior of the electric utility industry. This has been an expanding industry, not a contracting one. Expansion has been in fairly small increments with little control or coordination of siting by public decision makers. The siting methodology attempts to simulate these trends, although it assumes that the nation as a whole, or multistate regions, are served by a single utility company rather than the hundreds that now operate.

The methodology based upon these processes is inadequate for disaggregating short-term forecasts such as those for 1985 and 1990 in the MID-MID Scenario. Short-term forecasts frequently show sharp reductions from existing generating capacity, as well as reductions from future plans. There is nothing in the methodology to handle these occurrences since the method is based on siting, not unsiting (i.e., retirement), processes. Consequently, ORNL had to resort to ad hoc procedures to retire or postpone (i.e., unsite) excess generating capacity. These procedures vary between scenarios and between regions within a scenario, depending upon the severity of the projected reduction. These ad hoc procedures make it difficult for other laboratories and or DOE to compare the results of different scenarios. Recent assessments have also emphasized the near future, and conversations with DOE staff indicate that this emphasis will probably continue.

The region where this situation is most prevalent is Region 8 where the MID-MID Scenario is inconsistent with current utilities' plans for energy development. Several utility plants already under construction were not included in the scenario. Also, most existing and planned plants were shown operating at a small fraction of potential capacity. Because of the assumption that all electric power is generated in the region where it is used, the scenario and thus, the siting model, does not allow for interregional transfers of electricity. Over 50% of the region's planned capacity is owned by investor utilities from outside Federal Region 8 and will be used by their customers.

The roots of the methodology in current utility behavior place an additional limitation on ORSAM's usefulness. These roots lend credibility to the use of the model to answer "what if?" questions. Increasingly, however, the public sector is also beginning to ask "what if?" questions that assume substantial public control over power

plant siting decisions.* One way to mitigate impacts may be to change the locations of future power plants. The public sector's questions, and the processes that they imply, tend to be concerned with distributions and equity of impacts. Mathematical programming approaches are more appropriate than weighting and screening methods for answering many of these questions.

In addition, the current methodology is inadequate for disaggregating projections that show increased hydroelectric, peaking, or solar technologies. Suitability scores, one of the variables in site selection, were developed only for new coal-fired and nuclear steam-electric plants and for coal conversion facilities. ORNL assumed that any projections for new oil- and gas-fired steam plants could be handled using the coal suitability scores. The emphasis on coal-fired and nuclear steam plants seemed appropriate, since these technologies will probably account for most of the increase in the nation's base load generating capacity during the mid-term. Moreover, the most severe environmental and social impacts have been associated with these technologies.

However, other energy technologies also have effects. Hydroelectric dam construction can have the same type of effects as nuclear plant construction in terms of public reaction. Hydroelectric reservoirs also affect water quality. The air pollution effects of internal combustion or distillate turbine peaking units may be small compared to that of a coal steam plant, but they do exist.

DOE laboratories in the RIIA program have expressed concern about the need to assess effects of these technologies. To assist them, a system must be developed which will treat these technologies with the same rigor that has been applied to steam electric capacity. Unfortunately, these facilities had to be sited in in an ad hoc manner for RIIA I.

A second gap in the coverage of existing processes is in capacity retirement. ORNL assumed that no generating capacity, other than hydroelectric, runs for more than 50 years. This is a conservative figure. Many steam electric units have retirement plans ranging from 30 to 45 years with little consistency between technologies or regions of the country. When this information is available, ORNL incorporates it into the siting pattern. However, information of this type exists for less than 20% of all units and the 50-year assumption may well be retaining too much of the existing capacity and not siting enough new units. This will affect the siting pattern and the projected distribution of effects.

A third gap is in the treatment of Alaska and Hawaii. ORNL has some utility plans for these states, but no other data (e.g., suitability data) comparable to the rest of the United States. As a result, ORNL has had to rely heavily on advice from the DOE laboratories responsible for analyzing these states.

Finally, the siting method works with generating capacity and not directly with generation from that capacity. For any technology within a region, generation is a constant proportion of capacity. DOE directed that ORNL match the generation for each region, allowing it to adjust capacity up or down to provide a "reasonable" siting

*Massachusetts Energy Facility Siting Council, An Integrated Regional Approach to Regional Energy Facility Siting, Phase 1, Final Report, Boston, Massachusetts, NUREG/CR-0241, Vol. 1 (1978).

pattern. The distribution of plants to match capacity may be different from a pattern to match generation, and this will reduce, exaggerate, or relocate impacts. For the RIIA scenario, ORNL used this situation to avoid siting new hydroelectric and peaking capacity in some regions, and to maintain planned coal capacity in others.

B. INDUSTRIAL SITING

While the utility siting analysis involved sophisticated computer models and procedures, the industrial siting analysis was merely a further disaggregation of the state-BEA fuel usage projections described in Chapter 2. These state-BEA portion projections of industrial energy demand were disaggregated to the county level by Brookhaven National Laboratory (BNL) on the basis of the 1974 geographic distribution of major fuel burning installations (MFBIs). The key assumption of the disaggregation process was that each county's relative share of the total fuel use in a given state-BEA portion remained constant over time to discount possible future intraregional shifts in the spatial patterns of industrial activity. (Note, however, that interregional shifts of industrial activity, indicating overall national trends of regional growth and decline, were reflected in the state-BEA portion projection themselves.) Within each county, energy use was assigned to size classes of combustor capacity (25 MW equivalent, 10-25 MW, and 10 MW equivalent) on the basis of the 1974 MFBI size distributions.

C. FUEL EXTRACTION FACILITY SITING

Siting of coal mines for 1975, 1985, and 1990 was developed by the Mitre Corporation from county level production figures. Base year (1975) coal production from underground and strip mining was determined by converting county tonnage estimates from the Keystone Coal Industry Manual into energy values (BTUs) using county thermal content estimates published by the Surface Mining Research Library. In some instances, it was necessary to scale the county tonnage estimates to meet the Bureau of Mines (BOM) production totals prior to conversion into energy units.

Future county energy production estimates were derived through a two-phase procedure for determining the location of future coal mines. In the first phase, published information (from such sources as the BOM, the National Coal Association, and the Keystone Coal Industry Manual) was utilized to determine both the mine location and the size of planned coal mine openings. This information was placed into a file and rank-ordered by the year in which new capacity is expected to be brought on line, and added to the depreciated base year county underground and surface mining production estimates. These estimates were separated by type of mining (i.e., underground and surface) and were scenario dependent. When the sum of the planned additional county capacities no longer met the national control totals, the second phase commenced. In this phase, historic trends in underground and surface coal production were utilized to allocate that production not met by the coal industry's planned mine openings to coal supply regions. Further disaggregation to the county level was accomplished by assuming that the county shares were the same as when the planned additional county mine capacity file ran out.

Utilization of the above regionalization procedure provided unconstrained underground and surface coal mining forecasts at the county level. However, as was found in previous uses of this approach, it was often possible for a county's production to exceed its reserves. To prevent this from occurring, a constraining mechanism was added to the regionalization procedure. Essentially, this constraining mechanism operated in the following manner:

- Using BOM data, county underground and surface reserves were estimated and adjusted to reflect recoverability.
- All counties were identified where underground or surface production exceeded the estimated reserve constraints. If the county production did not exceed the reserves by more than 20 percent, no adjustment was made since the BOM reserve data was considered to be both quantitatively and qualitatively accurate within 20 percent.
- When county production exceeded county reserves by greater than 20 percent, that amount was allocated to all other counties within the same coal supply region possessing sulfur within 50 percent of the depleted county's sulfur content. This allocation was made proportional to remaining reserves which possess sulfur contents within 50 percent, the sulfur constraint was progressively relaxed until all excessive production had been allocated.

The siting of uranium mines was made in a manner similar to that followed to develop sites for coal mines. The BOM's 1974 Minerals Yearbook was the primary source of data on current surface and underground mining production levels and sites. BOM's Information Circular on "Projects to Expand Energy Fuel Sources in the West" and personal communications with BOM regional offices were used to identify future production levels and sites. For active or future sites for which there was no information on future mining activity, it was assumed that the mining would continue and that there would be new openings in areas or counties adjacent to active sites.* Finally, the surface-to-deep mining ratio in 1975 was 55:45.** Because there are more reserves in deep deposits than in stripable deposits, it was assumed that this ratio would shift to 52:48 in 1985 and 50:50 in 1990.

Sources of other fuels - oil and gas wells, geothermal wells and solar facilities - were not sited at this point in the RIIA program. Instead, it was the responsibility of the laboratories to site these facilities for the region(s) for which they conducted their impact assessments (see Chapter 5).

*Energy Research and Development Administration, Uranium Industry Seminar, October 19-20, 1976: Volume II. FJO-108(76).

**Emanuel Gordon, "Uranium 1975," Engineering and Mining Journal, McGraw Hill, New York, March 1976.

CHAPTER 4

"LEAD LAB" METHODOLOGIES

Following the establishment of 1985 and 1990 siting patterns for electric utilities, industrial facilities and mines, the laboratories participating in the RIIA program computed the impacts of these facilities upon the human and physical environments to which they would be introduced. This phase of the RIIA program was referred to as the "lead lab impact analysis" because each laboratory had the responsibility (or lead) in computing the effects of the MID-MID Scenario upon one or more impact categories for the entire nation. The data generated during these analyses were then distributed among the various laboratories to be used in their intensive assessments of the state and regional implications of the scenario.

Background of the Lead Lab Concept

The lead lab concept is relatively new, having its roots in the National Coal Utilization Assessment (NCUA)* conducted by RAD's sister organization, the Technology Assessments Division (TAD) during fiscal years 1977 and 1978. During the first iteration of NCUA, each of the participating national laboratories had the responsibility of assessing the environmental and socioeconomic impacts of a given national scenario for all impact categories for their region. Although the resulting analysis represented a comprehensive assessment of the regional implications of a national policy scenario, any attempt to aggregate or compare the results among regions was fruitless due to the inconsistencies incorporated in the laboratories' basic assumptions and analytical procedures. To remedy this situation, the second iteration of NCUA incorporated a procedure whereby each laboratory computed the impacts of the scenario for one or more impact categories for the nation utilizing a consistent set of assumptions and consistent methodologies across regions. The assignment of a particular laboratory to a specific impact category was made based upon that laboratory's expertise, as demonstrated in the first iteration of NCUA and other DOE-sponsored environmental assessments.

RIIA I represented a continuation and further refinement of this, the lead lab analytical concept. Under RIIA, new impact categories were added to the analysis and existing analytical procedures and computer models were adjusted to meet the specific goals and objectives of the RIIA program.

The Lead Lab Process

At first glance, it seems as though the lead lab concept would be relatively straightforward and rather simple to execute. However, as illustrated in Figure 6, the lead lab process is extremely complex requiring constant monitoring and expediting on the part of RAD and its contractor, Systems Consultants, Inc. (SCI).

*An Assessment of National Consequences of Increased Coal Utilization, Volumes 1 and 2, Department of Energy, Assistant Secretary for Environment, February 1979, TID-29425.

REGIONAL ISSUE IDENTIFICATION AND ASSESSMENT "LEAD LAB" PROCESS

FIGURE 6

PREPARED BY:

In all, eleven (11)* impact categories were addressed in the RIIA analysis:

- local air quality (ANL)
- Eastern long range pollutant transport (BNL)
- Western long range pollutant transport (PNL)
- visibility (LASL)
- water quality (ANL)
- water availability (ORNL)
- local socioeconomics (ANL)
- national economics (LBL)
- health effects (BNL)
- ecology/land use (ANL)
- solid waste (BNL)

In many cases, the computation of the effects of the MID-MID Scenario on one impact category was partially or totally dependent upon data from another impact category. For example, the visibility, health effects and ecology/land use analysis required data from the local air quality and Eastern and Western long range pollutant transfer analyses before the impacts could be quantitatively estimated. This situation, referred to as the "Critical Path" of the analysis, required the timely transfer of large amounts of data among the various laboratories. Considering the geographic dispersion of the laboratories participating in the RIIA program, as well as their varying computer capabilities, the successful and timely transfer of these data required the development of sophisticated data transmittal systems.

Furthermore, in order for a receiving laboratory to effectively utilize data from a generating laboratory, the data and the methodology used to generate them had to be well documented to be understood. To facilitate this understanding, RAD held a series of workshops at which lead laboratories explained their methodologies, described the format and utility of the forthcoming data, and entertained questions. These workshops not only aided the effective execution of the lead lab concept but also fostered the development of a team spirit among the laboratories by providing a forum for the exchange and discussion of relevant ideas and concepts.

This section of the report presents detailed descriptions of the methodologies and computer models utilized during the RIIA I lead lab analyses. These descriptions are arranged according to the following format:

AIR RESOURCES

- Air Pollution Emission Factors
- Local Air Quality
- Eastern Long Range Pollutant Transport
- Western Long Range Pollutant Transport
- Visual Air Quality

WATER RESOURCES

- Water Quality
- Water Availability

*Institutional constraints to energy development represent a twelfth impact category, however, these impacts were addressed during the regional assessment portion of the RIIA I analysis (see Chapter 5).

SOCIOECONOMICS

- Local Socioeconomics
- National Economics
- Health Effects
- Occupational Health and Safety
- Public Health

ECOLOGY AND LAND USE

- Ecology/Land Use
- Solid Waste

AIR RESOURCES

RIIA I's assessment of the impact of the MID-MID Scenario upon the Nation's air resources involved five lead lab analyses:

- 1) the calculation of air emission factors (BNL)
- 2) local air quality (ANL)
- 3) Eastern long range pollutant transport (BNL)
- 4) Western long range pollutant transport (PNL)
- 5) visual air quality (LASL).

The Critical Path of the RIIA analysis described in the previous section was most evident in this part of the study. As illustrated in Figure 7, the data output from the air emission factors analysis served as input to the local air quality and Eastern and Western long range pollutant transport analyses. Similarly, the data output from the long range transport analyses were used as data input to the visual air quality analysis. In addition, the ecology, solid waste and public health analyses all utilized data from the air resources analyses as input. These relationships and dependencies are further described below.

A. AIR POLLUTION EMISSION FACTORS

Brookhaven National Laboratory (BNL) developed and implemented the techniques for computing the air pollution emission factors for coal, oil and natural gas combustors. These techniques were extremely complex and are fully described in a document published by BNL.* A brief summarization of these techniques is presented here for utility and industrial sources.

Utility Sources

The calculation of utility emission rates was based on the siting information prepared by ORNL. The siting information was crucial because the location of a plant implicated a probable series of assumptions on coal, oil and gas characteristics, plant sizes, and emission controls to be required at each location to meet local air quality standards.

The ORNL siting data estimated the BTU electric requirements for utility plants (see Chapter 3). The following expression gave the annual emissions of SO_2 in pounds per year for each county:

$$E_{SO_2} = \sum_{j=1}^n \left(\frac{BTU_{outj}}{H_L} \right) \left(\frac{S_L}{100} \right) \left(1.988 (1-f_j) \right)$$

where:

H_L = heat content of fuel, in BTU/lb, for the L^{th} county

BTU_{out} = the electrical output for the plant, where $BTU_{out} = (\lambda g)$;
and λ = the number of plants having a certain emission system
 j (like FGD, FBC, etc.) and g the electrical output for oil,
gas and coal boilers

*Brookhaven National Laboratory, A Methodology for Estimating County Level Air and Solid Waste Residuals (Draft), September, 1979.

FIGURE 7

RELATIONSHIPS OF AIR RESOURCES ANALYSES

S_L = fuel's sulfur content, wt%, for the L^{th} county
 f_i = fraction of SO_2 removed by emission system j
 1.988 = ratio of molecular weights of SO_2 to S

Major Assumptions:

Coal Characteristics: Average heating value, ash and sulfur content of coal used in each state were assumed to correspond to those used in 1976, but excluding certain low sulfur coals shipped over long distances for blending purposes to meet State Implementation Plan (SIP) requirements. This definition of coal characteristics, and sulfur contents in particular, corresponds to the use of locally available coal likely to be in use by 1985 under the provisions of the 1977 Clean Air Act Amendments.

Plants Size and Location: The size and location of coal burning plants were determined by a nationwide siting analysis prepared by Oak Ridge National Laboratory (ORNL), the details of which are discussed in Chapter 3, the Siting Chapter of this report.

Emission Controls: Assumptions concerning the extent and efficiency of sulfur emission control systems are the most difficult to make with any precision. For this study, a differentiation between those plants that were in operation prior to 1976, plants built between 1976 and 1982, and plants built after 1982 was made.

Plants operating in 1985 and 1990 that were operating prior to 1976 were assumed to meet the SIPs. Plants that were built between 1976 and 1982 were assumed to meet the SIPs or the New Source Performance Standards (NSPS), whichever is more stringent.* Because of the uncertainty in the NSPS, which will be in effect for plants built after 1985, two scenarios of control were defined. The two scenarios are identical for plants built up until 1982, and assume either 85% or 90% long term removal of SO_2 for plants with startup dates after 1982.

Industrial Sources

Since industries use fossil fuels similar to those used by the utility sector, emission data at the county level were calculated by a method akin to that followed for the utility sector emission factor computations.

As previously mentioned, a somewhat complicated computational procedure was used to assign emission control devices to existing and new industrial capacity. Briefly, emissions for gas and metallurgical coal were left uncontrolled, as per EPA information. Other new plants (built from 1975-onward) were assumed subject to the SIPs.

The decrease in plant efficiency attendant with the imposition of increased controls is not reflected in the emission inventory. Thus, the BTUs of fuel consumed in the utility sector is not a function of the control level. As a consequence, the 90% control on emissions does not reflect the additional amount of fuel that must be utilized to compensate for the slightly reduced plant efficiency. The relatively minor decrease in emissions upon going from 85 to 90% control is due to the relatively small contribution of new (after 1982) plants to the total SO_2 emissions.

*After this study was completed, the EPA published (on 11 June 1979, 44FR33580) final rules on NSPS for electric utilities: for solid fossil fuels an emission limit of 1.2 lbs of SO_2 per million BTU heat input and a monthly reduction of 90%.

B. LOCAL AIR QUALITY

The purpose of the local air quality analysis was to determine the county-level air quality implications of the siting pattern for the MID-MID Energy Scenario (see Chapter 3). The study was designed as a "screening" analysis whereby Argonne National Laboratory (ANL) identified counties in the U.S. where significant local air impacts are most likely to occur in 1985 and 1990 as a result of the implication of the scenario.

ANL calculated expected changes in air quality concentrations of sulfur dioxide (SO₂) and total suspended particulates (TSP) for 1985 and 1990 using a rollback (or proportional) modeling technique. Rollback modeling is a simplified approach for determining increases (or decreases) in pollutant concentrations by assuming that a given percent increase (or reduction) in facility pollutant emissions results in a similar or proportional increase (or reduction) in pollutant concentrations.

Increments in air quality concentrations are calculated using the following equation:

$$AQ (CONC 85) = \frac{AQ (75) \times EM (85)}{EM (75)}$$

where:

AQ (CONC 85) = Increased (or decrease) air quality concentrations for 1985
AQ (75) = Actual 1975 air quality concentration
EM (85) = Projected emissions increase (or decrease) for 1985
EM (75) = Actual 1975 emissions

Input data to the rollback model requires total county level emissions for both the base year (1975 in this case) and for the forecast periods, 1985 and 1990. Input data also includes pollutant concentrations representative of air quality for the county in the base year. These input data are further defined.

Total emissions data for 1975 were obtained from the Environmental Protection Agency's National Emissions Data System (NEDS). This data base includes data regarding all pollutants emitted to the atmosphere from all sources. The energy combustion emission projections for 1985 and 1990 were provided to ANL by Brookhaven National Laboratory (BNL) (see previous section). It should be noted that since BNL only projected energy-related emissions for the two scenario years it had to be assumed that emissions from process operations (e.g., smelters, etc.) would remain constant.

Base year (1975) pollutant concentrations for SO₂ and TSP were obtained from EPA's 1975 Storage and Retrieval of Aromatic Data (SAROAD). SAROAD is a national summary of ambient air quality levels derived from actual EPA monitoring facilities located throughout the Nation. For the purpose of the RIIA I analysis, ANL utilized 3-hour, 24-hour and 1-year SO₂ concentrations from SAROAD and 24-hour and 1-year TSP concentrations. For averaging times of less than one year, the "highest, second highest" reading of monitors in a county was selected as the appropriate value to assess whether a county was in attainment or nonattainment of National Ambient Air Quality Standards (NAAQS) for 1975. For the rollback analysis, a non-source specific background was assumed for particulate matter (30 µg/m³ for the annual reading and 15 µg/m³ for the 24-hour reading, as a minimum). The lowest monitor readings were used if they were greater than these assumed values.

For counties in which a new facility was to be sited in 1985 or 1990 where none previously existed, an alternative method of analysis was utilized. In these counties, contributions to ambient air quality from new energy facilities were determined from curves relating maximum air quality impact to pollution emission rate. These curves were developed using dispersion models applied to a number of real utility sources.

For the purpose of screening those counties in which significant impacts would most likely occur in 1985 and 1990, ANL developed a scheme whereby potential conflicts between the air quality changes arising from energy development and applicable Federal air quality standards were identified. Twelve categories of impacts were identified and ranked in decreasing order of severity:

- A - PSD Class I increment exceeded
- B - Nonattainment counties for SO₂ and TSP
- C - Nonattainment counties for SO₂ only
- D - Nonattainment counties for TSP only
- E - NAAQS exceeded
- F - PSD Class II increment exceeded
- G - No 75 AQ data: >25% increase in SO₂ emissions
- H - No 75 AQ data: >25% increase in TSP emissions
- I - PSD Class I area siting but no violations
- J - Emissions increase but no projected violations
- K - Insignificant change in emissions (any circumstances)
- L - Decrease in emissions (or insignificant change for one year)

The results of this screening analysis were then disseminated to the other national laboratories participating in the RIIA program to be utilized in their regional assessments.

Assumptions

There are several important assumptions made during the local air quality analysis that should be kept in mind while reviewing the results of the RIIA exercise.

As previously mentioned, process emissions were assumed to remain constant between 1975 and 1990. In reality, emissions from existing sources will decrease as State Implementation Plan (SIP) requirements are met, and emissions from new sources will be added to the total. Unfortunately, these factors are unlikely to cancel out because the former will be more significant. Inclusion of these process emissions would therefore reduce the impacts identified in this analysis. Changes in transportation related emissions were likewise beyond the scope of this study.

Secondly, the ANL local air quality analysis was based on SIPs which are currently in existence. Revised SIPs, when promulgated, will be more restrictive and will thus act to mitigate the projected impacts.

It was also assumed that the whole of a county in 1975 would be nonattainment if the county contained a portion of a designated nonattainment area or if one monitor read in excess of the standard. In reality, many nonattainment areas are extremely small (a few square miles or less) and many counties are extremely large, especially in the West. Nevertheless, the assumption is a good one for a typical county, especially if the requirement, not to exceed the "significance levels", is taken into account.

Finally, the monitored TSP air quality data (SAROAD) include contributions from rural fugitive dust, which will not be counted by EPA as contributing to nonattainment. Thus, for several counties in the West, ANL's determinations of nonattainment were not significant from a regulatory standpoint.

Limitations of the Analysis

The national screening analysis is somewhat crude for describing site specific air quality impacts. Because the analysis procedures must be broad enough to address every county in the nation, the analysis tends to lose clarity for any individual county. Nevertheless, RAD considered the lead lab analysis to be a useful exercise to ensure that the regional laboratories did not overlook any possible impacts and to define all the kinds of impacts that may be encountered in the scenario years.

It should also be noted that the rollback modeling method is only an approximation of the actual relationship between emissions and ambient air quality. Site specific considerations such as subcounty siting patterns, interactions between new and existing sources and between two or more new sources, local topography, local meteorology and contributions from minor sources will all impact this relationship.

Finally, due to limited projected emissions data for 1985 and 1990, ANL only computed air quality concentrations for SO₂ and TSP. Other air pollutants, such as carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NO_x) will certainly be important factors in the future.

C. LONG RANGE POLLUTANT TRANSPORT

A third analysis included in RIIA I's assessment of the impact of the MID-MID Scenario upon the Nation's air resources was the long range transport (LRT) of sulfur dioxide (SO₂), sulfates (SO₄) and particulates. This analysis was conducted in two parts: Brookhaven National Laboratory (BNL) performed the LRT assessment for the Eastern United States (east of the Mississippi River); and Pacific Northwest Laboratory (PNL) performed the LRT assessment for the Western United States.

Although both of these analyses were based upon the utility and industrial emission calculations provided by BNL, the two laboratories utilized different models and slightly different model parameters to perform their respective analysis. The variance between Eastern and Western terrains and meteorology accounts for part of the difference between the two models, however it should be noted that their differences do represent a limitation to the overall RIIA study.* Nevertheless, it is expected that these two methodologies will eventually converge as the state-of-the-art in LRT analysis advances. A description of the methodologies follows.

*Following the conclusion of the National Coal Utilization Assessment, representatives from PNL and BNL met to compare their analysis results. This comparison revealed that the results of the two analyses were comparable despite the different methodologies employed.

Eastern Long Range Transport (BNL)

Long range air quality impacts due to estimated emissions in 1985 and 1990 were projected using BNL's Atmospheric Impact of Residual Sulfur Oxides (AIRSOX) model.* This model was used to compute the along wind-horizontal trajectories of polluted air parcels (puffs) from each point or area source. The winds used as inputs to the model are updated every six hours and are averaged within the atmospheric mixing layer. The upper boundary of the atmospheric mixing layer is typically several hundred to several thousand meters above the surface. In this calculation, a constant mixing height of 1000 meters was employed, being a characteristic average value for the month of July.

Horizontal diffusion (perpendicular to the direction of travel) was parameterized by Gaussian diffusion about the center of mass. Vertical diffusion was calculated using eddy-diffusivity or "K" theory. Neutral stability conditions were assumed throughout the calculation because they are the most common. Vertical concentrations were calculated using a variation of the variable grid Crank - Nickelson finite difference method similar to that of Shir, et. al.,** the difference being that a derivative boundary condition was used at the bottom boundary to allow for dry depositional removal. Since dry deposition is a result of SO_2 and SO_4 impacting upon the land, the use of a bottom boundary condition to allow for dry deposition (surface depletion) is, on physical grounds, preferable to the phenomenological approach of using a bulk deposition velocity (source depletion). It is to be noted in model versus model comparison that the bulk deposition velocity (source depletion model) calculation requires a lower deposition velocity as compared with the bottom boundary calculation (surface depletion model), in order to yield similar results. Deposition velocities of 3.4 cm/sec for SO_2 and 0.23 cm/sec for SO_4 were chosen on the basis of sensitivity calculations and literature values.

A linear rainout model was used to calculate removal rates of SO_2 and SO_4 from the vertical column whenever a plume segment encountered rainfall. There exists considerable uncertainty as to the mechanism of SO_2 and SO_4 incorporation into rainfall. For this reason, the BNL model used a set of rainout parameters (Table 8) which had previously been successfully used to calculate acid rainfall, albeit in a different geographical location.***

The mechanism for the chemical conversion of SO_2 and SO_4 in the atmosphere is also poorly understood, particularly in relation to the relative contributions of homogeneous and heterogeneous reactions. The conversion rate has, however, been measured under a variety of atmospheric conditions. Literature values for the temporally

*For detailed information regarding this model see Ronald Meyers, et. al., A Long Range Transport Model for Calculating the Atmospheric Impacts of Residual Sulfur Oxides, Brookhaven National Laboratory, June 1979, BNL 26185-RI.

**C. C. Shir, and L. J. Shieh, "A Generalized Urban Air Pollution Model and Its Application to the Study of SO_2 Distribution in the St. Louis Metropolitan Area," Journal of Applied Meteorology, 13, 185-204 (1974).

***W. B. Johnson, D. E. Wolf and R. L. Marcuso, "Long Term Regional Patterns and Transfrontier Exchanges of Airborne Sulfate Pollution in Europe," Atmospheric Environment, Volume 12, 1978.

Table 8

Model Parameters

Eastern Long Range Transport

<u>Parameter</u>	<u>Value</u>
1. Stack height	
utility	200 meters
industrial	100 meters
2. Amount of SO ₄ in effluent	2% of emitted SO ₂
3. Meteorology	July 1974
4. Mixing layer height	1000 meters
5. Atmospheric stability	neutral
6. Vertical levels	12
7. Conversion rate of SO ₂ to SO ₄	0.57%/hour
8. Dry deposition velocity	
for SO ₂	3.4 cm/sec
for SO ₄	0.23 cm/sec
9. Wet removal rate	
for SO ₂	0.216 P/hour
for SO ₄	0.07 P/hour
	P = rainfall (mm/hour)
10. Grid resolution, approximate	32 x 32 km

and spatially averaged linear reaction rate are clustered about a mean of approximately 0.5% per hour. A linear reaction rate of 0.57% per hour was chosen on the basis of sensitivity calculations. In addition to the SO_4 , which is produced by chemical conversion (secondary sulfate), 2% of the initial SO_2 (by mole) was assumed to be immediately converted to SO_4 to simulate instack production of SO_4 (primary sulfate). A summary of the input parameters employed in the BNL model is presented in Table 8.

To compute the SO_2 and SO_4 surface concentrations from a single source, the following procedure was used. Every six hours, during the time period being modeled, the source releases a puff which contains an amount of SO_2 and SO_4 equal to that emitted in six hours. The height of release is either 200 meters for a utility source or 100 meters for an industrial source. The advection of the puff was calculated at three-hour intervals, using historical wind data.* An interpolation scheme was employed to calculate the winds at the puff location, given the observed upper air winds at approximately 80 stations in and around the United States. Vertical diffusion, chemical transformation, dry deposition, and wet deposition were calculated at hourly intervals. The time intervals used in the calculation represent a compromise between a desire to limit calculational complexity and computer expense and the desire for sufficient temporal-spatial accuracy. At the completion of a three-hour advection step, the horizontal diffusion of the puff was calculated. The SO_2 and SO_4 concentrations occurring at a height of 2 meters (breathing height) in the puff were then mapped onto a grid which covers the United States. The grid resolution was approximately 32 km.

Western Long Range Transport (PNL)

A long range transport model** developed by PNL was utilized to assess the impact of the MID-MID Scenario on the long range transport of pollutants in the Western United States. The PNL model was designed to compute ground level air concentrations and surface depositions of SO_2 , SO_4 and particulates by accounting for transport, chemical transformation, dry deposition, and participation scavenging. Wendell, et. al.*** initially developed the computer model and Renne and Elliott**** modified it to incorporate

*National Center of Atmospheric Research, National Ocean and Atmospheric Administration, Ashville, N.C.

**For more detailed information on this model see W. F. Sandusky, et. al., Long Range Transport of Pollutants in the Western United States, Pacific Northwest Laboratory, January 1979 (PNL-SA-7486 and PNL-RAP-26).

***L. L. Wendell, D. C. Powell and D. J. McNaughton, "A Multisource Comparison of the Effects of Real Time Precipitation Data on SO_2 and Sulfate Particulate Removal in a Regional Assessment Model." Preprints of the Joint Conference on Applications on Air Pollution, November 28 - December 2, 1977, Salt Lake City, Utah.

****D. S. Renne and D. L. Elliott, Regional Air Quality Assessment for Probable Near-Term Coal-Related Energy Development in the Northwest. BNWL-1084-RAP-9, Battelle, Pacific Northwest Laboratories, Richland, WA, October, 1976.

techniques to approximate the effects of complex terrains on pollutant transport and removal. An elaborate graphic display package was also developed to readily illustrate the model's output.*

Transport of the effluents was determined from the spatial and temporal variations of the recorded upper-level winds interpolated to a uniformly spaced grid over the region. The winds were averaged over a specified layer to provide a "layer average" transport, and gridded wind fields were produced for each hour by interpolating between the routine 12-hour observations. Pollutants plume centerlines were simulated by the hourly sequential release of a series of massless particles from each source location into the wind fields. Average ground level air concentrations and the surface depositions were computed by summing the concentrations of the plumes, hourly, over an array of grid squares.

The vertical dispersion parameter was computed using the formulas of Eimutis and Konicek.** In the present study, the vertical distribution factor for each plume element was calculated by assuming a Gaussian vertical distribution from an elevated release modified by reflections from the surface below and from the top of the mixing layer above, until the plume element uniformly fills the mixed layer. Although not explicitly calculated by the model, the width of the plume was accounted for by the spatial and temporal meandering of the plume elements in the wind fields. For the purposes of sampling, the concentration associated with each plume element was uniformly distributed over the sampling grid box containing a plume element. A linear oxidation rate was assumed for the transformation of SO_2 to sulfate (see Table 9).

There are two ways by which a plume is depleted: gravitational settling (dry deposition) and rain (wet deposition). For computing dry removal, the model uses the technique of surface depletion. The removal rate is proportional to vd/z , where vd is a dry deposition velocity and z is a vertical distribution factor allowing initial travel to deplete the lower part of the plume and gradually the entire plume as it moves further from the source. Based on experimental data, the wet deposition of SO_2 was assumed to be directly proportional to the precipitation rate, which was determined from hourly precipitation data. The wet deposition of SO_4 was assumed to be proportional to the $5/8$ power of the precipitation rate.***

The complex terrains prevalent in the Western United States affect the transport and removal of air pollutants by channelling winds and depleting plumes at a faster rate than in simple terrains. Three techniques were used to approximate the effects of the complex terrain in the West on pollutant transport and removal. The first was to increase the network density of upper air observations by incorporating stations with upper air pilot balloon wind observations (pibals) at 0600 GMT and/or 1800 GMT. The

*W. F. Sandusky, et. al., Long Range Transport of Pollutants in the Western United States, Pacific Northwest Laboratory, January, 1979 (PNL-SA-7486 and PNL-RAP-26).

**E. C. Eimutis and M. G. Konicek, "Deveriations of Continuous Functions for Lateral and Vertical Atmospheric Dispersion Coefficients." Atmospheric Environment, 6, 859-863, 1972.

***B. C. Scott and M. T. Dana, "Wet Removal Rates for SO_2 Gas and SO_4 Aerosol." To be submitted for publication in Atmospheric Environment, Battelle, Pacific Northwest Laboratories, Richland, WA, 1978.

Table 9
Model Parameters
Western Long Range Transport

<u>Parameters</u>	<u>Value</u>
1. Stack height	
utility	200 meters
industrial	100 meters
2. Amount of SO ₄ in effluent	2% of emitted SO ₂
3. Meteorology	July 1974
4. Mixing Layer height	1000 meters
5. Atmospheric stability	Neutral
6. Vertical levels	12
7. Conversion rate of SO ₂ to SO ₄	0.5%/hour
8. Dry deposition velocity	
for SO ₂	1.4 cm/sec
for SO ₄	0.23 cm/sec
9. Wet removal rate	
for SO ₂	0.005 P/hr
for SO ₄	0.23 P ⁵ / ₈ /hour
10. Grid resolution, approximate	64 x 64 km

second technique involved specifying the appropriate layer of winds for transporting the pollutant. For the majority of stations, winds averaged over a layer between 100 and 1000 meters above the ground were used to estimate the pollutant transport. However, in mountain valleys and coastal locations the low-level winds are strongly influenced by mesoscale effects such as slope winds and sea breeze circulations. Thus, for rawinsonde stations located in mountain valleys or coastal locations away from the emission sources, 1000 to 2000 m layered winds were used to better approximate the long range transport. The third technique involved varying dry deposition velocities with terrain types. Deposition velocities were increased by a factor of two for forested terrain and five for mountainous terrain.*

Ground-level air concentrations and surface depositions of SO₂, SO₄ and particulates associated with the 1985 and 1990 industrial and utility coal use emission scenarios were computed using July 1974 meteorological data. July was chosen as a typical worst case month to exemplify the maximum impact emissions on air quality. This month was characterized by lighter mean wind speeds than the annual average over most of the United States. The computed concentrations for July, 1974 were assumed to equal or exceed typical annual average concentrations. Of course, the computed concentration and deposition patterns may vary somewhat from annual patterns, due to seasonal variations in prevailing wind directions and precipitation.

Verification of the model's results with actual measured concentration data for the Western United States has not been done. However, results from a very similar version of the model have been compared to actual measured concentration data in the Northeast United States. It should be remembered, however, that the model results are certainly no more accurate than the collective assumptions of the model, and the quantity of available meteorological data (e.g., density of upper air stations). Nevertheless, the model predictions in this study should be fairly representative (as a first order approximation) of the long range air quality impacts.

The model input parameters used in the long range transport analysis for the Western States are shown in Table 9.

Limitations of the Analysis

As previously mentioned, the fact that two different models were used to assess the long range transport of air pollutants in the Eastern and Western United States presents some limitations to the effectiveness of the LRT analysis. In addition, both analyses were based upon the meteorological data for one month (July). Although this month represents a worst case analysis, ideally, the models should be run for all months to account for seasonal variations in meteorology and deposition rates. Time and financial constraints render such an activity as impractical.

It should also be noted that, as in any modeling exercise, there are inevitable uncertainties due to assumptions inherent in the model as well as the practical limitations imposed. For detailed descriptions of these uncertainties, consult the model documentation prepared by BNL and PNL and footnoted at the beginning of this section of the report.

*D. S. Renne and D. L. Elliott, Regional Air Quality Assessment for Probable Near-Term Coal-Related Energy Development in the Northwest, BNWL-1084-RAP-9, Battelle, Pacific Northwest Laboratory, October, 1976.

D. VISUAL AIR QUALITY

Visibility impairment is an air quality issue which is currently receiving a great deal of attention and concern at the national level. Congress, through the Clean Air Act Amendments of 1977, has declared that existing impairments to visual air quality in mandatory Class I Prevention of Significant Deterioration (PSD) Federal areas must be remedied, and that no future impairment in these areas is to result from man-made air pollution. At this time, however, EPA has not promulgated quantitative criteria for acceptable visual air quality. Nevertheless, Los Alamos Scientific Laboratory (LASL) attempted, possibly for the first time, to make an initial comprehensive estimate of the impact of the MID-MID Scenario upon visual air quality using the light extinction coefficient and visual range as the measures of visual air quality.

Atmospheric visual air quality is an aesthetic air quality value. The appearance of scenic vistas is affected by the quality of the atmosphere between the observer and the scenic background. Particles and gases in the atmosphere generated by man's activities can absorb and scatter light and cause a degradation of the color, texture, line and form of a background scene. The color and texture are the first to be degraded followed by line and form. A haze caused by light scattering by atmospheric aerosols can make a background scene appear washed out. A colored plume across one's field of view can diminish one's appreciation of a scenic vista. Meteorological conditions of fog, precipitation, and high relative humidity can also impair visibility. The methodology for estimating regional haze visibility impacts in nonurban areas is discussed in this section.

Through a relationship proposed by Koschmieder,* visual range for black objects can be related to the extinction coefficient, b , defined in the Beer-Lambert Law. The relationship has also been found to be a good approximation for calculating the visual range of dark topographical features, such as forest covered mountain. The relationship for the "limiting distinguishable contrast" of a black object against the horizon sky for a standard observer is given by the following empirical relationship:

$$V = \frac{3.912}{b}$$

V is known as the "meteorological visual range." The value used for the limiting distinguishable contrast for the standard observer is .02.**

*L. K. Koschmieder, appears in Vision Through the Atmosphere by W. E. K. Middleton, University of Toronto Press (1952).

**W. E. K. Middleton, Vision Through the Atmosphere, University of Toronto Press (1952).

The extinction coefficient can be represented by the sum of the following components:* the light scattering coefficient due to atmospheric particles, b_{sp} ; the light scattering coefficient due to air molecules (Raleigh Scattering), b_{sg} ; the light absorption coefficient due to gases such as NO_2 , b_{ag} ; and the light absorption due to particles such as carbon black, b_{ap} . The relationship can be represented as follows:

$$b = b_{sp} + b_{sg} + b_{ag} + b_{ap} \quad (2)$$

For nonurban areas, where the Class I areas of interest are located, the anthropogenically-related extinction is primarily due to light scattering by particles. The concentration of NO_2 tends to be too low for light absorption by gases to be important and the light absorption coefficient due to particles tends to be an order of magnitude less than the light scattering coefficient due to particles.

The light scattering coefficient for a particulate species can be calculated as a product of its scattering to mass ratio, b_s/m , and its mass concentration, m . Particles in the size range comparable to the wavelength of light, .1 to 1 microns in radius, are the most effective light scatterers per unit mass.** Particles in the accumulation mode, formed by the chemical reaction and condensation of gases, are found in this size range.*** The bulk of the particulates in the accumulation mode are composed of sulfate, nitrate and organics with particulate sulfate typically comprising the largest mass fraction. Submicron particles, in the nuclei mode, and particles greater than 1 micron, in the coarse particle mode, are not effective light scatterers per unit mass.

For hygroscopic particles, the particles will grow in size with increasing relative humidity. The particle growth will cause the scattering to mass ratio to increase and can be mathematically expressed as follows:****

$$(b_s/m)_{RH} = (b_s/m)_0 * (1 - (RH/100))^n \quad (3)$$

where:

$(b_s/m)_{RH}$ = the scattering to mass ratio at relative humidity RH

$(b_s/m)_0$ = the scattering to mass ratio at zero relative humidity.

*R. J. Charlson, "Atmospheric Visibility Related to Aerosol Mass Concentration - A Review," Environmental Science and Technology, 3: 913 (1969).

**W. H. White and P. T. Roberts, "On the Nature and Origins of Visibility Reducing Aerosols in the Los Angeles Air Basin," Atmospheric Environment. 11:803 (1977).

***S. K. Friedlander, Smoke, Dust, and Haze, John Wiley and Sons, N.Y., N.Y. (1977).

****G. R. Cass, "The Relationship Between Sulfate Air Quality and Visibility in Los Angeles", Cal Tech Environmental Quality Laboratory Memorandum No. 18, Pasadena, CA (1976).

Cass (see previous footnote) has estimated values of n for Los Angeles which range from -0.53 to -1.09 for particulate sulfates and nitrates. Trijonis and Yuan* used an n value of -1 in their regression analyses. An inspection of plots of the scattering coefficient versus relative humidity based upon measurements in Seattle, Washington; Denver, Colorado; and Altadena, California indicate that an n value of $-1/2$ fits the data better than a value of $n = -1$.**

The extinction coefficient calculated from visual range observations has been significantly correlated with the concentrations of particulate sulfates (SO_4), with particulate nitrates (NO_3), with total suspended particulates (TSP) excluding the former two components, and with relative humidity. Regression relationships with these pollutants as independent variables have been fitted to extinction coefficient data. The regression coefficients can be interpreted as the extinction coefficient per unit mass for each pollutant.

The use of the extinction coefficient to characterize visual air quality has been recommended by Charlson, et. al.*** The limitations of the extinction coefficient for characterizing visual air quality are the following: it does not account for coloration effects; the visual perception of a scene is affected by the position of the observer and the sun; it does not completely characterize the visual range of colored objects; it is assumed that atmospheric concentrations of light scattering aerosols are spatially homogeneous; and it does not characterize the case of plume blight. The major advantages of the extinction coefficient are that it is simple to calculate and interpret, the scattering portion can be directly measured, its components are additive, and its relationship to visual range has been successfully tested.

The light extinction for Class I areas is calculated as the sum of the following three components: (1) light scattering due to gas molecules, b_{sg} ; (2) extinction due to the sources and light scattering aerosols accounted for in long-range transport calculations; and (3) the remaining light extinction due to the sources and light scattering aerosols not accounted for in long-range transport calculations. The equation used for the calculation of the total light extinction coefficient, b_T , is expressed as follows:

$$b_T = b_{sg} + \sum_{ij} b_{sij} + b_r \quad (4)$$

where:

*J. Trijonis and K. Yuan, Visibility in the Southwest: An Exploration of the Historical Data Base. Technology Service Corporation, Santa Monica, CA (1977).

J. Trijonis and K. Yuan, Visibility in the Northeast: Visibility Trends and Visibility/Pollutant Relationships. Technology Service Corporation, Santa Monica, CA (1978).

**D. S. Covert, R. J. Charlson and N. C. Ahlquist, "A Study of the Relationship of Chemical Composition and Humidity to Light Scattering Aerosols", Journal of Applied Meteorology, 11:968-976 (1972).

***R. J. Charlson, A. P. Waggoner and J. F. Thielke, Visibility Protection for Class I Areas: The Technical Basis. Prepared for the Council on Environmental Quality (1978).

b_{sg} = light scattering due to air molecules. $b_{sg} = 1.5 \times 10^{-4}$ meter⁻¹ at sea level.*

b_{sij} = light scattering due to aerosol i and source j.

b_r = the remaining light extinction due to the sources and light scattering aerosols which were not accounted for in the long-range transport calculations.

The light scattering coefficient, b_{sij} , is calculated using Equation (3). The estimation of the scattering to mass parameters is discussed in the next section. The mass concentrations are from long-range transport predictions which were supplied by Pacific Northwest Laboratory (PNL) for the Western United States and Brookhaven National Laboratory (BNL) for the Eastern United States. PNL predicted the concentrations of particulate sulfates due to sulfur dioxide emissions from major industrial process sources and from utility and industrial fossil-fueled power plants, and predicted the concentrations of primary particulates (PP) due to emissions from utility and industrial fossil-fueled power plants. BNL predicted the concentrations of particulate sulfates due to sulfur dioxide emissions from utility and industrial fossil-fueled power plants.

The major share of the calculated light extinction is accounted for by b_{sij} . The major anthropogenic sulfur dioxide source categories were accounted for in the long-range transport calculations. Extinction budget calculations indicated that the major share of the light extinction in nonurban areas is due to particulate sulfates which are formed by the oxidation in the atmosphere of sulfur dioxide. These results are supported by the extinction budgets for the Southwest and Northeast prepared by Trijonis and Yuan (see previous footnote). The greatest uncertainty in the calculation of the total light extinction coefficient is the contribution of natural sources. Except for meteorologically related impairment of visual air quality, visual air quality as indicated by airport observations of visual range are strongly related to regional anthropogenic air pollutant emissions.**

The light extinction budget was arranged into a regional summary of the estimated percent of the extra extinction due to particulate sulfates, particulate nitrates, and total suspended particulates (TSP), excluding sulfates and nitrates. The light extinction was calculated from relative humidity and nonurban air quality data for the period of 1970 to 1974. The scattering to mass ratio estimates discussed in the next section were used in the calculations.

The remaining light extinction was assumed to persist at existing levels. It was calculated from the baseline extinction** and factors which account for excluded emission sources and light scattering aerosols. The baseline extinction was calculated from median visual range statistics, using the Koschmieder relationship. The remaining extinction was calculated as follows:

$$b_r = (b_b - b_{sg}) * \sum_i F_{1ik} * F_{2ik} \quad (5)$$

where:

b_b = baseline extinction

*J. Trijonis and K. Yuan, Visibility in the Southwest: An Exploration of the Historical Data Base. Technology Service Corporation, Santa Monica, CA (1977).

**J. Trijonis and D. Shapland, Existing Visibility Levels in the U.S., Technology Service Corporation, Santa Fe, NM (1978).

- F_{1ik} = the fraction of the total emissions of pollutant i in region k for sources not accounted for in the long-range transport analysis. It was calculated from data in the 1972 National Emissions Report.*
- F_{2ik} = the fraction of the total light extinction due to aerosol i in region k.

Parameter Estimation

The scattering to mass ratios typical of nonurban locations and at zero relative humidity, as defined by Equation (3), were estimated using linear regression analysis. The scattering to mass ratios for fine particulate matter (FPM) and for Total Suspended Particulates (TSP), excluding FPM, were estimated (0.1 to 1.0 microns in radius). The former accounts for light scattering due to particles in the accumulation mode and the latter accounts for light scattering due to particles in the coarse particle mode. The sum of particulate sulfate and nitrate concentrations were multiplied by 1.3** to account for the mass of associated cations which are thought to be primarily the ammonium ion.

Averages of annual average nonurban air quality data for the period of 1970 to 1974 were used in the regression analysis. The air quality data were from measurements taken at 39 nonurban National Air Surveillance Network air quality monitoring sites. Seventeen sites were located in Western states and 22 were located in Eastern states. Mean daily and annual relative humidity, which were typical of the area in the vicinity of the sites were used.*** The observed values for the light extinction coefficient were calculated from the observed visual range data using the Koschmieder relationship. The observed visual range data were taken from isopleth maps compiled by Trijonis and Shapland. They are median values for the period of 1974 to 1976.

The scattering to mass ratios were estimated for three values of the relative humidity exponent: $-1/2$, $-2/3$, and -1 . The regression equation for which the exponent was $-1/2$ gave the best fit to the data. As would be expected, the scattering to mass ratio for FPM was estimated to be much higher than for TSP minus FPM in both the Western and the Eastern states. The higher scattering to mass ratio for TSP minus FPM in the East, as compared to the West, could be explained by the coarser particles in the West being larger in size due to a greater contribution from wind blown dust and a smaller contribution from industrial sources (auto emissions are already accounted for in FPM). The standard deviation of the parameter estimates were relatively smaller for FPM as compared to TSP minus FPM. The variance explained in the regression for the exponent of $-1/2$ was 66.7 percent.

A definition of the criteria employed to rank visual air quality impacts due to both regional haze and plume blight conditions is presented below. It should be noted that the capacities and percentages presented in these criteria are the subject of current research, and thus subject to change.

*U.S. Environmental Protection Agency, 1972 National Emissions Report, EPA-450/ 2-74-12 (1974).

**G. R. Cass, "The Relationship Between Sulfate Air Quality and Visibility in Los Angeles," Cal Tech Environmental Quality Laboratory Memorandum No. 18, Pasadena, CA (1976).

***J. L. Baldwin, Climates of the United States. U.S. Department of Commerce, NOAA/EDS. Washington, D.C. (1973).

Definition of Criteria for Rating Visual Air Quality Impacts

High	Medium	Low
There is a greater than 20% decrease in calculated visual range in Class I areas. Power plants sited in counties or adjacent to counties with Class I areas are greater than 1000 MW in size for coal- and oil-fired plants and greater than 2500 MW in size for gas-fired plants.	There is between a 10 and 20% decrease in visual range in Class I areas. Power plants sited in counties or adjacent to counties with Class I areas are between 500 and 1000 MW in size for coal- and oil-fired plants and between 1250 and 2500 MW in size for gas-fired plants.	There is less than a 10% decrease in calculated visual range in Class I areas. Power plants sited in counties or adjacent to counties with Class I areas are less than 500 MW in size for coal- and oil-fired plants and less than 1250 MW in size for gas-fired plants.

While there may be impacts associated with sunlight availability and ecological and human health effects, it is generally recognized that visual air quality is an aesthetic quality which is subjective and has many dimensions. The above criteria were selected based upon LASL's experience in producing computer simulated pictures of plume blight and regional haze under different conditions of meteorology, source characteristics, atmospheric chemistry, aerosol characteristics, background atmosphere, and plume geometry. Due to the inverse relationship between extinction and visual range (Equation (1)), the percent change in visual range is most sensitive to the marginal change in extinction in areas which experience the best visual air quality. The implications of this relationship are that areas with the best visual air quality are the most susceptible to degradation and the areas with the poorest visibility will require a substantial decrease in air pollution before a significant improvement will occur.

WATER RESOURCES

RIIA I's assessment of the impact of the MID-MID Scenario upon the Nation's water resources entailed two lead laboratory analyses. Argonne National Laboratory (ANL) computed the impact of the scenario upon future water quality while Oak Ridge National Laboratory (ORNL) computed the impact upon water availability. The purpose of the water quality analysis was to identify river basins in which energy development could potentially cause a violation of national water quality standards. The purpose of the water availability analysis was to compute the increased demand placed upon the Nation's water resources as a result of energy development.

It should be noted that both of these analyses served only as a screening mechanism whereby U.S. Water Resources Council (WRC) Aggregated Subareas (ASAs) (Figure 8) were identified as having potential problems with either water quality or water availability as a result of the energy development called for by the MID-MID Scenario. Subsequent analyses to further pinpoint the site specific impacts of the scenario upon water resources were the responsibility of the laboratories under the regional assessment portion of the RIIA analysis.

A. WATER QUALITY

ANL's study of surface water quality impacts was based on computing an average measure of pollutant concentration increments at the outflow points of the WRC ASAs. These outflow points are illustrated in Figure 9.

Surface water quality is a function of three factors: streamflow, natural stream quality, and additional pollutant loading. Depending upon the purpose of a particular assessment, different historical streamflows based upon statistical analysis may be used and are readily available. The historical streamflow data base incorporated in ANL's water quality model* was derived from the U.S. Water Resources Council. Historical water quality data in the model were obtained from the U.S. Geological Survey through the National Stream Quality Accounting Network. Essentially, the model combines energy-related pollutant loading rates with present stream quality and quantity data for each ASA and then calculates the projected stream quality at the ASA outlet for each scenario year. The model then compares the resulting stream quality with stream quality standards (Table 10) to evaluate the energy-related impact. The manner by which the model computes the energy-related pollutant loading rates is discussed below.

Pollutant Loading Rates from Coal Mining Activity

The pollutant loadings from coal extraction activities in each ASA were assessed by ANL. The pollutants from this activity originate from mine drainage, discharges from coal preparation plants, runoff from refuse piles, and runoff from surface mines land reclamation. It was assumed that all future pollution sources can

*For more information regarding this model see The Water Quality Impacts of Increased Coal Utilization, Department of Energy, Assistant Secretary for Environment, April 1979.

FIGURE 8

U.S. WATER RESOURCES COUNCIL AGGREGATED SUBAREAS (ASAs)

FIGURE 9
ASA OUTFLOW POINTS

comply with EPA effluent limitation guidelines and that surface mines will be reclaimed as required by the Surface Mining Control and Reclamation Act.

(1) Mine Drainage

The pollutant concentrations assumed for the parameters indigenous to mining activities are identified in Table 11. The table distinguishes between acid mine drainage and alkaline mine drainage. Table 12 indicates the drainage type in each Coal Supply Region (CSR) (Figure 10) and indicates the drainage volumes from deep and surface mines according to region. The pollution loading rate from mining activity for an ASA was defined by

$$L_i = C_i * P_A * Q_A$$

where:

L_i = pollutant loading rate for the individual pollutants

C_i = concentration of the individual pollutants according to Table 11

Q_A = effluent flowrate according to Table 12

P_A = production rate of mines, for each ASA.

i = individual pollutant

A = individual ASA

(2) Coal Washing Plant Drainage

The pollutants derived from coal washing plants and their assumed concentrations are listed in Table 11. A definition of the effluent quantity from coal washing activities was based on an assumption derived from the Department of Interior that 50% of the coal mined in each ASA would be cleaned and that 96% of all cleaning is accomplished by wet methods. In Coal Supply Regions 7 - 12 (i.e., the arid West regions), all wet cleaning is accomplished by closed circuit methods,* and therefore, no effluent streams are produced. In the other eight regions, it was assumed that only 60%** of the wet cleaning employs recirculation methods while the remaining 40% produce 2150 liters of effluent per metric ton of coal washed.***

Annual pollutant loading rates for this activity in each ASA were calculated according to the equation:

$$L_i = C_i * Q_w * P_A$$

*U.S. Environmental Protection Agency, Development Document for Interior Final Effluent Limitation Guidelines and New Source Performance Standards for Coal Mining, EPA-440/1-76/057-a, Office of Water and Hazards Materials, Washington, D.C. (1976).

**U.S. Bureau of Mines, Mineral Yearbook 1973.

***Hittman Associates, Environmental Residual Coefficients for the Project Independence Evaluation System Model (1976).

TABLE 10
QUALITY CRITERIA FOR WATER USES

PARAMETER ^a	CRITERIA	PARAMETER ^b	CRITERIA
TDS - 250 mg/L	Domestic Water Supply	CU - 1.0 mg/L	Domestic Water Supply
NH ₃ - 0.02 mg/L	Freshwater Aquatic Life	Cr - 0.050 mg/L	Domestic Water Supply
SO ₄ - 250 mg/L	Domestic Water Supply	FE - 0.3 mg/L	Domestic Water Supply
O & G - 0.0 mg/L	Domestic Water Supply	Pb - 0.050 mg/L	Domestic Water Supply
P - 0.50 mg/L	Freshwater Aquatic Life	Mn - 0.050 mg/L	Domestic Water Supply
Cl - 0.010 mg/L	Freshwater Aquatic Life	Hg - 0.002 mg/L	Domestic Water Supply
As - 0.050 mg/L	Domestic Water Supply	Ni - 0.046 mg/L	Freshwater Aquatic Life
Ba - 1.0 mg/L	Domestic Water Supply	Se - 0.010 mg/L	Domestic Water Supply
B - 0.750 mg/L	Agricultural Water Supply	Zn - 5.0 mg/L	Domestic Water Supply
Cd - 0.010 mg/L	Domestic Water Supply		

^aTotal dissolved solids, ammonia, sulfate, oil and grease, phosphorus, chlorine, arsenic, barium, boron, and cadmium, respectively.

^bCopper, chromium, iron, lead, manganese, mercury, nickel, selenium, zinc, respectively.

Source: Environmental Protection Agency.

TABLE 11
ESTIMATED ACTIVE MINE DRAINAGE AND COAL PREPARATION
PLANT EFFLUENT CONCENTRATIONS^{1,2} (mg/l)

	SURFACE MINES				DEEP MINES				COAL PREPARATION	
	acid		alkaline		acid		alkaline			
	a	b	a	b	a	b	a	b	a	b
Total Iron	26.00	0.47	0.78	0.78	178.00	0.30	1.54	1.54	25.20	2.55
Manganese	28.70	12.36	0.61	0.61	4.60	2.00	0.25	0.25	1.10	0.46
Aluminum	37.20	3.28	0.20	0.20	22.70	2.00	0.08	0.08	5.60	0.53
Zinc	0.97	0.23	0.14	0.14	0.84	0.20	0.06	0.06	0.30	0.03
Nickel	0.45	0.20	0.02	0.02	0.46	0.20	0.01	0.01	0.10	0.04
TSS	229.00	48.00	84.00	74.00	124.00	20.00	23.00	20.00	31241	35.00
TDS	4038	4015	2768	2669	4723	4697	2609	2516	1433	1433
Sulfate	1785	1628	1163	1029	2233	2095	444	393	949	894
Ammonia	4.30	2.09	4.59	4.99	7.96	3.89	1.03	1.12	1.34	0.66

^a Assuming 50% compliance with effluent guidelines. Used for 1975 calculations.

^b Assuming total compliance with effluent guidelines. Used for 1985 and 1990 calculations.

¹ Adapted from EPA Effluent Guideline Development documentation, Development Document for Interior Final Effluent Limitation Guidelines and New Source Performance Standards for Coal Mining, EPA 440/1-76/057-a, U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Washington, D.C. (May 1976).

² Assuming compliance with EPA effluent limitation guidelines. Adapted from Development Document for Interior Final Effluent Limitation Guidelines and New Source Performance Standards for Coal Mining, EPA 440/1-76/057-a, U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Washington, D.C. (May 1976).

TABLE 12
COAL SUPPLY REGION DRAINAGE TYPES AND VOLUMES

(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)
COAL SUPPLY REGION	ASA'S ACCORDING TO WRC DEFINITION	EFFLUENT TYPE ¹	DRAINAGE VOLUME (Liters per Metric Ton of Coal Produced ³)		COAL REFUSE PILE RUNOFF (Liters/Metric Ton of Coal Cleaned)	SEDIMENT POTENTIAL ² (Metric Tons per Hectare per Year)	LAND USE FACTOR ³ (10 ⁻⁶ Hectare per Metric Ton)	PERIOD TO COMPLETE REVEGETATION (Years)
			Surface Mines	Deep Mines				
1. Northern Appalachia	203, 204, 206, 501, 502, 503	Acid	210	2002	31	14.6	91	5
2. Central Appalachia	205, 504, 507, 601	Acid	189	230	44	27.6	90	5
3. Southern Appalachia	306, 307, 308, 602	50% Acid	189	230	42	28.9	90	5
4. Midwest	403, 505, 506, 704, 705	50% Acid	1064	200	31	14.5	70	5
5. Central West	703, 1009, 1010, 1011, 1103, 1104, 1105	50% Acid	1064	200	29	14.8	68	5
6. Gulf	801, 802, 1107, 1201, 1202, 1203, 1204, 1205	20% Acid	0	0	29	8.5	38	5
7. Fort Union	901, 1001, 1005	Alkaline	443	0	11	3.6	16	10
8. Northwest Great Plains	1002, 1003, 1004, 1007, 1701, 1703	Alkaline	601	0	11	6.9	21	10
9. Rocky Mountains	1102, 1301, 1401, 1402, 1403, 1601, 1602	Alkaline	696	0	11	11.7	25	10
10. Southwest	1302, 1501, 1502 1501, 1502	Alkaline	601 0	0 0	8.8	13.2	52	10
11. Northwest	1702, 1705, 1706	Alkaline	601	0	37	3.8	70	10
12. Alaska	1901	Alkaline	601	0	37	3.8	70	10

¹If an effluent type is 50% acid, then it is also 50% alkaline.

²Adapted from Midwest Research Institute, "National Assessment of Water Pollution from Nonpoint Sources," (draft), for the U.S. EPA, Nov. 1975.

³Annual Environmental Analysis Report: A Preliminary Environmental Analysis of Energy Technologies Using the Assumptions of the National Energy Plan, Volume IV, Draft Copy, the MITRE Corporation, Sept. 6, 1977, P. 42.

SOURCE: U.S. Department of Interior,
U.S.G.S.

FIGURE 10
COAL SUPPLY REGIONS

where:

C_i = concentration of the individual pollutants according to Table 11

Q_w = effluent flow rate according to the assumptions for coal washing

(3) Refuse Pile Runoff

Refuse is produced from coal cleaning and is expected to cause polluted streams when exposed to rain and snowfall. From literature surveys, it was assumed that 40% of the annual precipitation in each CSR results in an effluent runoff stream. Table 12 indicates the expected runoff in each CSR. In the National Coal Utilization Assessment it was determined that the area exposed to precipitation can be defined as 7.08×10^{-6} hectare per metric ton of coal cleaned with an exposure time of one year before the refuse pile is buried or covered. The effluent quality characteristics of the runoff stream was assumed to be identical to those of active mine drainage streams. The loading rate in each ASA for each pollutant was expressed by:

$$L_i = C_i * Q_R * P_A$$

where:

C_i = concentration of the individual pollutants, according to Table 11

Q_R = effluent flowrate, according to precipitation data for each ASA.

(4) Mine Land Reclamation Runoff

During the period from when the surface soil is removed to the time when the soil is replaced and finally restored to vegetative production, pollutant loading is expected because of accelerated erosion of the disturbed land. The pollutant is identified as sediment and its loading factor varies throughout the Nation according to Table 12. The definition of sediment loading rate potential for reclamation land was from a data base established by EPA on National Assessment of Nonpoint Source Pollution and the assumption that the use of sedimentation can achieve 80% control efficiency. It was used to reduce sediment yields from mine sites. The area of land affected by coal mining in the different CSRs is described as the land use factor in Table 12. The total area of land under reclamation at any time is also defined in Table 12.

The sediment loading is calculated by:

$$L = l_R * Y_R * U_R * P_A * (1.0 - 0.8)$$

where:

l_R = sediment loadings in each region according to Table 12.

Y_R = time in years to reclaim disturbed land according to Table 12.

U_R = land disturbed to extract coal according to Table 12.

R = individual coal supply regions according to Table 12.

Pollutant Loading Rates from Utility Activity and Industrial Boiler Activity

The effluent waste streams produced by utility and industrial boiler operations and regulated by effluent guidelines are identified by an X in Table 13. The characteristics of each effluent stream are described in Table 14 and incorporated in the analysis according to control guidelines.

TABLE 13
UTILITY AND INDUSTRIAL EFFLUENT WASTE STREAM

Waste Stream Number	Production Facility							
	Utility				Industrial			
j	Coal	Oil	Gas	Nuclear	Coal $< 250 \times 10^6$ Btu/hour	Coal $> 250 \times 10^6$ Btu/hour	Oil	Gas
1 Boiler Blowdown	x	x	x		x	x	x	x
2 Metal Cleaning	x	x	x	x	x	x	x	x
3 Low Volume Waste Water	x	x	x	x	x	x	x	x
4 Cooling Tower Blowdown	x	x	x	x				
5 Flue-Gas Desulfurization	x					x		
6 Ash Handling (Fly and Bottom)	x				x	x		
7 Coal Pile Runoff	x				x	x		

The guidelines are based on: Best Practicable Control Technology (BPCT) that became effective in July, 1977; Best Available Control Technology Economically Achievable (BACTEA) that will become effective in July, 1984 for existing production facilities; and New Source Performance Standards (NSPS) that became effective in July 1977 for all new production facilities. All values in Table 14 are based on an assumed generating load factor of 55% capacity for utilities and a thermal efficiency for industrial boilers of 78%.

The volume of coal pile runoff in a region is partially dependent upon local precipitation and evaporation rates. For the assessment, it was assumed that 40 percent of the average annual precipitation in each ASA would cause coal pile runoff. In addition, it was assumed that a 90-day coal pile reserve would be maintained covering 0.02 acres per megawatt of installed electric generating capacity. These assumptions are based upon the findings of the National Coal Utilization Assessment.

Wet cooling-type evaporation is the largest contributor to water consumption in utility activity. Although the evaporation rate in an area is dependent upon several factors including climate and type of cooling used, a rate of 0.010×10^6 gallons per

TABLE 14
WASTE STREAM CHARACTERISTICS

EFFLUENT ¹	BOILER BLOWDOWN	METAL CLEANING	LOW VOLUME	COOLING TOWER BLOWDOWN	FLUE-GAS DESULFURIZATION	ASH HANDLING		COAL PILE RUNOFF
						FLY	BOTTOM	
TSS	80-200,30 ^{2,3}	80-200,30 ^{2,3}	70,30 ^{2,3}	-	30,30 ^{2,3}	30,30 ²	2.4,2.4 ² ,1.5 ³	625,50 ^{2,3}
TDS	50-150	3000-200000	1000-9000	5,500	3500-10500	750-1250	350-750	250-29000
NH ₃	1-3	.05-3.5	.15-.45	-	.35-.95	.5	.5	-
CN	-	-	-	-	.005-.015	-	-	-
SO ₄	-	700-2200	8-24	372-500	900-2000	40-240	40-240	1600-3600
Oil & Grease	15,15 ^{2,3}	15,15 ^{2,3}	15,15 ^{2,3}	-	-	15,15 ²	1.2,1.2 ² ,.75 ³	-
PO ₄	30	.5-1.5	-	5.5 ² ,0 ³	.05-.15	.007-.022	.025-.075	.3-.9
Chlorine	-	-	-	12.5,.2 ^{2,3,4}	-	-	-	-
K	-	.5-3.5	-	1-9	-	-	-	-
Al	-	-	-	-	.2	1.2	1.2	-
As	-	-	-	-	.016	.01	.01	-
Ba	-	-	-	-	.15,.03 ⁵	.07,.03 ⁵	.07,.03 ⁵	-
B	-	-	-	-	-	.5	.5	-
Cd	-	-	-	-	.004	.01	.01	-
Cu	1.0,1.0 ^{2,3}	3-11,1.0 ^{2,3}	-	.05-.15	.03	.0225	.015	1.8,.5 ⁵
Cr	-	2.5-11.5,.3 ⁵	-	10-14,.2 ² ,0 ³	.03	.6,.3 ⁵	.045	.8,.3 ⁵
Fe	1.0,1.0 ^{2,3}	1000-1600,1.0 ^{2,3}	-	.05-2.2,1.0 ⁵	.1	3.6,1.0 ⁵	1.55,1.0 ⁵	250,1.0 ⁵
Pb	-	-	-	-	-	.01	.01	0.1
Mn	-	-	-	-	.4,.05 ⁵	.31,.05 ⁵	.405,.05 ⁵	.027,.05 ⁵
Hg	-	-	-	-	.0004	.001	.001	.01
Ni	-	56,.5 ⁵	-	-	.22	.01	.01	.03
Se	-	-	-	-	.41,.29 ⁵	.04	.04	.03
Zn	-	0-10,1.0 ⁵	-	15-25,1.0 ² ,0 ³	.04	.055	.105	0.1-12.5,1.0 ⁵
Flow Rate	50-60	15.20	100-130	2000-5488	100-500	100,0 ³	400,250 ^{2,3}	

¹All values in mg/l except flow rate which is in gal/day/MW capacity

²BACTEA Effluent Guideline Limitations

³NSPS Effluent Guideline Limitations

⁴Maximum of 2 hr/day discharge

⁵Assumes coagulation and precipitation treatment to meet effluent guideline limitations for TSS, CR, Fe, and Zn

day per megawatt of installed capacity for coal fired and 0.017×10^6 gallons per day per megawatt for nuclear fuel electricity generating facilities were used in the analysis.

The loading rates for each pollutant parameter varies according to the waste stream from which the pollutant was derived. The loading rates for utility and industrial sector for each ASA were calculated by the equation:

$$L_i = \left(\sum_{j=1}^n C_{ij} Q_j \right) * P$$

where:

- L_i = loading rate of pollutant i
- C_{ij} = concentration of pollutant i in waste stream j (identified in Table 14).
- Q_j = flowrate in waste stream j (identified in Table 14 as "flowrate" except for coal pile runoff which is dependent on local precipitation levels.)
- P = Production level
- i = pollutant parameter (from Table 14).
- j = waste stream (from Table 13).
- n = number of waste streams evaluated for a particular production process (from Table 14).

Limitations of the Analysis*

Although the water quality lead lab analysis identified and considered many of the pollutants discharged directly to the streams from energy activities, certain limitations exist in data and methodology of this study. Perhaps the most significant limitation of the water quality analysis methodology was the inability to assess water quality impacts occurring in areas more localized than the ASA level. At energy sites, the residual discharges in the stream are most concentrated and most apt to cause stream water quality problems. Closely associated with this limitation is the assumption of residual conservancy. As residuals are transported downstream, chemical, physical, and biological factors change their nature and concentration. Local environmental conditions, such as stream flow and temperature could significantly affect the resulting residual stream concentrations. Closely related to local impacts is the problems caused by thermal pollution. In this assessment, thermal discharges were not quantified and it was assumed that cooling towers or ponds will be used in new energy generation facilities, providing adequate protection against thermal pollution. Although this assumption is in accordance with the EPA guidelines promulgated in 1974, there is an ongoing debate as to whether closed-cycle cooling will be imposed as rigorously as the guidelines specify. Commensurate with stream temperature increases is the decrease in stream dissolved oxygen content and increased toxicity of pollutants. In addition, chemical and biological oxidation processes are accelerated exacerbating the stream quality problems.

*For more information, see M. F. Torpy, et. al., The Water Quality Impacts of Increased Coal Utilization, Argonne National Laboratory, April 1979.

Many other substances currently not limited by discharge regulations, but which will be discharged from energy activity, were not calculated. The substances are organic and inorganic in nature and their concentrations may ultimately be controlled by additional legislation and by Public Law 95-217 (referred to as the Settlement Agreement or Consent Decree). Under this law, discharging of toxic pollutants (elements, compounds, or family of compounds) will be regulated. Final regulations for the 65 pollutants are scheduled for completion between March 31 and December 31, 1979. Meeting the limitations and standards would then be achieved no later than June 30, 1983.

Changes in energy activity will promote corresponding population migration during utility construction, mining, and industrial growth. Population increase will change the consumptive water requirements in an area and promote additional waste volumes and pollutant loading rates to publicly owned waste treatment works (POTW). Industrial activity changes will increase consumptive requirements and change the volume and quantity of process wastes directly discharged to surface waters and/or to POTWs. The magnitude of this effect is industry specific and was not accounted for in this assessment.

Adverse effects from these secondary changes will most likely be in areas where population growth is rapid and large. These areas, sometimes referred to as "boom town" areas, are often located in the western states where populations and water availability are low, water quality is relatively high, and increases in extraction and/or utility and industrial activity is projected. Consumption water requirements by populations and industries will affect water quality by reducing the amount of surface water available for assimilating effluent discharges.

The Clean Air Act Amendments (PL95-95) also play an important role in determining the characteristics of waste water from utility and industrial activity. Although proposed Best Available Control Technologies effluent guidelines under the act have not been defined, they will require significant control of sulfur and particulates in flue gases. The establishment of Prevention of Significant Deterioration (PSD) and Non-attainment Area regulations for particulates and sulfur may increase the degree to which effluents must be controlled. One method of controlling flue gas sulfur effluents is flue gas desulfurization (FGD). Liquid wastes from flue gas desulfurization units contribute a significant proportion to the total effluent loadings from fuel combustion. The extent to which effluent levels must be reduced (which will affect the total volume of control wastes) will vary with location and be dependent upon yet to be finalized BAT and PSD designations.

The ultimate water quality effects resulting from gas stack emissions depositing on land and water surfaces are becoming increasingly important because of increased combustion activity. However, these effects were not quantitatively identified in this assessment. The increasing incidence of acid rain in the U.S., including increased soil erosion from foliage kills, heavy-metal leaching from soils, and lowering stream-buffering capacity and pH, is caused largely by sulfur and nitrogen oxides stack emissions. Other stack gas materials, such as unburned hydrocarbons and vaporized heavy metals, although unaccounted for in this assessment, are certain to accompany increased energy development, and make notable impacts on water quality.

One source of water pollution that was not considered in the quantitative assessment was from disposed coal ash leachate transfer. The results from a special topic study indicate that trace elements such as Ag, As, Cd, Fe, Hg, Mn, Pb, and Se,

from coal ash leachates, could violate EPA drinking water criteria. These elements and other potentially toxic beryllium, cobalt, molybdenum, nickel, antimony, tin, strontium, tellurium, and vanadium pose potential water quality hazards if adequate leachate control is not implemented. Although the special topic study indicated that state-of-the-art methods for leachate control may be economically feasible, continued research to ensure protection for water quality is essential. The interpretation and implementation of the Resource Conservation and Recovery Act (PL94-580) and the Toxic Substance Control Act (PL94-469) for all energy activities may promote more stringent standards for many more coal-derived residual parameters.

Other factors related to the problems of not addressing more localized issues is the inability to accurately characterize discharges from energy activities. It would be a monumental, if not impossible task, to define differences in fuel types, operational procedures, background concentrations, and many other environmental factors as well as project timing for the enforcement of effluent guidelines, actual industrial boiler activity, and to the extent ocean discharges will be allowed.

Another factor that could cause deviations in water quality occurs from the assumption that discharge standards for all energy activities would be fully implemented on schedule. Deviations from the levels of control or the time schedule would imply a different set of conclusions. An important area where full compliance of discharge standards may prove difficult and perhaps impossible is related to coal extraction. Abatement of water pollution, in addition to changes in mining methods, requires soil and water management, revegetation, and mine sealing. Unlike utility and industrial activity, effluent discharge compliance requires extensive control at the scattered pollution sources resulting from land disruption. Although mine operators have been charged with the responsibility of maintaining acceptable performance standards required by environmental guidelines, wide-scale implementation of the guidelines has not been demonstrated. Extensive monitoring will be required to assess the extent and effectiveness of the regulations.

B. WATER AVAILABILITY

The water availability analysis for RIIA I contained two components: the estimation of water supply and the comparison of this supply with water use.

Estimating Water Supply

The water availability analysis focused on the seasonal period in each ASA when the total demand utilizes the greatest proportion of estimated supply. Surface water supply estimates for ASAs were based on the monthly 95% discharge ("exceedence" statistics) of the 1975 present modified flows.*

*United States Water Resources Council, The Nation's Water Resources: The Second National Water Assessment by the United States Water Resources Council, Washington, D.C. (draft data, April 1978).

United States Geological Survey, Surface Water Supply Statistics for the U.S. Water Resources Council's 1975 National Assessment, Reston, Virginia (draft data, 1975).

The Center for Research in Water Resources, University of Texas at Austin, Review of Present Modified Flow Estimates for the Water Resources Council, Austin, Texas, May 5, 1977, revised June 7, 1977.

Also see J. E. Dobson and A. D. Shepherd, Water Availability for Energy in 1985 and 1990, ORNL/TM-6777, Oak Ridge National Laboratory, Oak Ridge, TN, October, 1979.

"Exceedence" statistics for ASAs represent the aggregated flows of all streams within an ASA as a set of discharge values giving flow rates that will be exceeded a certain percentage of the time (i.e., flows that have an 80, 90, or 95% chance of being exceeded as a mean for each month or as an annual average). Most siting specialists and many river basin authorities recognize the importance of appraising water availability on the basis of the risk of environmental damage to a stream as its rate of flow falls below certain critical levels.* Thus, the amount of water in a stream during periods of minimal flow and the probability of recurring levels of low-flow are important water availability measures.

Even though higher "exceedence" levels correspond to more critical stream-flow conditions, these statistics are not really low-flow measures since they do not state minimum flows of any duration or frequency. In general, even the 95% level tends to represent higher flow rates than other measures of critical streamflows, such as the seven-day/ten-year low-flow, that are preferred by many water resource specialists and have been incorporated into the administrative regulations of some states. The seven-day/ten-year low-flow, a standard measure of flow used in water quality studies, is a probability function interpreted as the seven-day average minimum flow likely to occur once every ten years. Substantial reduction of the seven-day/ten-year low-flow can result in water-quality problems affecting recreation, fish and wildlife, and other in-stream uses.** Calculated seven-day/ten-year low-flow estimates, however, are not presently available for the Nation as a whole. Hence, the 95% "exceedence" discharges were used because they most closely approximate low-flow conditions.

In calculating the Critical Surface Supply (CSS) for each ASA, the monthly 95% "exceedence" discharges were adjusted by ORNL for the 1975 level of surface-water depletion by all uses, including those of upstream ASAs. This adjustment avoided double accounting of the 1975 level of streamflow depletion by existing uses and also included the amount of water used from reservoir storage. Therefore, the amount of existing surface storage capacity used to support consumptive uses was indirectly represented in the calculation of the CSS values through the adjustment of the discharge values to compensate for the 1975 level of depletion by all uses. Most Western basins have more water available during the critical supply period than Eastern basins because of their greater storage capacities. In the more highly regulated basins, the seasonal peak use of water for irrigation is supported mainly from reservoir storage, with only a nominal amount coming directly from streamflow.

Data on the actual operation of reservoirs, including seasonal storage capacities and commitments and the proportion of each consumptive use provided from storage capacity, are lacking. Hence, the additional quantity of water that could theoretically be provided by altering the management of existing storage and the prospects of building new reservoirs to provide additional storage were not addressed directly in RIIA. The latter alternative, however, is currently much less attractive in the Eastern United States than it has been historically in the West because of restrictions on inundations of land for reservoir construction.

*J. S. Jalbert and A. D. Shepherd, A System for Regional Analysis of Water Availability, ORNL/NUREG/TM-82, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 1977.

**A. D. Shepherd, A Spatial Analysis Method of Assessing Water Supply and Demand Applied to Energy Development in the Ohio River Basin, ORNL/TM-6375, Oak Ridge National Laboratory, Oak Ridge, Tenn., August, 1979.

The estimated contribution by groundwater sources to total ASA water use was also considered in the analysis. If the groundwater portion of total water use exceeded 10% in any ASA,* a determination was made regarding the feasibility of increased groundwater withdrawals. The determination was based on the existence of adverse impacts, including:

- mining of groundwater that exhausts the water source,
- withdrawal that diminishes spring or streamflow,
- withdrawal that causes subsidence and fissures, and
- withdrawal that causes saltwater intrusion into freshwater aquifers.

If existing groundwater problems were identified in an ASA and increased groundwater withdrawal could be expected to add to these problems, future groundwater withdrawal was held constant at the 1975 level. Otherwise, future groundwater use was assumed to increase proportionally to the increase in total water use. No direct appraisal of the regional potential for groundwater development was made for this assessment, beyond these assumptions. Interbasin water transfers and surface evaporation from reservoirs were assumed to remain at 1975 levels.

Comparing Water Use and Supply

ASA water supply estimates were compared to projections of annual and monthly water consumption by sector (e.g., domestic, manufacturing, steam-electric generating, agriculture, etc.). Steam-electric generation was emphasized in the RIIA analysis because it accounts for most of the water requirements for energy. The regional demand for electricity was converted to an estimate of needed generating capacity and compared to the existing and proposed capacity expected to be on line. If additional capacity was needed, it was sited by county in consideration of accessibility to the load center, proximity to water, population density, seismic activity, air quality, and rail and barge accessibility. Conversely, excess capacity was retired or canceled wherever it appeared reasonable to do so under the assumptions of the scenario (see Chapter 3).

Water consumption by energy facilities was calculated based on both the average monthly generation needed to match the scenario and maximum base load generation conditions. Rates of water withdrawal and consumption for energy were determined for each ASA using the unit water requirements shown in Table 15. Data for all other non-energy uses were obtained from the WRC.

Monthly data on water use and availability were then entered into ORNL's Automated Downstream water availability Accounting Model (ADAM) to compute the percentage of the CSS consumed in each ASA.** The water accounting model is a computerized system designed to perform the cumulative downstream order accounting of available water supplies against projected use. In RIIA, an accounting was made of the monthly CSS estimate for each ASA in comparison to the projected water requirements of energy and all other sectors.

*The approximate percentage contribution by groundwater to total ASA water use in 1975 was derived from a study conducted by Utah State University for the U.S. Water Resource Council's Second National Water Assessment.

**A. D. Shepherd, P. E. Johnson, and D. L. Wilson, A System for Downstream Accounting of Regional Water Availability and Use, ORNL/TM-6376, Oak Ridge National Laboratory, Oak Ridge, Tenn., August, 1979.

TABLE 15

UNIT WATER REQUIREMENTS BY PLANT TYPE, FUEL TYPE, AND COOLING OPTION

Plant type or activity	Fuel type	Cooling option	Withdrawal ^a (Mgd)	Consumption ^a (Mgd)
Steam-electric generation ^b	Nuclear	Once through	1400	4
		Cooling pond or canal	42	26
		Wet cooling tower	28	17
		Dry cooling tower	0.3	0
	Fossil ^c	Once through	830	3
		Cooling pond or canal	25	15
		Wet cooling tower	17	10
		Dry cooling tower	0.2	0
Underground coal mining ^d				
Appalachian reserve			0.0033	0.00027
Eastern interior reserve			0.0036	0.00027
All western reserves			0.036	0.036
Surface coal mining ^d				
Appalachian reserve			0.0030	0.00008
Eastern interior reserve			0.0033	0.00012
All western reserves ^e			0.036	0.036

^aThese are national average rates. Zero discharge has not been assumed due to uncertainties as to how widespread its application may be.

^bPlant capacity: 1000 MWe.

^cFlue gas desulfurization units add 1 Mgd to withdrawal and consumption rates.

^dPlant capacity: 10⁶ short tons per year.

^eAssumes current levels of revegetation.

Source: J. E. Dobson et al., *A Nationwide Assessment of Water Quantity Impacts of the National Energy Plan; Volume I: Summary and Conclusions*, ORNL/TM-6098, ORNL/OPEA-3, Oak Ridge National Laboratory, Oak Ridge, Tenn., December 1977.

The critical month for each basin was defined as the month having the highest percentage consumption of its CSS by all sectors. Complete downstream accountings were run for several months to determine the critical supply month for each ASA. After these monthly data were analyzed, a composite file of the critical month water availability and use for each ASA was created for problem area identification.

Limitations of the Analysis

As with the water quality analysis, a major weakness of the water availability analysis is the dependence on the ASA-level projections of water use by other nonenergy sectors. These data were prepared for WRC's Second National Water Assessment* by the Council's member agencies and are the only projections of water use by other sectors presently available. Therefore, a comprehensive nationwide analysis considering water use by all sectors is restricted to these data at the ASA level. The WRC projections do not reflect shifts that might be induced by the national energy initiatives, and they contain data only for the years 1975, 1985, and 2000. Year 1990 values for all nonenergy sectors were interpolated between the WRC projections for 1985 and 2000.

Water supply values for ASAs were approximated from the aggregate discharge from an ASA and totaled as if the area had a single outflow point. Actually many ASAs do not have a single outflow point, but in an ASA-level assessment the separate flows of all the streams within an ASA are represented by a single water availability estimate and compared against an aggregate total projected consumption. For example, ASA 503 (Figure 8) combines the Muskingum, Scioto, and Miami River basins, each of which flows independently into the Ohio River.

At any scale of analysis, the implied assumption is that the estimate of water available at the discharge point is equally available throughout the entire analysis unit. This assumption of equal availability results from the selection of data reporting units and is not a stated premise in most studies. If the reporting unit is excessively large, such as an ASA, this generalization ignores any disparity between water availability in headwater and main-stem portions of the basin. Problem areas identified with aggregate ASA values have been shown to vary substantially from those identified with tributary basin or county-level values.**

In areas of the Western United States, where entitlements are based on annual or seasonal volumes of water rather than instantaneous flows, ASA-level analysis is somewhat useful. However, in most of the Eastern United States, where sustaining a natural minimum level of flow is important for maintenance of the aquatic biota, aggregate basin comparisons are generally inadequate to detect local water problems. The distributions of available water use within a basin are lost at such a gross scale of generalization, and potentially significant local water supply problems may be masked or distorted.

*U.S. Water Resources Council, The Nation's Water Resources: The Second National Water Assessment by the United States Water Resources Council, Washington, D.C. (draft, April 1978).

**A. D. Shepherd, A Spatial Analysis Method of Assessing Water Supply and Demand Applied to Energy Development in the Ohio River Basin, Oak Ridge, Tennessee (in press).

SOCIOECONOMICS

RIIA I's examination of the socioeconomic impacts of the MID-MID Scenario involved two lead lab analyses: local socioeconomics and national economics. The local socioeconomic analysis quantified the impacts on a county associated with increased population and increased demand for public services as a result of energy development. The national economic analysis estimated the materials and manpower (direct impacts) and the value added and employment generated (indirect impacts) by the MID-MID Scenario.

A further description of these analyses and detailed discussions of the methodologies used to perform them are presented below.

A. LOCAL SOCIOECONOMICS

The purpose of the local socioeconomic component of the RIIA I study was to provide a reliable indication of the relative impacts in terms of employment, population growth, and secondary effects on a county and community infrastructure from energy developments as called for by the MID-MID Scenario. To quantify and qualify these effects a consistent data base, methodology and computerized assessment model was used to analyze the technology- and site-specific factors associated with the energy developments identified in the county-level siting scenario.

The Social and Economic Assessment Model (SEAM) at Argonne National Laboratory (ANL) was used to determine whether and to what extent adverse impacts would be experienced in the subject counties. It estimated the increased population and public facility costs attributable to the construction and operation of additional electrical generating capacity and the expansion of coal mining in each applicable U.S. county. For each subject county or combination of counties, SEAM provided the following estimates and/or projections on an annual basis:

- Annual changes to the year 2000 in the size and composition of the baseline population of the subject county and those adjacent to it.
- Direct employment requirements of the anticipated technologies.
- Indirect (energy-induced) secondary employment requirements in the retail, commercial, and service sectors of the local economy.
- Availability of men and women with basic and/or secondary skills in subject and adjacent counties.
- Size and composition of the population that was induced to the subject county as a result of the economic stimulus from energy development (i.e., immigration).
- Annual costs of expanding public facilities and services in the impacted county sufficiently to accommodate the immigrating population without causing a reduction in provisions to the resident population.

The SEAM model computes these projections through a computerized series of integrated component submodels and data bases that permit the user to specify particular inputs and/or criteria associated with their respective usage in response to the exigencies of research needs. The two components that have generated output for the RIIA program are the Employment Impact Projection Model (EMPIMP) and the Public Cost Projection Model (IPCO/PUBCOST). In the following paragraphs, a description of the model inputs, parameters and corresponding output are briefly summarized as well as the implicit and explicit procedures used in transforming the technologies and siting pattern provided by the scenario into county-specific socio-economic impact estimates.

Social and Economic Assessment Model (SEAM)*

The model is activated by specification of the FIPS code for the subject (i.e., host) county. From this identification the model begins projecting the baseline population (expected populations without the exogenous stimulus provided by the development project) for each subject county and its adjacent counties within 60 highway miles. These projections report annual population figures for each of these counties by age, sex and race to the year 2000.** With these projections providing a population baseline, the EMPIMP component of the model is activated. It displays all the county-specific parameters available for modification by the user and requests identification of the technology, size (in megawatts) and the corresponding construction or operation date for each energy development projected in the subject county. From this construction profile the direct employment schedules are derived from the data bank incorporated in the model. This data bank contains manpower requirements for 1) each electric facility type and size; and 2) strip and deep mines for different sizes and regions of the country.

Given the estimates of new direct employment (attributable to the energy projects) required each year, the model predicts the number of secondary jobs in the retail, commercial, and service sectors that will be created as a result of the stimulus provided by the energy development(s). This prediction is accomplished with the assistance of an employment multiplier constructed from data on the subject county.*** The multiplier specifies the relationship between new direct jobs and the creation of secondary jobs in the retail, commercial, and service sectors that will be created as a result of the stimulus provided by the energy project(s). The temporal relationship between new direct jobs and the creation of secondary employment is lagged to reflect the interval required for the increased demand generated by the energy sector jobs to be transmitted to the secondary sector.

* Eric J. Stenehjem, Summary Description of SEAM: The Social and Economic Assessment Model, Argonne National Laboratory, ANL/IAPE/TM/78-9, 1978.

**This procedure is a refinement of the cohort component methodology of population projection developed by Daniel Bogue of the University of Chicago and incorporated into the Demographic Projection Module (DEMPRO) of SEAM.

***The employment multiplier is theoretically founded on the export base approach to regional economic development and is designed to indicate indirect (or income-induced) employment and economic effects of an exogenous activity (i.e., a new level of basic employment). In the SEAM program, the employment multiplier is derived from the ratio of total to basic employment in the county being calculated.

The model next estimates the number of men and women in the subject and all adjacent counties who will be available annually to fill these basic and secondary positions. This estimate is obtained by comparing labor force participation rates in these counties to the average rates for all U.S. counties and assuming that labor participation in the subject and adjacent counties will increase to at least the national average. This provides an estimate of men (women) available to take new jobs in both the subject and adjacent counties. This pool of available workers is reduced by the percentages living at different distances likely to be unwilling to commute. The final estimate of the numbers of men and women in the available labor pool comprises only those persons expected to be both willing and able to work. The basic and secondary skill mix of these workers is calculated using data on the proportion of men (women) in each county currently working in basic and secondary jobs. The new basic and secondary positions in the subject county are offered to local workers first; and, if in any year their number is insufficient to fill these jobs, workers from outside the immediate area are assumed to immigrate. This process is determined through balancing annually the direct and indirect energy manpower requirements with available supply to determine if additional workers are needed. If additional demand is identified, then it is presumed that they will be provided through immigration.

If the population of the subject county is forecast to increase in any single year due to job-induced immigration, the service needs of the new households are prescribed and the estimates of the costs of building and operating expanded facilities determined. This is accomplished through accessing the PUBCOST component of the model.* The public services and facilities evaluated in this study and included in the sub-module are hospitals, social welfare, police, fire, sewers, water, solid waste disposal, recreation, libraries, general government, and primary and secondary schools. This list is not exhaustive of all publicly provided services in all local (i.e., community and county) levels. Among the most important exclusions are county roads and local streets. These are not included because of the wide variations in requirements and costs among locales due to geography, climate, and state-local cost sharing formulas.

Estimates of the incremental public costs attributable to energy development are provided for two different levels of immigration. First, estimates of the total costs of constructing new facilities and operating new services are computed for the level of immigration associated with the peak increase in population. A peak population increase usually occurs during the construction of a new power plant and generally lasts for one to two years. Secondly, similar cost estimates are prepared for the population increase that is expected to be permanent. This increase is usually associated with the period that the power plant or mine is in actual operation. Three separate costs are computed for each of the 11 public facilities and services in both the peak and operation periods. They are the total capital costs of constructing new facilities to accommodate the expected population increase, the annual incremental costs of operating these services, and the total annualized facilities and service costs obtained by discounting the capital costs over 20 years at 8% and adding the resulting figure to the annual service costs.

*The PUBCOST submodel is an accounting model which identifies and then computes the relevant costs for the construction of a public facility from a triangular data matrix. The data for this matrix were gathered through surveys of county records and are correlated according to county size, type and the peak (construction and long-term (operational)) impact-related increase in population.

The public cost estimates provided by this model were used in this analysis to indicate the relative magnitude of local socioeconomic impacts experienced in the counties subjected to new energy development. These cost estimates, which reflect the per capita costs of providing new facilities and services in the 11 public good categories mentioned above, can also be viewed as indices of the "social costs" imposed upon communities as a result of energy development. That is, these estimates can also be interpreted as the dollar equivalent values of the reductions in community infrastructure, and hence living standards, suffered by the pre-impact local residents. The estimates of public service needs and costs reflect the per capita requirements of the newcomers. If new persons arrive and use existing services, the decline in availability of these services to the permanent residents should be roughly equal to the estimated service needs of the new residents. The social costs (externalities imposed by benefit "spillouts") to the permanent residents should, therefore, approximate the estimates of the costs of expanding the services to meet the needs of new residents. Thus, these estimates of the partial costs confronting impacted communities provide both evidence of the relative "social" costs experienced by these host counties and an index of the relative extent of impact among counties and regions. It is the latter purpose for which they are used in this local socioeconomic analysis.

Data and Methodology Assumptions

The SEAM model estimates the public infrastructure costs associated with the construction of energy facilities and coal mines after it calculates the corresponding employment requirements and population growth in the impact county(ies). Inherent in both the data and methods employed to calculate the impacts through the use of the SEAM model are a series of assumptions and limitations.

1. The Data Base: County-Specific Siting of Energy Extraction and Production

Regional totals of energy growth and expansion from the MID-MID Scenario were disaggregated by ORNL to identify 12 electric-generating capacity types within three time periods: 1975, 1985, and 1990 (Chapter 3). In preparing this data base for input into the SEAM program, a number of procedures were employed to manipulate the data into the required input format.

Since the ORNL siting tape identified 12 energy types, a decision was made by ANL to focus on only the five primary facility types that could generate the greatest socioeconomic impact during the time periods being analyzed. These included coal, nuclear, combined cycle, and gas and oil steam. From this condensed list of county-specific energy facilities, the megawatt capacity differentials for the time increments of 1975-1985 and 1985-1990 were computed. In this format, the data were available for direct input into SEAM. The one qualification pertaining to the input data is that only increases (positive) in production capacity were input to the model. Decreases in capacities were explicitly excluded.

In addition to the county-level energy facility sitings, county-specific coal extraction data for the three time periods was also provided. This data file identified, in trillions of Btus, the regional adjusted reserves and production associated with deep and strip mining by county. The SEAM input format requires coal extraction to be specified in employees/year. Because of this format inconsistency, the following procedures described below were organized to modify the units from trillions of Btus to employees/year.

2. The Model: Converting Projections of Incremental Capacity to Direct Employment

The conversion of incremental mine capacity to increased employment was accomplished by referring to the Keystone Manual—Mine Production, 1976, for mine production greater than 500,000* tons/year/state. A list of the qualified mines with their corresponding characteristics of type (deep or strip), number of employees, and 1976 production levels was compiled. From this tabulation, a production-weighted average of employees/million (10^6) tons/year was calculated for each state identified in the production and reserves data.

The regionally adjusted reserves and production data were transformed from trillions of Btus, in the three time periods 1975, 1985, and 1990, to 1,000-ton units for the incremental periods of 1975-1985 and 1985-1990. To assist in this computation, a county-specific factor was utilized which identified the Btu content per ton of coal mined. The calculated 1,000-ton units were then characterized as million ton units and rounded to the nearest .01 million tons.

The format-corrected production statistics were then distributed from the increment periods to individual years according to one million ton units for deep mining and six million ton units for strip. These deep mining units were allocated by one million ton blocks, or fractions thereof, to the years 1982, 1981, 1980, 1979, and 1978 in order to simulate actual mine expansion. Mine production to begin in the 1975-1985 period was allocated, in million ton per year units, first to the year 1982 with the remainder, if any, distributed to preceding years according to the format stated previously. If the production capacity was greater than five million tons for the 1975-1985 period, the one million ton blocks were distributed over the five years 1982-1978 with any remainder being allocated in an identical manner beginning in 1982. For the 1985-1990 increment, production units were allocated to 1987 and 1986 only, according to the same procedure described above. The procedure for strip mining is identical to that of deep mining, except that the unit blocks are six million tons instead of one.

After determining the number of tons to be produced in the applicable years by deep and strip mining, the county-specific units were multiplied by their respective ton-weighted average of employees/million (10^6) tons/year. The summation of the individual annual products for deep- and strip-mined coal resulted in the annual employee increase in coal mining by county. These data were then input into the SEAM model either individually or in combination with another selected technology(ies).

Two qualifications should be noted with respect to the production methodology: one is that any decreases in production capacity were ignored and only increases in production greater than .005 million tons were included; and two, all employment figures were rounded to the nearest whole number.

As mentioned, the incremental capacity of the five selected energy facility types was stated in terms of megawatts. The SEAM program utilizes regression equations to calculate the basic manpower requirements corresponding to a specific megawatt level of capacity. The five technologies being analyzed were evaluated with respect to construction during periods and employment levels (construction and operation) unique to the capital or labor-intensiveness of the facility.

*If particular states did not have a sufficient number of mines producing greater than 500,000 tons/year, a random sample of the 200,000-400,000 tons/year category increased the representation of mines within that state.

The required historical construction and operation characteristics of each of the five specified facilities were obtained from the report entitled Forecasts of Cost, Duration, and Manual Man-Hour Requirements for Construction of Electric Generating Plants, 1977-1981, which summarizes the results of a joint DOL/DOE manpower study. The data presented in the report correlated work-hours to kilowatts of electricity which was transformed for the RIIA program into work-years per megawatts of electricity. The logarithm of these variables was computed so that a least squares line could be utilized in correlating megawatts of capacity to work years.

$$\text{LOG } Y = \text{LOG } a_0 + a_1 \text{ LOG } X$$

where:

$$a_0 = \frac{(\sum Y)(\sum x^2) - (\sum x)(\sum xy)}{N(\sum x^2) - (\sum x)^2} \quad Y = \text{Work Years}$$

$$a_1 = \frac{N\sum xy - (\sum x)(\sum y)}{N(\sum x^2) - (\sum x)^2} \quad X = \text{Megawatts}$$

The energy-specific equations and work-year schedule resulting from fitting the data to a straight line by the least squares method is presented below. The work-year schedule for the coal, oil, and gas steam technologies are presented with a capacity base size of 500 megawatts (MW) and construction duration period for four full years.* This base size and duration schedule was selected because they represent the typical size and corresponding construction characteristics of these selected facility types. For nuclear facilities, a base capacity size of 800-MW was used with a standard construction duration period of six years. The results for each standard-sized facility are presented in Table 16.

These base capacity size work year schedules are utilized as the framework from which the EMPIMP component of SEAM computes the work-year schedule associated with the energy type and megawatt size inputted into the model. When the specified megawatt size is greater (less) than the base capacity size, the model computes a new schedule by using the WY/MW least squares equation(s) to modify the construction and operation periods. If the specified megawatt size is less than the base capacity size, this new schedule is used to compute the employment and population changes associated with that size energy development; whereas, if the input megawatt size is greater than the base, the differential construction and operation schedule is added to the base schedule for that particular type of energy facility in single-year stages. This type of arrangement allows for any size plant to be constructed and its impact calculated without overloading the various economies of scale associated with the construction of these facilities. The results are demonstrated in Table 17 for the total direct employment associated with an 800-MW coal-fired electric generating facility.

*The combined cycle technology did not have an available historical construction and operation record; therefore, its capital and labor requirements were evaluated and found to most closely resemble the characteristics of the coal technology. Throughout the remainder of this description, the coal equation will also represent that of the combined cycle.

TABLE 16
DIRECT EMPLOYMENT FOR EACH TECHNOLOGY (BY YEAR)

TECHNOLOGY SCHEDULE	COAL ^a	OIL	GAS	NUCLEAR
Construction Work-Year Equation	WY = 20.47 MW ^{.7584}	WY = 15.34 MW ^{.7760}	WY = 14.96 MW ^{.7639}	WY = 46.19 MW ^{.7150}
WY ₁	285.054	278.342	141.585	405.802
WY ₂	848.320	570.307	487.012	812.703
WY ₃	914.452	727.884	792.774	1123.927
WY ₄	232.604	392.920	303.175	1358.720
WY ₅	-	-	-	1218.504
WY ₆	-	-	-	579.009
WY (Total)	2280.430	1906.453	1724.546	5498.665
Operations Work-Year Equation	WY = .185 MW	WY = .180 MW	WY = .139 MW	WY = .0636 MW

^aCombined cycle equation(s) and schedule are identical.

TABLE 17
ESTIMATION OF DIRECT EMPLOYMENT FOR AN
800-MW COAL-FIRED PLANT

Period	WY for Standard 500-MW Coal Plant	WY for a 300-MW Coal Plant Calcu- lated By-Formula Delayed One Period	Total WY for an 800-MW Coal Plant by Year
WY ₁	285	0	285
WY ₂	848	194	1042
WY ₃	914	576	1490
WY ₄	233	621	854
WY ₅	93	158	251
WY ₆	93	56	149
.	.	.	.
.	.	.	.
.	.	.	.
WY ₂₀	93	56	149

3. The Model: Specific Assumptions and Limitations

The previous sections briefly identified the procedures undertaken to translate data on facility siting into estimates of direct annual employment requirements at the county level. While the assumptions and qualifications employed to expedite this task are a part of the overall SEAM model, there are many more which pertain to the manner in which the model utilizes these data in preparing estimates of increased total employment, population, and infrastructure requirements and costs. While most relevant assumptions and data limitations are mentioned in the description of the model, several need explicit mention.

One of the most important variables in the model is the available labor force in each county. The model computes available labor force by subtracting the county-specific labor force participation rates (LFPRs) by age cohort and sex from the corresponding national figures to obtain the percentage of men and women in each age group who are not currently in the local work force but would, if sufficient jobs existed, be available to work. Thus, the model assumes that LFPR will grow at least to the national average as a result of increased employment opportunities. In those counties where the LFPRs in all age groups are greater than the national figures, no available work force will be identified and immigration is assumed to meet the demand. However, because the total available local work force for any given new facility is computed from all counties within 60 highway miles, the model has never failed to "find" some available workers. This computational problem is derived from the comparison of local LFPRs with the national average which suppresses regional and county type participation rate deviations. (Modifications in this regard are currently under development.)

Another variable that is not presently included in the model is a differentiation of skills according to the available labor force or existing employed labor force. Furthermore, the model excludes any consideration of labor union

preferential or contractor import crews that may cause the actual economic impact of the county to increase substantially. Consequently, the basic assumption is that all local available workers, including communities within a 60-mile radius, can and will work to fill the vacancies with all excess demand being satisfied by immigrants. The model further assumes that the immigrants are the first to be released if the demand for workers is reduced.

These factors, together with the lack of labor competition in the energy impacted county and its adjacent counties, limit the model to compute only rough employment trends within the basic and secondary markets. Included in this limitation is the implicit assumption that the available labor force is restricted to supplying its resources to those jobs created directly and indirectly by the energy facility. Thus, unless competing basic industrial development is explicitly included, the model will assume that none takes place. This will result in an overstatement of available workers and an understatement of impacts if, in fact, new basic industry is attracted to the site during the same time period.

Given the estimates of immigrating workers and their households, projections of annual increases in county populations are prepared. The public cost component of SEAM then computes the annual incremental costs of accommodating the new population attracted by the energy facility. That is, the public cost model computes the cost of expanding and operating 11 specific publicly provided services using 1977 dollar figures on the capital and operating costs of each service. The specific cost figures used for each service were separately calculated for communities of different sizes (e.g., less than 10,000; 10,000 to 30,000; 30,000 to 100,000 and greater), different types (e.g., independent outlying, dependent outlying, suburban), and different census regions. However, the model is unable to determine the extent of existing capacity available in any of the 11 services within a county. Thus, it estimates the cost of expanding services on the assumption that no excess capacity exists in any of the 11 services. In addition, the list of 11 public services is not exhaustive of all publicly provided services at the community, township, special district, and county levels. For example, city streets and county and township roads are not included. Thus, the total of public costs presented understates the entire cost borne by all these jurisdictions as a result of energy impacts.

In summary, although the model has several areas where refinements could be developed, it utilized the most comprehensive and uniform data base presently available for the RIIA I analysis. Since completion of this first RIIA program, several modifications and further research on the theoretical foundations and future adaptations to the model have been completed. Some of these new developments will eliminate the identified limitations of the model while others will augment the existing computational and procedural exercises. Although these refinements will complement the current status of the model, it does/will not remove the analyses which must be performed by laboratory personnel. In the RIIA I assessment, the socioeconomic impact estimates, from the SEAM output, prepared for each region, were not adequate to explain and/or identify the effects of development precisely but did provide the regional laboratories with county-level impact characteristics and the ability to compare relative impact levels among counties, regions and technologies. It is from these county-specific projections that detailed socioeconomic analysis originated within each laboratory.

B. NATIONAL ECONOMICS

The national economics analysis for RIIA I was conducted by Lawrence Berkeley Laboratory (LBL). This analysis estimated both the direct and indirect economic impacts of the MID-MID Scenario. Direct economic impacts included estimates of future capital materials and manpower requirements for energy supply to the Nation. Indirect impacts included the income (secondary value added) and employment opportunities due to construction of new energy facilities.

These two types of impacts were estimated utilizing two separate models. The Energy Supply Planning Model (ESPM)*, as modified at LBL, was used to estimate future capital and manpower requirements for given quantities and types of energy supply as dictated by the national scenario. The resulting capital requirements for construction of new facilities were then used as an incremental final demand vector for LBL's interindustry transactions model. The gross output estimates derived from this model were then translated into the number of employees and value added in each industry.

This methodology is summarized in Figure 11 and the following discussion briefly describes the models and data used to calculate the direct and indirect economic impacts of the scenario.

Direct Impacts

The ESPM was developed for the National Science Foundation (NSF), and DOE by the Bechtel Corporation, a major facility construction company. The model was designed to estimate the capital, materials and manpower (direct impacts) required to construct and operate a variety of energy-related facilities, including power plants, mining operations, refineries, and energy transportation systems. Essentially, the model converts a national scenario into the number of facilities required to meet the supply dictated by the scenario through the year 2000. Based on the construction and operation data collected by Bechtel and incorporated in the ESPM for each type of facility, the model then estimates total annual direct impacts for the scenario for the 113 types of materials and manpower (occupational) skills presented in Table 18.

Both the programs and the data have been improved since the model was developed in late 1975. Some of the programs were updated to expand the time span under consideration from 1975-1995 to 1975-2010, while others were changed to provide better aggregations and tabulations of results. The data base was improved to include data on wind, solar and biomass power plants and the cost information was updated to constant 1977 dollars from constant 1974 dollars.** The construction and operating costs now included items such as interest during construction and overhead and other administrative costs which were not included in the earlier estimates (see Table 19). LBL utilized this updated version of the ESPM for the RIIA I analysis.

*Bechtel Corporation, San Francisco, California, The Energy Supply Planning Model, Volumes I and II, August 1975.

**Bechtel Corporation, "Escalation in the Costs of Manpower, Materials, and Equipment Needed for Energy Facilities," PAE-3794-7, October 1977.

FIGURE 11

NATIONAL ECONOMICS ANALYTICAL METHODOLOGY

Table 18

CONSTRUCTION RESOURCES

1	Non-Manual Technical Manpower
2	Non-Manual Non-Technical Manpower
3	Manual Manpower
4	Manpower Total
5	Wood Products (20)
6	Chemicals + Allied Prod. (27, 28, 30, 32)
7	Petroleum Products (31)
8	Glass, Clay + Stone Products (35, 36)
9	Primary Iron + Steel Products (37)
10	Primary Non-Ferrous Metals (38)
11	Fabricated Structural Products (40)
12	Other Fabricated Products (42)
13	Miscellaneous Materials
14	Materials Total
15	HVAC Heating + Cooling Units (52)
16	HVAC Ductwork + Accessories (40)
17	Turbines (43)
18	Gas Welding Sets (47)
19	Electric Welding Sets (53)
20	Construction, Mining, + Oil Field Equipment (45)
21	Materials Handling Equipment (46)
22	General Industry Equipment (49)
23	Instrumentation + Controls (62)
24	Electrical Equipment (53)
25	Fabricated Plate Products (40)
26	Miscellaneous Equipment
27	Equipment Total
28	Service + Miscellaneous
29	Other Constructor Costs
30	Construction Cost Total
31	Land + Land Rights
32	General Plant
33	Intangible Assets
34	Construction Start Total
35	Escalation During Construction
36	Interest During Construction
37	Working Capital
38	Capital Cost Total
39	Escalated, Undeclared Cost Total
40	Constant Dollar Cost Total
41	Chemical Engineers
42	Civil Engineers
43	Electrical Engineers
44	Mechanical Engineers
45	Mining Engineers
46	Nuclear Engineers

Table 18, (con't)

47	Geological Engineers	
48	Petroleum Engineers	
49	Other Engineers	
50	Engineers Total	
51	Designers + Draftsmen	
52	Supervisors + Managers	
53	Non-Manual, Technical Total	
54	Non-Manual, Non-Technical	
55	Non-Manual Total	
56	Pipefitters	
57	Pipefitter/Welders	
58	Electricians	
59	Boilermakers	
60	Boilermaker/Welders	
61	Iron Workers	
62	Carpenters	
63	Equipment Operators	
64	Linemen	
65	Teamsters + Laborers	
66	Other	
67	Manual Total	
68	Construction Manpower Total	
69	Cement	(S Tons)
70	Concrete (includes cement)	(S Tons)
71	Bentonite (in drilling mud)	(S Tons)
72	Barite (in drilling mud)	(S Tons)
73	Carbon Steel	(S Tons)
74	Alloy Steel	(S Tons)
75	Stainless Steel	(S Tons)
76	Steel Total	(S Tons)
77	Copper	(S Tons)
78	Aluminum	(S Tons)
79	Manganese	(S Tons)
80	Chromium	(S Tons)
81	Nickel	(S Tons)
82	Cast Iron	(S Tons)
83	Steel Castings	(S Tons)
84	Aluminum Castings	(S Tons)
85	Brass + Bronze Castings	(S Tons)
86	Iron + Steel Forgings	(S Tons)
87	Structural Steel Shapes	(S Tons)
88	Steel Plate < 1.5 in. thick	(S Tons)
89	Steel Plate ≥ 1.5 in. thick	(S Tons)
90	Pipe, Carbon Steel	(S Tons)
91	Pipe, Alloy + Stainless Steel	(S Tons)
92	Oil Country Tubular Goods	(S Tons)
93	Reinforcing Bar (Rebar)	(S Tons)
94	Valves, Carbon Steel	(S Tons)

Table 18, (con't)

95	Valves, Alloy + Stainless Steel	(S Tons)
96	Steam Turbogenerators (Megawatts)	
97	Steam Turbines (excluding turbogenerators)	(1000 HP)
98	Gas Turbogenerators (Megawatts)	
99	Draglines	(Cubic yards)
100	Drill Rigs, Onshore	(Rig Years)
101	Drill Rigs, Offshore	(Rig Years)
102	Drill Bits	(Number)
103	Pumps + Drivers < 1000 HSEPWR	(1000 HP)
104	Pumps + Drivers ≥ 1000 HSEPWR	(1000 HP)
105	Axial Compressors 5000 HSEPWR	(1000 HP)
106	Centrifugal Compressor + Drivers < 10000 HP	(1000 HP)
107	Centrifugal Compressor + Drivers ≥ 10000 HP	(1000 HP)
108	Heat Exchangers	(1000 sq. feet surface)
109	Non-Nuclear Press Vess < 1.5 in. wall	(Tons)
110	Non-Nuclear Press Vess 1.5-4 in. wall	(Tons)
111	Non-Nuclear Press Vess > 4 in. wall	(Tons)
112	Boilers	(Million pounds steam per hour)
113	Nuclear Steam Supply Systems	(Megawatts)

Table 19

OPERATING AND MAINTENANCE RESOURCES

1	Non-Manual Technical Manpower
2	Non-Manual Non-Technical Manpower
3	Manual Manpower
4	Manpower Total
5	Wood Products (20)
6	Chemical + Allied Prod. (27, 28, 30, 32)
7	Petroleum Products (31)
8	Glass, Clay + Stone Products (35, 36)
9	Primary Iron + Steel Products (37)
10	Primary Non-Ferrous Metals (38)
11	Fabricated Structural Products (40)
12	Other Fabricated Products (42)
13	Miscellaneous Materials
14	Materials Total
15	HVAC Heating + Cooling Units (52)
16	HVAC Ductwork + Accessories (40)
17	Turbines (43)
18	Gas Welding Sets (47)
19	Electric Welding Sets (53)
20	Construction, Mining, + Oil Field Equipment (45)
21	Materials Handling Equipment (46)
22	General Industry Equipment (49)
23	Instrumentation + Controls (62)
24	Electrical Equipment (53)
25	Fabricated Plate Products (40)
26	Miscellaneous Equipment
27	Equipment Total
28	Electricity
29	Natural Gas
30	Water
31	Utilities Total
32	Rents, Royalties, etc.
33	All Taxes
34	Services + Miscellaneous
35	Annual Operating Cost (excluding fuels)
36	Chemical Engineers
37	Civil Engineers
38	Electrical Engineers
39	Mechanical Engineers
40	Mining Engineers
41	Nuclear Engineers
42	Geological Engineers
43	Petroleum Engineers
44	Other Engineers
45	Engineers Total

Table 19., (con't)

46	Designers + Draftsmen	
47	Supervisors + Managers	
48	Other Technical	
49	Non-Manual, Technical Total	
50	Non-Manual, Non-Technical	
51	Non-Manual Total	
52	Pipefitters	
53	Welders	
54	Electricians	
55	Boilermakers	
56	Mechanics	
57	Machinists	
58	Ironworkers	
59	Carpenters	
60	Equipment Operators	
61	Other Operators	
62	Meter Readers	
63	Teamsters + Laborers	
64	Linemen	
65	Other	
66	Manual Total	
67	Manpower Total	
68	Fixed Land	(Acres occupied)
69	Incremental Land	(Acres occupied)
70	Right-of-Way	(Acres occupied)
71	Underground Lease	(Acres occupied)
72	Water Consumption	(Acre-feet per year)
73	Coal (Million tons)	
74	Crude Oil (Billion barrels)	
75	Natural Gas (Trillion cubic feet)	
76	Oil Shale (Billion barrels)	
77	Uranium (Thousand tons U ₃₀₈)	

The energy supply system boundary (Figure 12) shows the activities for which resources are estimated by the model. It does not include items such as government subsidies or investment in mass transit and automobiles which are use-oriented. It does include resources required for local distribution of electricity, for transportation of fuels and for production and processing of these fuels. Furthermore, resources required for facilities located in the United States and its offshore areas are included, whereas similar requirements in foreign countries for energy supply to the U.S. are not included.

As shown in Figure 13 the fuel mix generator is used to convert the energy scenario into 270 paths by which the fuel flows reach the consumer. Based on this model of the U.S. energy supply system the fuel mix is translated into annual number of energy facilities of standard size, required up to 2000. These facilities include energy production facilities such as power plants, mines, refineries and oil wells. The facilities are linked together by the fuel flows shown in Figure 13. The number of transportation facilities required for these flows are estimated based on the energy facility locations, the regional demand for energy, the fuel flow rules and the modal splits between competing modes. Having estimated the number of energy and transportation facilities, the total resource requirements are estimated based on the data for an individual facility. The capital resources are listed by standard two-digit input-output category (items 5-30 on Table 18), the manpower requirements are listed by occupational skills, and materials and equipment are listed by about 45 major categories.

Indirect Impacts

The indirect economic impacts of the MID-MID Scenario were estimated using an input-output table. In an input-output table the economy is broken up into sectors such as coal mining, automobile manufacturing or retail trade. Each element in the table is the dollar purchases by one sector of the output of another sector during one year. Reading across the rows shows the sales of a given commodity to all sectors including final demand. (Final demand is the consumption by ultimate consumers such as households, government, exports, and capital formation.) Reading down a column shows all the inputs to a given sector including value added which represents payments to the factors of production (land, labor, capital, etc.). The sum of all the elements in a column is called the gross output of that sector. If each element in the column is divided by the gross output, the resulting vector of technical coefficients shows the inputs from each sector needed to produce one dollar's worth of output in that sector. Insofar as these technical coefficients do not change significantly over the time period considered in this study, an input-output table can be used to calculate the change in gross output due to a change in final demand.

A 368-sector national input-output table which was developed at LBL* was used to calculate the indirect impacts of the MID-MID Scenario. The 1967 national table at the 368-sector level published by the Bureau of Economic Analysis** was

*Lawrence Berkeley Laboratory, Report in Preparation.

**U.S. Department of Commerce, Bureau of Economic Analysis, "Input-Output Structure of the U.S. Economy: 1967", Volume I, 1974.

Cost Factors Included in Report

Investment Costs

Construction

- Design and Installation Manpower
- Materials
- Equipment
- Contractor Indirect Overhead and Fee

Owner's Costs

- Escalation (Future)
- Interest During Construction
- All Other Owner's Costs (land costs, preliminary studies, environmental impact studies, leases, etc.)

Annual Costs

- Materials
- Equipment
- Direct Plant Labor
- Other Labor (main office, sales, clerical, R&D)
- All Other Operations and Maintenance Costs (capital charges, taxes, royalties, fees, insurance, main office expense)
- Fuel Cycle¹

¹Delivered fuel price is excluded, but capital and operation and maintenance costs of fuel cycle facilities are covered.

FIGURE 12 - ENERGY SUPPLY SYSTEM BOUNDARY

FIGURE 13 - THE ENERGY SUPPLY PLANNING MODEL:
METHODOLOGY OVERVIEW, INPUTS AND OUTPUTS

updated to 1972. Published data from the National Income and Product Accounts,* the 1972 Economic Census and other sources provided 1972 control totals for gross output, final demand and value added. An RAS (matrix balancing) method was used to balance the resulting table. More details of this procedure may be found in an article published in Technological Forecasting and Social Change.**

Construction of Final Demand Vectors

The steps in constructing the final demand vectors from the direct requirements calculated by the energy supply model are shown schematically in Figure 14. The model output gives the construction requirements from 1974 to 1990 for the categories of materials, manpower and equipment listed in Table 18. A total capital cost is also given. All these data are expressed in purchaser's prices in first quarter 1977 dollars. The first step is to aggregate these requirements to five-year intervals starting with 1976 and to deflate the data to constant 1972 dollars. This was done using deflators obtained from the Bechtel Corporation and The Center for Advanced Computation (CAC)**.

Of the 24 requirements categories only six correspond to the detailed BEA 368-sector classification; the rest correspond to two-digit or groups of two-digit codes. The proportions used to disaggregate the requirements to 368-sectors were derived in the following manner. A representative capital formation final demand vector was constructed by adding the columns from the 1972 national I-O table for: 1) new construction of non-residential buildings; 2) new construction of public utilities; and 3) gross private capital formation excluding the five new construction rows. This 368-order final demand vector is an approximation to the requirements for both structures and equipment needed in constructing energy facilities. The requirements calculated by the model were disaggregated according to these proportions. Transportation costs and trade margins*** were subtracted from each producing sector and assigned to the appropriate transportation or trade sector. The remaining construction costs not included in the 24 requirements categories were allocated to the service and government sectors and to imports in proportion to the two construction sectors contained in the representative final demand vector.

The expenditures for construction manpower were used to construct a second set of final demand vectors which represent the personal consumption expenditures (PCE) of the construction workforce. The five-year manpower expenditures, after deflating to 1972 dollars, were multiplied by the ratio of PCE to employee compensa-

*U.S. Department of Commerce, Bureau of Economic Analysis, "The National Income and Product Accounts of the United States 1929-74".

**H.C. Davis, E. M. Lofting and J. A. Sathaye, "Alternative Methods of Updating an Input-Output Matrix: A Statistical Evaluation," published in Technological Forecasting and Social Change, Volume 10, 1977.

***Private communication with D. Pilati of the Center for Advanced Computation, University of Illinois. These deflators were obtained by CAC from the Bechtel Corporation.

FIGURE 14 - INDIRECT ECONOMIC IMPACTS

tion (0.78) for 1977 from the National Income and Products Accounts.* The resulting figure was apportioned to the 368-sectors using the PCE vector from the 1972 national input-output table.

Changes in Gross Output, Value Added and Employment

The change in gross output X due to each incremental final demand vector was calculated using the following equation:

$$\Delta X = (I - A)^{-1} \Delta Y$$

where:

I = Unit Matrix with ones on the diagonal and zeroes elsewhere

A = Coefficient Matrix

Y = Final Sum and Vector

The value added and employment coefficients were computed using the value added from the 1972 Input-Output table and employment data from a previous LBL study.* The resulting change in value added and employment were then calculated using the gross output vector:

$$\Delta V_i = v_i \Delta x_i$$

$$\Delta E_i = e_i \Delta x_i$$

The coefficients v_i and e_i are the value added and employment in sector i divided by the sectoral gross output from the I-O table. Finally, the gross output and value added were inflated to 1977 dollars using a GNP inflator of 1.40.** This calculation was performed for twelve (12) final demand vectors: two types of facilities (all energy facilities and coal-related only), two final demand components (capital formation and PCE) and three five year intervals (1976-80, 1981-85 and 1986-90).

Limitations of the Analysis

The only major limitation of the national economic analysis are concerned with the identification of indirect impacts. The estimates of indirect impacts are based on linear models and average values for coefficients. The impacts identified, however, are marginal effects. Since marginal increases in employment are generally less than their average values, it is likely that the results of the analysis overstate the indirect impacts. For example, construction workers generally have above average incomes

*Deane Merrill, Lawrence Berkeley Laboratory, "U.S. Employment for 368 Input-Output Sectors for 1963, 1967 and 1972", UCID 3757, July 1975.

**U.S. Department of Commerce, Bureau of Economic Analysis Survey of Current Business, April 1978.

and thus are likely to have a lower marginal propensity to consume than the average value used in the analysis. Furthermore, labor productivity has increased at a rate of a few percent per year. Employment coefficients used in this analysis were not corrected for changes in productivity, which would result in an overestimation of employment. Overall, these results could be 10 to 30 percent too high by 1990.

It should also be noted that the indirect impacts may not represent a net increase in employment and income for the economy as a whole. If the economy is at full employment, then the energy sectors would have to compete against other industries for employees. Only if there were unemployment in the skill categories that are required would there be a net increase in employment. The results of the analysis, therefore, should be interpreted as the amount of employment and income attributable to energy facility construction.

In addition, the input-output table utilized by LBL to obtain the value added and employment impacts of the MID-MID Scenario contains 1972 data. The results of this analysis should therefore be viewed with caution since these data are somewhat outdated.

Finally, although not specifically a limitation of the analysis, it should be noted that some considerations need to be taken into account when interpreting the data and conclusions of the national economic analysis. Although the RIIA scenario only forecasted energy demand to 1990, it was necessary to interpolate demand to 2000 due to the time required to construct new energy facilities. For example, for nuclear power plants coming on line in 1999, resources are distributed by the ESPM over its nine-year construction period starting in 1990. As a result, the scenario had to be specified for nine years beyond the last year for which results were estimated.

HEALTH EFFECTS

Brookhaven National Laboratory (BNL) conducted the lead lab analysis for health effects. The objective of this analysis was to provide the regional laboratories with state-level estimates of the health damage resulting from the energy flows associated with MID-MID Scenario. The BNL health effects analysis addressed both public health and occupational health and safety.

In general, health damage was estimated by applying a health damage function to the energy flow levels embodied in the Scenario. These damage functions were derived from statistics on past experience with the various energy processes or from results of epidemiological studies. With a few exceptions, damage functions were presented as 60% confidence ranges to provide the regional laboratories with some feeling as to the degree of uncertainty involved. Table 20 summarizes the health damage coefficients used. These are discussed in more detail below.

A. OCCUPATIONAL HEALTH AND SAFETY

Coal

Occupational health damage in coal mining and processing and occupational public accidental injury in coal transport were estimated using national level factors in the same way as in Morris, et. al.* Although mining risks vary somewhat regionally, national average estimates provide a better statistical base. State-by-state comparisons of predicted versus actual 1975 accidents showed no deviation beyond that expected from random fluctuation. While length of mining experience has been a factor in mine accidents in the past, this may be eliminated by more extensive training programs. Therefore, no increase in accident rate was estimated to accompany the marked increase in coal mined underground and the concomitant increase in the proportion of new miners. In addition, no change in productivity levels in the mines was assumed.

Statistics on mortality and morbidity due to occupational disease in coal miners are subject to great uncertainty. Although there are several surveys on the prevalence of disease in miners, the incidence of occupationally related disease is not known as well as accidental injury deaths; this year's incidence is related to a long exposure history -- not this year's production. Dust concentrations in coal mines have decreased by a factor of 3 to 4 in recent years and the character of the exposure may have changed as well. The range in estimates of these effects calculated by BNL reflected a lower bound of zero and an upper bound based on a linear extrapolation from epidemiological studies, considering the decrease in dust levels.

Accidental deaths and injuries in coal processing and transport were developed following the methods described in Morris, et. al. (previous footnote).

*S. C. Morris, K. M. Novak and L. D. Hamilton, Health Effects of Coal in the National Energy Plan, Brookhaven National Laboratory, 1979.

TABLE 20
HEALTH DAMAGE COEFFICIENTS

FUEL CYCLE COMPONENT	EFFECT	DAMAGE COEFFICIENT	
		RANGE	UNIT
Underground Coal Mining	Occupational Accidents		
	• deaths	0.17 - 0.63	deaths/ 10^6 tons
	• injuries	19 - 71	injuries/ 10^6 tons
	Occupational Disease		
	• deaths	0 - 0.47	deaths/ 10^6 tons
	• disease	0 - 5.6	cases/ 10^6 tons
Surface Coal Mining	Occupational Accidents		
	• deaths	0.05 - 0.17	deaths/ 10^6 tons
	• injuries	2.7 - 10	injuries/ 10^6 tons
Coal Cleaning	Occupational Accidents		
	• deaths	0.017 - 0.027	deaths/ 10^6 tons
	• injuries	1 - 1.6	injuries/ 10^6 tons
Coal Transport - Rail	Occupational Accidents		
	• deaths	1.8 - 7.0	deaths/ 10^6 Btu
	• injuries	1.3 - 5.7	injuries/ 10^{14} Btu
	Public Accidents		
	• deaths	0.52 - 2.2	deaths/ 10^{14} Btu
	• injuries	1.1 - 4.7	injuries/ 10^{14} Btu

Source: S.C. Morris, K.M. Novak and L.D. Hamilton, Health Effects of Coal in the National Energy Plan, Brookhaven National Laboratory, 1979.

TABLE 20 (Continued)

FUEL CYCLE COMPONENT	EFFECT	DAMAGE COEFFICIENT	
		RANGE	UNIT
Coal Transport - Barge	Accidents		
	• deaths	1.7	deaths/ 10^{15} Btu
	• injuries	1.7	injuries/ 10^{13} Btu
Coal Transport - Pipeline	Accidents		
	• deaths	2.0	deaths/ 10^{16} Btu
	• injuries	1.8	injuries/ 10^{14} Btu
Coal Electric Generation	Occupational Accidents		
	• deaths	8 - 12	deaths/ 10^{12} KWH
	• injuries	4.6 - 5.5	injuries/ 10^{10} KWH
Oil Extraction	Occupational Accidents		
	• deaths	2.2	deaths/ 10^{15} Btu
	• injuries	2.1	injuries/ 10^{13} Btu
Oil Transport	Occupational Accidents		
	• deaths	9	deaths/ 10^{16} Btu
	• injuries	8	injuries/ 10^{14} Btu
Oil Refining	Occupational Accidents		
	• deaths	1.3	deaths/ 10^{15} Btu
	• injuries	9.6	injuries/ 10^{14} Btu

TABLE 20 (Continued)

FUEL CYCLE COMPONENT	EFFECT	DAMAGE COEFFICIENT	
		RANGE	UNIT
Oil Electric Generation	Occupational Accidents		
	• deaths	2.0	deaths/ 10^{12} KWH
	• injuries	1.8	injuries/ 10^{10} KWH
Natural Gas Production	Occupational Accidents		
	• deaths	2.2	deaths/ 10^{15} Btu
	• injuries	2.1	injuries/ 10^{15} Btu
Natural Gas Processing	Occupational Accidents		
	• deaths	2.1	deaths/ 10^{18} Btu
	• injuries	1.9	injuries/ 10^{15} Btu
Natural Gas Transport	Occupational Accidents		
	• deaths	4	deaths/ 10^{17} Btu
	• injuries	1.4	injuries/ 10^{14} Btu
Air Pollution from Fossil Fuel Combustion	Premature Deaths	0.5 - 8	deaths/ 10^5 person- $\mu\text{g}/\text{m}^3\text{SO}_4$
Underground Uranium Mining	Occupational Accidents		
	• deaths	0.24	deaths/ $\text{GW}_e\text{-Yr}$
	• injuries	9.2	injuries/ $\text{GW}_e\text{-Yr}$
	• non-radiation induced disease	0.08	deaths/ $\text{GW}_e\text{-Yr}$
	• radiation induced cancer	0.05	deaths/ $\text{GW}_e\text{-Yr}$

TABLE 20 (Continued)

FUEL CYCLE COMPONENT	EFFECT	DAMAGE COEFFICIENT	
		RANGE	UNIT
Surface Uranium Mining	Occupational Accidents		
	• deaths	0.036	deaths/GW _e -Yr
	• injuries	1.4	injuries/GW _e -Yr
	• radiation induced cancer	0.005	deaths/GW _e -Yr
Uranium Milling	Occupational Cancer	3	deaths/10 ¹² KWH
	Public Cancer	0.002	deaths annually/GW _e -Yr
UF ₆ Conversion	Occupational Cancer	3.3	deaths/10 ¹³ KWH
	Public Cancer	1.2	deaths/10 ¹⁴ KWH
Enrichment	Occupational Cancer	1	deaths/10 ¹³ KWH
	Public Cancer	1.3	deaths/10 ¹⁴ KWH
Fabrication	Occupational Cancer	9.7	deaths/10 ¹³ KWH
	Public Cancer	2.1	deaths/10 ¹⁴ KWH
Reprocessing	Public Cancer	5.5	deaths/10 ¹¹ KWH
Nuclear Transportation	Occupational Cancer	1.3	deaths/10 ¹³ KWH
	Public Cancer	2.8	deaths/10 ¹³ KWH
Nuclear Power Generation	Occupational Cancer	1.5	deaths/10 ¹¹ KWH
	Occupational Accidents		
	• deaths	0 - 3	deaths/10 ¹¹ KWH
	• injuries	0.5 - 2	injuries/10 ¹⁰ KWH
	• public cancer	1.5	deaths/10 ¹¹ KWH

Over half of the accidents involving the public involve collisions between train and motor vehicles at grade crossings. A major national effort initiated in 1973 to decrease these accidents may result in lower than estimated health damage in this sector in 1985 and 1990. Because of the uncertainty in the composition of "other transport", no estimates of damage have been made. This category includes truck transport which, although no reliable health damage estimates are available, is likely to be the most hazardous form of coal transport.

Bertolett and Fox* reported 0.1 deaths (60% confidence range 0.05 - 0.18) and 3.3 non-fatal injuries (60% confidence range 3 - 3.6) per 1000 MWe plant-year in coal power plants. Assuming a 75% capacity factor gives 60% ranges per 10^9 KWH as:

Deaths:	0.008 to 0.012
Injuries:	0.46 to 0.55

Based on the electric production estimates incorporated in the scenario, BNL estimated occupational accidents in coal electric plants for 1975, 1985 and 1990 by EPA Region.

Oil

Accidental deaths and injuries to workers in oil extraction per unit energy have been estimated by Hall, et. al., to be 2.2×10^{-15} deaths and 2.1×10^{-13} injuries per Btu.** Assuming 5.8×10^6 Btu/bbl***, these convert to 1.28×10^{-8} deaths and 1.22×10^{-6} injuries/bbl. BNL applied these damage coefficients to the production estimates embodied in the MID-MID Scenario to estimate expected deaths and injuries. It should be noted that occupational deaths and injuries which occur in association with extraction of foreign oil used in the U.S. were not included in BNL's calculations.

BNL applied Hall's estimates, 9×10^{-16} deaths and 8×10^{-14} injuries per Btu oil transported in both pipelines and tankers, BNL applied this to the oil estimates of the scenario to derive expected deaths and injuries in 1985 and 1990. Similarly, using Hall's estimates of 1.3×10^{-15} deaths and 9.6×10^{-14} injuries to workers in oil refineries per Btu output, and assuming 5.8×10^6 Btu/bbl and an efficiency of 0.91,**** BNL derived coefficients of 7.54×10^{-9} deaths/bbl and 5.38×10^{-7} injuries/bbl for oil refining workers.

In a survey covering nearly 300,000 man-hours at oil-fired power plants, Bertolett and Fox found 0.013 deaths and 1.2 injuries per 1000 MWe plant-year. Scaling to deaths and injuries per 10^9 KWH on the basis of 6.57×10^9 KWH per MWe plant-year gives:

* A. D. Bertolett and R. J. Fox, "Accident-rate Sample Favors Nuclear," Electrical World, 182:40-41, July 15, 1974.

** E. Hall, P. Choi and E. Kropp, Assessment of the Potential of Clean Fuels and Energy Technology, EPA 600/2-74-001, Washington, D.C., 1974, pp. 109-110.

*** M. Beller, et. al., Sourcebook for Energy Assessment, BNL 50483, Brookhaven National Laboratory, 1975, p. 193.

****M. Beller, op. cit., p. 100.

2.0E-3 deaths 10^{-9} KWH⁻¹
1.8E-1 injuries 10^{-9} KWH⁻¹

Natural Gas

Since oil and gas extraction are frequently inseparable, the same occupational accident rates apply to both. Applying the estimates from Hall to the state gas production figures embodied in the scenario, BNL computed death and injury estimates attributable to natural gas production for the scenario years.

Natural Gas Processing and Transport Estimates in the Brookhaven Energy Model Data Base (EMDB) for gas processing (H₂S removal) are 2.1×10^{-6} deaths and 1.9×10^{-3} injuries per 10^{12} Btu output.* Occupational health damages associated with gas pipelines are estimated at 4×10^{-5} deaths and 1.38×10^{-2} injuries per 10^{12} Btu.** BNL applied these estimates to total natural gas production to derive estimates of deaths and injuries attributable to natural gas transport for the two scenario years.

Liquified natural gas (LNG) has important considerations with regard to health risks. Estimates were not made by BNL for LNG, but the reader is referred to Van Horn and Wilson for a discussion of their risks.**

Nuclear Fuel Cycle

The health effects of principal concern in the nuclear fuel cycle are cancers resulting from exposure to ionizing radiation. The basic sources of damage functions for this effect are the 1972 report of the Advisory Committee on the Biological Effects of Ionizing Radiation*** known as BEIR, and the more recent report of the United Nations Scientific Committee on the Effects of Atomic Radiation† known as UNSCEAR. Additional health damage functions were developed as part of the Reactor Safety Study.†† The BEIR Committee is in the final stages of producing a new report which reportedly will take a more sophisticated approach to damage functions for radiation induced cancer. Unfortunately this report is not yet available.

* M. Beller, ob sit., pp. 81-82.

** A. J. Van Horn and R. Wilson, "The Potential Risks of Liquified Natural Gas," Energy, 2:375-389, 1977.

***Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, Division of Medical Sciences, National Academy of Sciences - National Research Council, Washington, D.C., 1972.

† United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), Sources and Effects of Ionizing Radiation, New York, 1977.

†† U.S. Nuclear Regulatory Commission, Reactor Safety Study, Appendix VI, WASH-1400, Washington, D.C., 1975.

Radiation is known to cause genetic damage also, but no genetic effects have been demonstrated in the offspring of irradiated human populations. There are thus no direct quantitative data available for man. Based on studies in the mouse, most of the genetic hazard from low radiation dose rates is seen in the male, and mutation frequencies are believed to be linearly related to dose. The effect is small, however. It has been estimated that exposures surrounding a nuclear reactor (of about 0.01 mrem/yr) would result in increases of the spontaneous mutation rate of 0.0005% making no allowance for repair.*

The nuclear fuel cycle also includes the more common accidents and occupational diseases seen by all industrial and mining operations. Based on 1964-69 data, the former Atomic Energy Commission** estimated occupational accident rates in uranium mines are:

	<u>cases per 10⁶ tons ore</u>	
	<u>Underground</u>	<u>Surface</u>
Fatal	1.92	0.29
Non-fatal	73.9	10.8

These rates are even higher than coal mines but the amount of ore required per KWH is less. An ore requirement 182 metric tons (200 short tons) U₃O₈ per plant year (at 80% capacity factor) was assumed.** Converting to 100% capacity yields 250 tons per GW_e-yr (assuming an ore grade of 0.2% U₃O₈).

These estimates assumed fuel reprocessing to be a part of the fuel cycle. The current fuel cycle would have a higher ore requirement. Combining the above ore requirement with the AEC WASH 1224 accident rates yields:

Underground:

$$\frac{250 \text{ tons ore/plant yr} \times 1.92 \times 10^{-6} \text{ deaths per ton ore}}{0.002 \text{ Ton U}_3\text{O}_8/\text{ton ore}} = 0.24 \text{ deaths/GW}_e \text{ Yr} = 2.74\text{E-11 deaths/KWH}$$

$$\frac{250 \times 73.9 \times 10^{-6}}{0.002} = 9.02 \text{ injuries/GWY}_e = 1.05 \text{ E-9 injuries/KWH}$$

Surface:

$$\frac{250 \times 0.29 \times 10^{-6}}{0.002} = 0.036 \text{ deaths/GWY}_e = 4.11 \text{ E-12 per KWH}$$

$$\frac{250 \times 10.8 \times 10^{-6}}{0.002} = 1.35 \text{ injuries/GWY}_e = 1.54\text{E-10 injuries/KWH}$$

* L. D. Hamilton, Health Effects of Electricity Generation, Testimony presented before joint hearings of the New York State Board on Electric Generation Siting and the Environment and the Atomic Safety and Licensing Board, U.S. Nuclear Regulatory Commission, NRC Docket 50-549, Albany, NY, June 1978.

**U.S. Atomic Energy Commission, Comparative Risk-Cost-Benefit Study of Alternative Sources of Electrical Energy, WASH-1224, Washington, D.C., 1974.

These estimates were applied to the state level mining production estimates to yield estimates of accidental deaths. Using testimony prepared by Binder, et. al., BNL estimated occupationally related lung disease other than cancer in uranium miners.

UNSCEAR estimates external gamma radiation exposure to underground uranium miners to be 0.05 person-rad/MW-yr and the collective alpha dose to the lung due to inhalation of radon and daughters to be 0.1 person rad/MW-yr. External exposure levels to surface miners have been estimated to be 0.5 rad annually leading to a dose of 0.05 man-rad/MW-yr. BNL applied BEIR health damage functions to these doses to derive 0.05 occupational cancer deaths among underground miners and 0.005 among surface miners per GW_e-yr. These estimates are then applied to the state production estimates to determine the effects for the MID-MID Scenario.

In a survey covering nearly 1 million man-hours at nuclear power stations, Bertollett and Fox found no deaths and 0.7 injuries per 1000 MWe plant-year. BNL scaled these estimates to deaths and injuries per 10⁹ on the basis of 6.57 x 10⁹ KWH per 1000 MWe plant-year:

0 to 0.03 deaths per 10 KWH
0.05 to 0.2 injuries per 10 KWH

B. PUBLIC HEALTH

Health Effects of Air Pollution

Fossil fuel combustion produces a wide range of air pollutants, including particulates, SO_x, NO_x, CO, polycyclic aromatic hydrocarbons (PAH), and trace metals such as iron, mercury and cadmium. These primary pollutants contribute to atmospheric chemical reactions producing secondary pollutants such as ozone, sulfate, and nitrate compounds. Current knowledge is inadequate to describe fully and quantitatively the health effects of these pollutants. Considerable evidence links sulfur-particulate air pollution with health effects. It is currently hypothesized that the causative agents are sulfate compounds produced by oxidation of SO₂ in the atmosphere. This hypothesis is detailed in an EPA position paper.* The quantitative health-damage function used here is drawn from Morgan et. al.** and is discussed further below. Potential qualitative health effects of other pollutants were not quantified since necessary dose-response information is not available. In addition, because exposures to many pollutants are simultaneous, it is difficult to ascribe effects of air pollution to individual agents. Thus, while sulfate compounds are supposed to be the principal agent affecting health, sulfates are used as an index. Some effects attributed to sulfates may be due to other compounds. Independent estimates of effects from more than one compound were not added to avoid potential double counting.

* U.S. Environmental Protection Agency, Position Paper on Regulation of Atmospheric Sulfates, EPA 450/2-75-007, Research Triangle Park, NC, 1975.

**M. G. Morgan, S. C. Morris, A. K. Meier and D. L. Shenk, A Probabilistic Methodology for Estimating Air Pollution Health Effects from Coal-Fired Power Plants, Energy Systems and Policy, 2:287-309, 1978.

The health-damage function used by BNL links annual average sulfate exposure with increased annual mortality rate. It does not represent the acute effects of episodes but the long-term impact on the population of a continuing environmental exposure. While the sequence of events leading to this impact in the population is unknown, it is hypothesized that long-term exposure to air pollution, particularly in childhood, increases susceptibility to respiratory infection. A history of repeated respiratory infection, possibly coupled with continued air pollution exposure, increases the prevalence of chronic respiratory disease. This leads to higher mortality rates from a broad range of cardiopulmonary diseases. Thus, an increase in air pollution exposure results in a degradation of the overall health of the population which is eventually reflected in the mortality rate. Deaths attributable to air pollution exposure in a given year do not necessarily occur that year, but are distributed over the lifetime of the exposed population. We are not yet able to estimate how these deaths are distributed in time. Reasonable estimates of the age distribution of deaths attributable to air pollution exposure lead to 5-15 years average difference between age at death and age at full life expectancy.* Of course these individuals might not reach full life expectancy even in the absence of air pollution. Mortality estimates not only represent premature deaths, but years of decreased respiratory function and possibly disability before death. In addition, since all induced respiratory diseases may not result in premature death, the annual incidence of new-disease cases is undoubtedly higher than the annual number of deaths.

Under steady-state conditions, the number of deaths occurring over future years attributable to air pollution exposure this year equals the number of deaths occurring this year due to the combined pollution exposure of all previous years. Based partly on this, a linear health damage function was drawn from cross-sectional studies as a simplifying approach to estimating effects of the MID-MID Energy Scenario. Using this simplifying linear damage function, an incremental sulfate exposure this year inevitably leads to an increment of health damage and a given number of premature deaths, whatever the absolute level of exposure.

It seems doubtful that the damage function is truly linear and with no threshold over the entire range of exposure. More likely, at low absolute levels of exposure the health impact of a unit increase in sulfate is reduced. There may be a threshold below which there is no health impact. The data on which the dose-response function is based are from urban areas with generally high-background sulfate levels, but, significantly, the linear function has been shown to be consistent with available data from urban and rural areas with high and low pollution levels.** Use of a linear function to estimate effects of small changes in sulfate levels in areas with high-background levels seems reasonable. Estimates of the effects of substantial changes in background levels, or of small changes in areas with low initial background levels, increase the uncertainty in the results. In the current study, most of the population exposure is in areas with high ambient concentrations of sulfate. The increment for which effects were predicted, however, is a large fraction of the total sulfate.

* M. G. Morgan, et al., op. cit.

**S. R. Bozzo, preliminary calculations, Brookhaven National Laboratory, Upton, NY.

The health-damage function described by Morgan et al. ranges from 0 to 12 deaths per 10^5 per $\mu\text{g}/\text{m}^3$ sulfate, with 60% confidence interval of 0.5-8. This subjective probability distribution describes the best scientific judgement of the authors at the time, based on data available from correlation studies of the type conducted by Lave and Seskin.* Standing alone, these studies are inadequate to ascribe the observed effect to sulfate air pollution. Used in concert with toxicological** and epidemiological studies***, however, they provide a useful means of calibrating the magnitude of the effect.

The air quality analyses described earlier in this section of the report provided BNL with the ambient SO_x concentrations for 1985 and 1990. As previously stated, the air quality analyses were based upon 85% and 90% SO_2 removal at new utility plants. These increased control levels are sufficient to result in a substantial reduction in population exposure over 1975 even with increased fuel consumption. This reduction is so marked that it overwhelms population growth resulting in lower estimates of attributable deaths. Between 1985 and 1990, however, increased energy production and increasing population again begin to move the impacts upward, although still not surpassing 1975.

Insufficient information was available to divide the population exposure and health damage estimated for 1985 and 1990 into fractions contributed by old and new plants. The full implications of the scenario are not clear due to the long turnover rate of facilities and the resulting contribution of air quality impacts of pre-1975 plants even in 1990.

Exposure from Uranium Milling

The public radiation exposure from uranium milling is due to the release of radon gas. This exposure is minute, but, unlike most other exposures in the fuel cycle, radon will continue to be released from the tailings unless they are covered. One GWY nuclear electric production results in an individual risk of 8.6×10^{-12} cancer death per year in the U.S. thereafter. With about 2×10^8 people in the U.S., this is about one excess cancer death every 600 years. BNL applied these estimates to state level milling production from the scenario to yield estimates of public health damage.

* L. B. Lave and E. P. Seskin, Air Pollution and Human Health, Johns Hopkins University Press, Baltimore, 1977.

**M. O. Amdur, "Toxicological Guidelines for Research on Sulfur Oxides and Particulates," Proceedings, 4th Symposium on Statistics and Environment, American Statistical Association, 1977, pp. 48-55.

***U.S. Environmental Protection Agency, Health Consequences of Sulfur Oxides: A Report from Chess, 1970-1971, EPA 650/1-74-004, Research Triangle Park, NC, 1974.

ECOLOGY AND LAND USE

The assessment of the impact of the MID-MID Scenario on ecology and land use involved two lead lab analyses: Argonne National Laboratory (ANL) identified potential ecological impacts at the county level due to air residuals and changes in land use patterns; while Brookhaven National Laboratory (BNL) calculated the amounts of solid waste residuals which will result from the energy production and processing levels implied by the scenario, as well as the land required to dispose of these residuals.

A. ECOLOGY/LAND USE

ANL's ecology/land use analysis addressed the impacts of sulfur dioxide (SO₂) on crops and natural vegetation for 1985 and 1990. In addition, ANL identified and assessed changes in land use for these years due to mining, the construction of new power-generating facilities, and the expansion of communities to accommodate the new residents immigrating to participate in these projects. BNL provided listings of the endangered species potentially found in each impacted county.

High ambient concentrations of SO₂ can lead to visible injury of plant tissue as well as to more subtle effects such as changes in photosynthetic or respiration rates. Reductions in growth, yield, or nutritional value can result, which in natural systems could lead to complex changes in community structure. Sensitivity to SO₂ varies between species, and crop species and natural vegetation can be grossly classified as sensitive, intermediate, or resistant to SO₂. Under the RIIA I analysis, experimental data from literary sources* were used to identify crop-specific threshold short-term (3-hour or 24-hour) SO₂ concentrations above which damage may be expected to occur (see Table 21). In addition, vegetation communities (e.g., Great Lakes Pine Forest, Oak-Hickory Forest) were classified as sensitive, intermediate, or resistant based upon the sensitivity of dominant species. The community was classified as sensitive if there was at least one dominant species classified as sensitive; intermediate if there were no sensitive species and at least one intermediate; and resistant if there were only resistant dominants listed. The vegetation communities were those identified by Kuchler (see footnote).

The average, maximum 3-hour sulfur dioxide concentration predicted in the lead lab analysis for local air quality was used to predict the impact to vegetation. As detailed in the air resources section of this report, the local air quality analysis used data from the 1975 EPA monitoring program to estimate 1985 and 1990 ambient SO₂ levels based on the ratio of SO₂ emissions to ambient concentrations in 1978 and projected emissions in 1985 and 1990. When 3-hour concentrations were not available

*Literary sources consulted include: for crop data, Bureau of the Census, U.S. Department of Commerce, 1974, Census of Agriculture; for natural vegetation, A. W. Kuchler, Potential Natural Vegetation of the Conterminous United States, American Geographical Society, N.Y., 1964; and for nature preserves, The Nature Conservancy, Critical Natural Areas, Nature Conservancy Data Base Program, Arlington, VA, 1978.

Table 21

THRESHOLD SO₂ CONCENTRATIONS CAUSING CROP INJURY

<u>Category</u>	<u>Species¹</u>	<u>Range²</u> <u>ug/m³</u>	<u>SO₂ Concentrations</u>		
			ppm	<u>3-hr</u> <u>ug/m³</u>	<u>24-hr</u> <u>ug/m³</u>
Berries	Gooseberry	786-1572	.30	786	131
Corn			5.00	13100	5240
Cotton			.80	2096	131
Hay	Red Clover	973 - 1230	.36	973	131
Irish Potato			.50	1310	131
Orchards ³	Apple	1179-13100	.45	1179	131
Other small grains	Barley, Oats	891-1179	.34	891	131
Peanuts	Legumes		.45	1179	131
Sorghum			5.00	13100	5240
Soybeans			.50	1310	131
Sweet Potato			.45	1179	131
Tobacco			.50	1310	131
Vegetables	Bean	1153-13100	.44	1153	131
Wheat			.45	1179	131

¹Most sensitive species of group from which baseline data was calculated.

²Range of concentrations causing injury among most species within the category.

³Impacts for orchards may be misleading in counties having most orchard acreage in citrus, which is resistant to SO₂.

from the EPA data, maximum 24-hour concentrations were calculated. Threshold values in the latter case were estimated using values given by EPA* for the lowest SO₂ concentrations causing injury after 8 hours of exposure. Ambient concentrations in counties which do not have an air quality monitoring program were calculated by assuming a low 1975 baseline concentration; a direct correspondence between projected emissions increments and ambient SO₂ concentrations was then developed (see discussion of local air quality).

A computer model was developed at ANL** which identified counties where the projected 3-hour or 24-hour SO₂ concentration in 1975, 1985 or 1990 was above the threshold for the most sensitive plant species. A report was generated for each of these counties which provided data on the crop species and the natural vegetation communities known to occur in the county which are likely to be impacted; information was only provided for the vegetation types whose damage threshold values are below the projected SO₂ concentrations.

The second part of the ANL lead lab analysis concentrated on changes in land use due to mining, the construction of power plants, and the expansion of communities as implied by the MID-MID Scenario for 1985 and 1990. The acres of land likely to be disturbed by each of these activities were calculated as described below, and data on existing land use (including acres in Federal lands and nature preserves),*** crop types, and natural vegetation were retrieved from the data base (described above) for each of these counties.

The total number of acres potentially disturbed by mining during the periods of 1975 to 1985 and 1975 to 1990 were calculated separately for surface mines and deep mines. Based on the siting and production estimates provided by Mitre Corporation (see Chapter 3), the calculations further assumed:

- (a) similar coal seam thickness within each of the coal resource regions;
- (b) recovery of only 50% of the coal mined underground and 80% of the coal mined by surface methods; and
- (c) a 2.4% subsidence rate of undermined land.

Each of these assumptions were based upon a literature search of relevant government and private publications and are consistent with similar assumptions routinely made by the U.S. Bureau of Mines.

*Environmental Protection Agency, "Effects of Sulfur Oxides in the Atmosphere on Vegetation," Chapter 5 (revised) in Air Quality Criteria for Sulfur Oxides, U.S. EPA-R3-73-030, Washington, D.C., 1973.

**For more information see S. W. Ballou, et. al., "Identifying the Potential for SO₂-Induced Vegetation Damage in the Evaluation of Energy Policy Scenarios," to be presented at the International Conference on Energy Use Management, Los Angeles, CA, October 22-26, 1979.

***Soil Conservation Service, U.S. Department of Agriculture, National Inventory of Soil and Water Conservation Needs, 1967, (Conservation Needs Inventory), Statistical Bulletin No. 461, Washington, D.C., 1971.

The ANL ecology/land use analysis also identified counties where increases in generating capacity were projected by the utility siting scenario prepared by ORNL (Chapter 3), and estimated the acreage required to support this increase for each technology sited. The acreage estimates were for the total site, excluding the area occupied by cooling ponds. The calculations assumed:

- (a) a linear relationship between the generating capacity and site size;
- (b) that all of the increased capacity projected for the period 1975 to 1985 will come from a single facility. If an additional increase is projected for the technology during the 1985-1990 interval, it was assumed that a second facility would be built; and
- (c) in some cases where an increase in capacity for a technology is exactly balanced by a decrease in another technology this change reflected a simple change in fuel type (not a new facility), if the equal and opposite increments involved either the two turbines (oil or gas) or two of the three steam technologies (oil, gas or coal).

The size of utility sites can vary greatly depending on the number of units at the site, the geographic location, utility policy, and state and local ordinances. For example, a survey of 95 Environmental Impact Statements for nuclear plants yielded a range of sites from 113 acres/1000 MWe to 1681 acres/1000 MWe.* The estimates used for the lead lab analysis were based primarily on information presented in a 1973 CEQ report** which provides the best estimates available at this level of analysis.

The amount of land required to support energy-related increases in population was estimated on the basis of numbers generated by the local socioeconomic analysis (see the human resources section of this report). Different conversion factors were used for permanent new residents and for transients projected to live in the county during the construction phase. The conversion factor for permanent residents was 11 acres per 100 residents*** and was based on estimates of land required for new homes, municipal services and commercial facilities to support the new population. The conversion factor for transient residents was 7.4 acres per 100 residents and was based on the assumption that these people would live in mobile homes. This factor also accounted for municipal services (such as roads and sewers) but did not include estimates of land required for commercial establishments.

*W. A. Buehring, A Model of Environmental Impacts from Electrical Generation in Wisconsin, Ph.D. Dissertation, University of Wisconsin-Madison, 1975.

**Council on Environmental Quality, Energy and the Environment - Electric Power, Government Printing Office, Washington, D.C., 1973.

***J. C. Anderson, et. al., Draft Final Report on the Macroeconomic Effects of Coal and Oil Shale Development in the Intermountain West, prepared for the Federal Energy Administration by the Utah State University Foundation, 1976.

Limitations of the Analysis

Although the crop and natural vegetation species which may be susceptible to damage from future SO₂ concentrations are relatively easy to identify, the extent of the possible damage due to these concentrations is difficult to assess. For example, the amount of vegetation actually exposed to the damaging concentrations cannot be defined at this level of analysis, and variations in cultivar, time of year, meteorological conditions, agricultural practices, and frequency and duration of exposure all have marked influence on plant response to air pollution. It was not possible to account for all of these factors at the lead lab level of analysis.

Secondly, the ANL analysis only addressed those impacts which are associated with SO₂ concentrations and their effects upon terrestrial vegetation. A comprehensive ecological assessment would also address the impacts of energy development upon aquatic ecological systems, including the effects of water quality deterioration, thermal impacts, acid rain impacts, entrainment, and habitat alteration. Such an analysis would also address the impacts of acid rain on terrestrial systems and provide more information on the potential for impact on endangered species. Although this type of an analysis was beyond the scope of RIIA I, it is anticipated that RIIA II will address these issues. ANL is currently compiling the necessary data bases and computer models to expand their lead lab capabilities in order to accomplish this type of a comprehensive ecological assessment.

B. SOLID WASTE

The purpose of BNL's solid waste lead lab analysis was to assess the degree to which solid waste management problems may impede the energy production goals embodied in the MID-MID Scenario. To this regard, BNL computed the amounts of solid waste residuals that would be generated in 1985 and 1990 from electric utilities, industry, and mining and processing operations. Descriptions of the methodologies utilized for each of these computations are presented below.*

Overall, the approach of the solid waste analysis was to take the county-level siting patterns (Chapter 3) and estimate the associated solid waste residuals. These residuals were then translated into impact measures (i.e., land area required for disposal, etc.) and compared to the impacts from other non-energy cycle waste sources (e.g., municipal refuse, waste treatment sludge, etc.). Constraints to the scenario were then identified on the basis of the availability of land for waste disposal and the environmental impacts of alternative waste disposal practices.

Electric Utility Sector

The starting point for the electric utility solid waste analysis was the county level siting pattern for electric generation capacity, provided to BNL by ORNL (Chapter 3). A second key input was a file of fuel characteristics obtained from the

*For more detailed descriptions of the solid waste methodology see P. Meier, et. al., A Methodology for Estimating County Level Air and Solid Waste Residuals, Draft, Brookhaven National Laboratory, September, 1979.

former Federal Power Commission (now known as the Federal Electricity Regulatory Commission (FERC)). Because the MID-MID Scenario did not account for the sulfur, ash and heat contents of fuels, some additional assumptions were necessary. It was assumed for the RIIA I analysis that fuels used in each state in the future scenario years will be the same as those used in 1976 for which data is readily available. (This corresponds to the assumption of locally available coal as is to be expected with implementation of the Best Available Control Technology (BACT) provisions of the 1977 Clean Air Act Amendments.)

The computer program, UTILRES* computed a series of county level tables for each state and a series of regional summaries for each Federal Region. It should be noted that the computations of solid waste residuals are consistent with those utilized in the air emission factors analysis and that UTILRES creates a series of computer files that are accessed directly by BNL's air quality models.

The residuals computations assume that all flue gas desulfurization (FGD) systems would be of the lime/limestone type. This proves to be the conservative posture in terms of identifying potential solid waste constraints since any significant market penetration of other systems would reduce the level of solid waste generation. In any event, it would be most difficult to assign given levels of market penetration for a particular alternative technology to the county level; a priori, there is little basis to assume that certain counties favor a particular FGD system technology, and any numerical assignment would be entirely arbitrary; and, a review of the existing market penetration of non-lime/limestone systems reveals little in the way of systematic regional patterns, or a correlation with the characteristics of the particular coal being utilized.

Industrial Sector

As in the solid waste analysis for the utility sector, the starting point for the industrial solid waste analysis was the county-level siting pattern. The solid waste computations were conducted in two computer programs, FUEL and INDRES.* The latter program created the file "BNLINDRESy" which contained county level fuel use. This file was then used to compute the associated solid waste residuals, and was also assessed by the air emission factors program. Consistency between SO₂ and particulate emissions for air quality analysis, and the corresponding ash and scrubber sludge residuals, were thereby attained.

Program SWIND, which also required access to the National Residuals Discharge Inventory (NRDI), compiled by the National Commission for Water Quality, then produced a series of state and regional tables with estimates of residuals and impact measures for 1975, 1980 and 1990. Residuals were expressed in terms of ash and FGD sludge, in 1000 tons per year and the corresponding land required for disposal. The increase in land area for the scenario years, expressed as a fraction of the 1975 base year requirement, was also given in the residuals tabulation.

* Le Tien, P. M. Meier and H. Rostoker, The Solid Waste Impacts of Increased Coal Utilization, Brookhaven National Laboratory, BNL 24786, February, 1979.

Coal Mining and Cleaning

Coal, as mined, is often cleaned mechanically before delivery to end-use customers. The main purpose of the cleaning process is to separate coal from impurities such as rocks, particulates and sulfur elements. The amount of refuse resulting from the cleaning depends upon the fraction of the total mined coal to be cleaned, as well as upon the extensiveness of the cleaning. These factors, in turn, depend on the ash and sulfur contents of the coal before and after cleaning.

Once again, the starting point of this analysis was the county-level mine siting pattern. The siting pattern provided estimates of surface and underground production by county for 1975, 1985 and 1990, consistent with the coal utilization forecasts embodied in the MID-MID Scenario. The detailed methodology utilized to derive the county-level residuals and land requirements for disposing of these residuals is far too complex for describing here but may be obtained by consulting the source identified in the previous footnote.

Limitations of the Analysis

The assumption of a single set of coal characteristics for each region represents a limitation on the analysis since other characteristics would affect the level of environmental control needed, and, therefore, the amount and type of solid waste generated. In most cases the average sulfur and ash content per unit energy of locally available coal is quite similar to the average for all coals actually used in each region at the present time. In general, the assumption of a locally available coal is a conservative one since this leads to a situation in which desulfurization technologies, with their ensuing solid waste impacts, are used to the maximum extent. The range of impurities in local coals, however, can be considerable (e.g., a factor of two for sulfur in many regions), and this could affect any quantitative results should future average characteristics shift away from present values.

Similarly, solid waste management issues are generally site-specific in nature. The degree to which solid waste residuals from energy-related facilities will pollute the environment depend on the characteristics of the disposal such as the chemical and biological compositions of the soils, the amount of precipitation in an area and the proximity of the disposal sites to surface and groundwaters. At the lead lab level of analysis it was not practical to try to assess all of the different ways by which the calculated amounts of solid waste residuals would interact with the local environment. Instead, it was left to the individual regional laboratories to perform such an analysis during the regional assessment portion of the RIIA I study.

In addition, the recent passage of the Resource Conservation and Recovery Act (RCRA) and the Toxic Substances Control Act (TSCA) will ultimately impact solid waste management decisions of utilities, industry and operators and will certainly impact the cost of solid waste disposal. However, because the regulations derived from these two laws have yet to be promulgated and because little is currently known about how energy-related solid waste residuals may be classified under these regulations, issues involving the impact of RCRA and TSCA upon the realization of the MID-MID Scenario were not addressed.

Finally, BNL did not calculate solid waste residuals from oil refineries, oil shale development, geothermal operations, and uranium mining and processing operations. This is due, in part, to the lack of siting data for these facilities. As previously mentioned in Chapter 3, the regional laboratories were tasked to identify potential sites for these energy technologies within the region(s) for which they were responsible. Similarly, it was the regional laboratory's responsibility to identify any issues that may be associated with these technologies, including issues involving solid waste.

CHAPTER 5

REGIONAL ASSESSMENTS METHODOLOGY

Following the conclusion of the lead laboratory analyses, the national laboratories participating in the RIIA I program began their assessments of the impacts for the Federal Region(s) assigned to them. The regional assessments are identified graphically in Figure 2 and summarized below:

- Brookhaven National Laboratory - Federal Regions 1, 2 and 3
- Oak Ridge National Laboratory - Federal Regions 4 and 6
- Argonne National Laboratory - Federal Regions 5 and 7
- Los Alamos Scientific Laboratory - Federal Region 8
- Lawrence Berkeley Laboratory - Federal Region 9
- Pacific Northwest Laboratory - Federal Region 10

The regional assessments portion of the RIIA program involved three distinct tasks:

- institutional analysis;
- the interpretation and graphical presentation of the data generated by the lead lab analyses; and
- collection of supplemental information and analysis where the lead lab data were either insufficient or too highly aggregated for a comprehensive assessment of potential conflicts between energy development and the regional environment.

Each of these tasks are further described below.

A. INSTITUTIONAL ANALYSIS

Institutions interact with energy development in a number of ways. First, institutions form an important part of the real-world context in which an energy policy alternative moves from the status quo to some desired outcome - in this case the supply and demand totals embodied in the MID-MID Scenario for the years 1985 and 1990. In implementing energy policies, certain laws must be complied with, certain organizations must be relied on, and certain political processes may become engaged.

Second, a number of legal, organizational and political constraints may stand in the way of achieving the desired outcome of an energy policy. These constraints can appear at the national level (e.g., New Source Performance Standards), at the state level (e.g., State Implementation Plans) or at the local level (e.g., local zoning ordinances). Third, legal, organizational and political impacts may arise as a result of decisions and actions taken at each stage of the policy implementation process (e.g., law suits).

In addition, reaching the desired outcome from a particular energy policy may require the design of new institutional relationships if existing arrangements tend to constrain the implementation of a new policy. Finally, institutional constraints, institutional impacts and institutional design choices may require readjustment of calculations about technical performance, environmental impacts, economic performance, and socioeconomic impacts.

Methodology

There was not a consistent methodology utilized by the laboratories in assessing the institutional implications of the MID-MID Scenario. Rather, each laboratory was encouraged to develop its own methodology based upon guidelines developed by Systems Consultants, Inc. (SCI). The purpose of these guidelines was only to provide the laboratories with rough boundaries to which they should limit their analyses.

Essentially, each laboratory identified Federal, state and local regulations which could potentially constrain the energy development goals incorporated in the MID-MID Scenario. In addition, the laboratories identified the types of institutional behavior and activities which tend to interact most commonly with energy development. In identifying these interactions, the laboratories sought answers to some basic questions:

1. Legal
 - a. What are the relevant federal, state, and local statutes, regulations, and adjudicatory decisions?
 - b. What are the relevant legal principles?
 - c. What standards must be met?
 - d. What licensing procedures must be followed?
 - e. What legal conflicts and uncertainties may arise?
 - f. What processes may be used to resolve conflicts and uncertainties?
2. Organizational
 - a. What are the relevant public and private organizations--i.e., what organizations must take actions?
 - b. What are each organization's
 - i. goals and missions?
 - ii. standard operating procedures?
 - iii. resources?
 - iv. approaches to recruitment and training of members?

3. Political

- a. What are the relevant political interests (both in government and outside)?
- b. Who participates? Whose interests are affected?
- c. What is the likely position of each participant with respect to relevant issues?
- d. What determines each participant's preferences and interests?
- e. How are preferences combined? That is, what are the "action channels"?
- f. What are the sources of influence?
- g. Whose preferences count? That is, which participants are "heavies" and which participants are "lights" in the process?
- h. How stable is the distribution of relative "weight" among participants?

Answers to these and similar questions were obtained by the laboratories through literature searches and through interviews with state and local officials as well as with representatives from regional commissions, public utility commissions, and interest groups. The literature consulted included local newspapers, various newsletters, reports and position papers provided by the states. In addition, on numerous occasions, regional offices of DOE and EPA were consulted.

Although not limited to the institutional analysis, two of the laboratories - LBL and PNL - convened workshops to identify, from various perspectives, the important energy-related environmental issues relevant to their regions.* The participants representing diverse views included state energy offices and regulatory agencies, public utilities commissions, utility companies, local government, several public interest groups, DOE and EPA.

For both of these workshops, the departure point was a discussion of the MID-MID Scenario and its implications for the regions in question. Following this discussion, the workshops generally evolved into brainstorming sessions where institutional, environmental and socioeconomic issues were identified and discussed.

B. INTERPRETATION AND GRAPHICAL PRESENTATION OF LEAD LAB DATA

The major portion of the regional assessments phase of the RIIA I program was spent interpreting the large amounts of data generated by the lead lab analyses. As one might expect from the discussion of the lead lab methodologies in Chapter 4,

*For more information concerning the LBL workshop see R. L. Ritschard and K. F. Haven, Regional Energy Issues: Summary of a Workshop Held at Lawrence Berkeley Laboratory, Lawrence Berkeley Laboratory, LBID-061, June 1979.

the data generated during impact analyses resulted in vast amounts of computer printouts and tapes. It was the responsibility of the regional laboratories to filter through the data for their region(s) and to assess the significance of the data in light of state and regional background issues and the laboratories' knowledge of their regions.

The RIIA program was designed to provide Federal energy policy-makers with an understanding of state and regional environmental and socioeconomic issues and their relative significance as they relate to alternative energy futures. In keeping with this objective, RAD requested the laboratories to interpret the lead lab data on a regional basis and on a state-by-state basis, and to graphically display their assessments in a way that would facilitate easy comparison of alternative energy futures. An example of this graphical presentation system is presented below for the water quality/availability impacts expected in Illinois as a result of the implementation of the MID-MID Scenario. This example was extracted from ANL's Federal Region 5 report.

Example of Interpretation and Graphical Presentation of Study Results

Water Quality/Availability Issues - Illinois

- More stringent waste load allocations and/or river basin management will be required to alleviate projected total dissolved solids, copper, chromium, and sulfate violations in the Fox, upper Illinois, and Sangamon Rivers (Illinois River Basin).
- Water availability may restrict projected utility siting in the northern counties due to seasonal low flows of the Rock and Fox Rivers and in central Illinois on the Sangamon River. Water allocation issues may restrict siting in the Lake Michigan basin.

Description

Major increases in utility siting are projected in the upper Illinois River Basin and tributaries which drain northern and northeastern Illinois. Due to artificial flow reversal of the Chicago and Calumet Rivers, the Illinois basin also receives waste water from the metropolitan Chicago area which would flow to Lake Michigan under natural conditions.

The southern portion of the basin has a large assimilative capacity, diminishing the effect of waste loads from the northern part of the state. However, parts of the southern Illinois River Basin experience mercury, phenol, and BOD violations below industrialized areas and large municipal treatment facilities.

Background Issues

- Illinois water quality and water availability issues are most pronounced in the northeastern river basins.
- The Fox and Sangamon Rivers are frequently unable to assimilate industrial and municipal waste loads due to seasonal low flows.
- Water removal from Lake Michigan is subject to allocation under Federal mandate. Water from the lake is used for drinking water, process water, and for sewage dilution by many municipalities in northern Illinois.

Scenario-Induced Changes

- Increases in total dissolved solids and copper concentrations are projected in the Fox River, primarily from utility increases. River basin management and implementation of discharge standards would be expected to reduce the incidence of the copper violations.
- The assimilative capacity of the Illinois River diminishes the severity of those violations which occur upstream. Although efforts are being made to improve the quality of the upper reaches, TDS levels are expected to increase.
- Upper reaches of the Sangamon River would experience significant water depletions from increased utility activity, causing TDS, DO, Cu, and Cr violations without flow augmentation and/or discharge management. High residual concentrations would diminish downstream.

C. ADDITIONAL ANALYSES PERFORMED AT THE REGIONAL LEVEL

In some cases, it was determined by the regional laboratories that the lead lab data was not sufficient to accurately assess the environmental and socioeconomic issues for their region(s) and the states within their region(s). In these cases, the regional labs were encouraged by RAD to utilize specialized models or analytical techniques that could supplement or further disaggregate the lead lab data. A brief description of these additional analyses is presented below for each laboratory participating in the RIIA I program.

Brookhaven National Laboratory - Federal Regions 1, 2 and 3

Because of the heavy reliance of BNL's regions upon electricity generated from nuclear facilities and the current widespread resistance to future nuclear energy development, BNL concentrated their efforts on accurately describing the environmental, socioeconomic and institutional impacts of these facilities. BNL's analysis of the nuclear power issue included an assessment of radioactive waste management issues and the institutional impacts associated with these issues (both of which were not addressed by a lead lab analysis).

In addition, BNL found the data from the water quality lead lab analysis to be too highly aggregated (the ASA level) to accurately assess the impact of energy development upon the regions' water resources. As a result, BNL's water resources experts ran more specialized models for the river basins in their regions. These models included those developed by the Delaware River Commission and other regional commissions as well as those developed at BNL. Similarly, because of the long coast line associated with BNL's regions and the off-shore energy development currently underway, BNL conducted special analyses of the impact of energy development on coastal waters.*

*For more detailed information regarding the water analyses, contact Ed Kaplan, Brookhaven National Laboratory, National Center for the Analysis of Energy Systems.

Finally, BNL accessed ANL's SEAM model (see Chapter 4, Socioeconomics Section) directly to rerun the local socioeconomic analysis for certain impacted counties in its regions. BNL felt that certain model assumptions made by ANL did not accurately reflect Northeast conditions. For example, the 60 mile worker commuting limitation did not account for particular aspects of a county that would make it possible for workers to commute to a county even though they reside over 60 miles from the site of energy development.

Oak Ridge National Laboratory - Federal Regions 4 and 6

Because the water quality data generated by the lead lab was at the ASA level, ORNL supplemented these data with qualitative analyses to further pinpoint the water quality issues for their regions. Utility siting patterns and coal mining regions were transferred to maps indicating water subareas within ASAs. These maps were examined to determine the places where analysis at the larger ASA level would mask impacts in individual subareas. Qualitative estimates of problems were then made from these maps. Finally, ORNL compared the problem areas identified in this effort to the water quality problems of the various areas discussed in other reports pertaining to their regions. These comparisons were used to supplement qualitative estimates of problems and to determine whether the water quality problems associated with energy technologies would be interacting with other problems (e.g., water availability) or would occur separately.

Because the lead lab analysis for determining the impact of air pollution on ecosystems did not take into account the transfer of pollutants within or between counties, the data was supplemented by ORNL with in-house data concerning animal and plant species in its regions. Ecological impacts in counties with energy facilities were generalized by ORNL based upon the known effect of pollutants on these species.

Argonne National Laboratory - Federal Regions 5 and 7

Region 5 is the most heavily industrialized region in the country, as a result, ANL supplemented the solid waste lead lab analysis with additional analyses. As it was mentioned in Chapter 4, solid waste problems are generally site specific in nature, thus requiring detailed analyses at the subcounty level. While ANL did not conduct case studies to determine the site specific impacts of solid waste disposal for certain areas, it did supplement its discussion of this issue area with data from reports previously prepared on the subject.

Because Region 7 is the "bread-basket" of America, supplying a majority of the world's food supply, ANL concentrated its efforts on identifying and assessing the potential conflicts that may arise between agriculture and energy development.

Los Alamos Scientific Laboratory - Federal Region 8

The analyses conducted by LASL to supplement the data generated by the lead laboratories were largely confined to the solid waste area. Because the Rocky Mountain Region is a major producer of uranium and a potential producer of oil shale, LASL supplemented the lead lab data for solid waste with in-house data on solid waste residuals from these two energy sources. To this regard, LASL analyzed the potential health and water quality impacts associated with the disposal of uranium mill tailings in New Mexico. In addition, LASL assessed the complexities of disposing solid wastes from oil shale mining and processing and coal and uranium mining in rugged terrains.

In addition, LASL worked with Sandia National Laboratory to identify the major institutional constraints to energy development in the region. Sandia's contribution was part of a much larger effort that was conducted for DOE.

Lawrence Berkeley Laboratory - Region 9

Region 9 is a somewhat unique area which does not readily lend itself to the national scale analyses conducted during the lead lab portion of the RIIA study. For example, in order to account for emissions from mobile sources (transportation), LBL obtained estimates of present and future vehicular registrations and expected Vehicle Miles Travelled (VMT) from state officials. Using these estimates, the scenario projections for gasoline consumption at the BEA level, the Department of Transportation's mileage standards, and EPA present and new emissions standards, vehicular emissions were estimated at the county level for 1985 and 1990. Air quality impacts were then computed using ANL's rollback methodology as described in Chapter 4.

The lead lab water resources analyses relied upon assumptions about river flows and consequent water quality impacts of discharges from power plants and industrial facilities. Generally, the inland siting of facilities in most Western states depends more on water allocation and conveyance, and not the availability (or lack thereof) of river water. As a result, LBL assessed water availability at the county level by looking at present water uses, and whether either excess (unallocated) water might be available, or whether alternative sources (such as municipal waste-water) might also be present. For water quality, LBL investigated those potential water quality contaminants that might be present in the area, or resulted from the technology in question. LBL's assessment, therefore, was based on whether there were potential effects, it did not try to model numerical results.

LBL's assessment of land use ecology focused primarily on the effects of geothermal energy development and impacts in the California coastal zone due to energy development. LBL's approach was to look at current land use (e.g., heavy agricultural development in the Imperial Valley), and where energy developments based on the scenario might raise conflicts (e.g., consumptive use of water or process effluents due to geothermal development). The ecological data developed by ANL was used in conjunction with state data to portray potential agriculture and endangered species impacts. In addition, certain sites where technology-specific impacts are likely to occur were identified by referencing case studies or other literature such as Environmental Impact Statements. Similarly, local socioeconomic issues were analyzed by consulting case studies to identify issues and conflicts.

Pacific Northwest Laboratory - Federal Region 10

Overall, the energy and environmental characteristics of Region 10 were not well described by the lead lab level of information. Often times Alaska, which constitutes 70 percent of the Region's geography, was not represented. This deficiency, due primarily to the lack of data concerning Alaska's physical and human environments, was remedied through direct contact with Alaska state offices and through the use of qualified consultants familiar with Alaskan issues.

The lead lab data that was provided for the remaining 30 percent of the Region was often highly aggregated and could not, in many instances, be used to identify or detect energy specific impacts. For example, very high volumes of water flow through most of Region 10's ASA water areas and the impact of an energy activity upon water quality and availability depends largely on which waterway and where on that waterway it is located. At the aggregated level of analysis (ASA) an activity may appear to have no impact while, in reality, locating the activity on a specific waterway may have measurable impacts. PNL was able to identify scenario induced impacts by supplementing lead lab water quality and availability data with river reach water quality information obtained from EPA and with information from specific Environmental Impact Statements.

In addition, many of the land use impacts identified for the Federal Region 10 scenario were related to expansion of the hydroelectric system. The lead lab land use data for expanded hydroelectric generation did not respond adequately to a system where additional capacity is added either by expanding capacity at existing facilities or by adding run of river facilities. To this extent, the lead lab data was supplemented by PNL's study team's knowledge of the Region's unique hydro system.

A detailed analysis was conducted on the institutional constraints to implementing the MID-MID Scenario. The results of that analysis for Idaho, Oregon and Washington are reported in a separate report entitled Institutional Barriers to Developing Power Generation Facilities in the Pacific Northwest.^{*} This report discusses in detail legal, organizational and political barriers to achieving the specified scenario, and the major findings reported in the Study Results volume of the RIIA-I analysis.

^{*}F. A. Morris, C. H. Sawyer and J. H. Maxwell, Institutional Barriers to Developing Power Generation Facilities in the Pacific Northwest, Battelle Human Affairs Research Center, June 22, 1979.

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FOREWORD*(are described)*

(are given)
~~This report describes~~ the overall assessment methodologies and models utilized for the first project under the Regional Issue Identification and Assessment (RIIA) program. ~~This report includes~~ detailed descriptions of the methodologies used by "lead laboratories" for the quantification of the impacts of an energy scenario on one or more media (e.g., air, water, land, human and ecology), and by all laboratories to assess the regional impacts on all media.

This report serves as an adjunct to the study results report which delineates major national and regional effects of implementing future energy development on the Nation's physical and human environments.

We believe this assessment to be innovative, that is, it is the first time the Federal Government has attempted to examine comprehensively and in detail the impacts of national policy at the state and sub-state level. It provides the type of insight that should make it a valuable and important tool for the formulation of energy policy at all levels of government.

→ The research and assessments reflected in this document were performed by the following national laboratories:

- Argonne National Laboratory;
- Brookhaven National Laboratory;
- Lawrence Berkeley Laboratory;
- Los Alamos Scientific Laboratory;
- Oak Ridge National Laboratory; and
- Pacific Northwest Laboratory.

This report contains five chapters. Chapter 1 briefly describes the overall study methodology and introduces the technical participants. Chapter 2 is a summary of the energy policy scenario selected for the RIIA I study and Chapter 3 describes how this scenario was translated into a county-level siting pattern of energy development. The fourth chapter is a detailed description of the individual methodologies used to quantify the environmental and socioeconomic impacts of the scenario while Chapter 5 describes how these impacts were translated into comprehensive regional assessments for each Federal Region.

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