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SITE: A methodology for assessment of energy facility siting patterns

MASTER

Regional Studies Program

Energy/environmental assessments

Argonne National Laboratory

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REGIONAL STUDIES PROGRAM

SITE: A METHODOLOGY FOR ASSESSMENT
OF ENERGY FACILITY SITING PATTERNS

by

N. A. Frigerio,* L. J. Habegger, R. F. King,
L. J. Hoover, N. A. Clark,** and J. M. Cobian†

Energy and Environmental Systems Division

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SITE: A METHODOLOGY FOR ASSESSMENT OF ENERGY FACILITY SITING PATTERNS

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ABSTRACT

The timely development of the nation's energy production capacity in a manner that minimizes potential adverse local and regional impacts associated with energy facilities requires the use of sophisticated techniques for evaluation of siting alternatives and fuel cycle options. This report is a documentation of the computerized SITE methodology that has been developed for evaluating health, environmental, and socioeconomic impacts related to utilization of alternate sites for energy production within a region of interest. The cost, impact, and attribute vectors, which are generated and displayed on density maps, can be used in a multiparameter overlay process to identify preferable siting areas. The assessment of clustered facilities in energy centers is also possible within the SITE analysis framework. An application of the SITE methodology to Northern Illinois is presented. Also included is a description of the ongoing extension of SITE for the accumulative evaluation of alternative regional energy siting patterns and fuel cycle options. An appendix provides documentation and user information for the SITE computer program.

INTRODUCTION

Rational and systematic methods of selecting energy facility sites are essential if the United States is to develop its energy production capacity with minimal adverse environmental effects. The projected concentration of large-scale, energy-related activities in energy centers, coupled with heightened public awareness of the environmental and socioeconomic implications of such facilities, in particular, calls for increasingly more complex and detailed evaluations of proposed energy facility sites.

This evaluation process has been formalized into public policy by federal and state legislation. The Energy Reorganization Act of 1974 ordered the Nuclear Regulatory Commission to identify candidate sites for nuclear energy centers -- integrated facilities with power generation capabilities of

10,000 to 50,000 Mw and on-site fuel reprocessing and refabrication. The National Environmental Policy Act of 1969 (NEPA) requires not only an impact assessment for a proposed facility or cluster of facilities, but also comparative assessments of impacts associated with alternate sites and fuel choices. Various states also have passed related legislation; for example, laws in Maryland and Ohio require consideration of the impacts of a particular energy facility and site before state approval is given for construction.

Concern over the cumulative pattern of regional energy development has also resulted in state and federal legislation related to energy centers and statewide analysis of energy facility impacts. The wide range of fuel cycle options (coal, oil, nuclear, etc.) is an additional factor in stimulating development of comprehensive methods for evaluating energy supply impacts.

In response to the need for more thorough evaluation, Argonne National Laboratory is developing successively more comprehensive versions of a computerized methodology called SITE, designed to:

- (1) screen candidate energy facility sites or areas within an electric utility region, based on the region's physical and socioeconomic attributes, the planned facility's characteristics, and impact assessments, and
- (2) evaluate the cumulative regional impacts associated with alternate energy supply options and interregional energy import/export practices, specifically, comparison of different energy technologies and their regional distribution in clustered or dispersed patterns.

This ongoing project is part of Argonne's role in the energy-related Regional Studies Program being conducted by the national laboratories of the Energy Research and Development Administration (ERDA).

Candidate Area Selection

The comprehensive NEPA site evaluation process for nuclear energy facilities has been identified as a bottleneck in the deployment of nuclear reactors, and as a result, consideration is being given to separate predesignation of sites as required to satisfy long-range regional energy demands. Future development of a proposed plant would then involve more detailed environmental assessment of the particular plant design at a predesignated site.

The analysis required for this site predesignation can be accomplished only by a methodology capable of identifying constraints on energy facilities, eliminating unacceptable locations, and assessing on a preliminary basis the relative impacts associated with remaining candidate siting areas.

The SITE package can be used to screen and analyze such potential energy facility locations. The SITE approach originally was applied to nuclear energy facilities; however, it has been extended to include other types of energy production and conversion facilities. Ultimately it could be used to evaluate potential sites for industrial facilities with possible environmental impacts.

The SITE methodology is based on the quantification of three major site-related vectors. A cost vector is determined which identifies site-specific costs, such as transmission costs, cooling costs as related to water availability, and costs of specific controls needed to protect the surrounding environment. An impact vector is also computed for each potential site, using models of health and environmental impacts incurred in areas adjacent to the site. Finally, a site attribute vector is developed which reflects such characteristics as population, seismic conditions, meteorology, land use, and local ecological systems. This vector can be used to eliminate certain sites because of their inability to satisfy specific constraints. These three vectors can be displayed as density maps and combined in a simple overlay approach, similar to that developed by I. L. McHarg⁴, to identify candidate sites. Or, the vector elements also can be computationally combined into a weighted sum to obtain quantitative indicators of site suitability.

A detailed example based on the application of SITE to Northern Illinois is presented in this report. The parameters considered in this application include (among others): geology and seismology...meteorology and its relation to dispersion of routine and accidental atmospheric releases...population density...maximum and total dosage from routine and accidental releases...water quality...cooling system costs...land use...aesthetics. SITE uses standardized plant designs, which establishes a common starting point for evaluating each possible energy facility site.

Documentation and user information for the SITE computer code are included in an appendix of this report.

Regional Assessment of Energy Development Options

Also presented is a description of Argonne's ongoing effort to expand the capabilities of the SITE package, an extension that will enable SITE to evaluate cumulative impacts associated with alternative energy supply/demand options. The extended SITE methodology will be designed to compare nuclear, fossil fuel, and advanced energy development locational options, to minimize related adverse socioeconomic, environmental, and public health impacts.

When used in this mode, SITE can help decision-makers meet the requirements of various state and federal regulatory agencies. For example, North Dakota's recently developed Regional Environmental Assessment Program calls for developing appropriate methodologies and a data base to assess the impacts of state energy development options. The extended SITE package also could be used by state siting commissions responsible for identifying cumulative or long-term impacts of energy facility development.

1. EVALUATION OF SITING ALTERNATIVES - CANDIDATE SITE SELECTION

The process for selecting a site for construction of an energy production or conversion facility involves, either explicitly or implicitly, the four basic steps as follows:

1. Determination of the region of interest, which for utility systems includes the entire geographic area within which the utility could conceivably locate plants (or combined areas for pooled utility groups).
2. Determination of candidate areas in which to look for new sites within the region of interest.
3. Determination of the candidate sites, within the candidate areas, that are judged potentially capable of development.
4. Selection of a proposed site from evaluation of the candidate sites. This is the site for which construction and operation permits will be sought.

Whether the objective is optimization of energy production economics, minimization of health and environmental impacts, or a balancing of these and other objectives, the procedures used by utilities for site selection have either formally or informally involved each of these steps.¹ The concept of dividing the site-selection process into phases has been used in the guidelines Preparation of Environmental Reports for Nuclear Power Plants,² and is conceptually applicable to not only nuclear and other energy-related facilities but also to selection of sites for major industrial or public works projects.

The distinction and separation between the phases of site selection are not necessarily precise and clearly defined. Some considerations used in determination of, for example, candidate areas would also be used in selection of candidate and proposed sites, but the degree of treatment becomes more detailed and the importance may vary. Also, a preceding step of the process is not always absolutely necessary to the subsequent step. Determination of candidate areas is not essential, for example, to determination of candidate sites, but the possible result of this omission is more detail than necessary in evaluating sites in areas that could have been eliminated as candidate areas.

As a basis for public justification of site selection, particularly as required for a National Environmental Policy Act (NEPA) review, it is essential that the process of site selection be formalized and documented, and that the logic used in completion of each step be clearly set forth and available for review. The SITE methodology, as outlined in this section, provides a mechanism for systematically determining candidate sites within the region of interest and displaying the basis for that selection, using easily comprehended computer-generated geographic displays of the site-related regional attributes and facility impacts. By using less detail in the input data, larger geographic scales, and appropriate evaluation procedures, the framework of the SITE methodology can also be used for determination of candidate areas. This procedure would be similar to that used in state or multistate assessment of energy supply impacts in which precise location of future energy sites is not desired. This application is the topic of Sec. 3.

The overall structure of the evaluations performed by the SITE package for candidate site selection is illustrated in the flow diagram in Fig. 1, with a more detailed listing of the elements of analysis given in Table 1. (A similar analysis is used for candidate area selection, but with less detail as described above.) A basic component of the SITE package is a geocoded accounting system that stores an inventory of geophysical, demographic, socio-economic, and ecological attributes for each potential plant site and for the surrounding region that may be impacted by the plant. As shown in Fig. 1, certain sites, such as those with probable seismic faults, can be immediately eliminated from further consideration. For the remaining potentially suitable sites, the site-specific facility development, and operational needs, beyond those required by the standard plant, are then identified. An example of such a site-specific development is the installation of supplementary environmental controls to protect sensitive natural habitats or threatened species or the development of supplementary transportation facilities. An estimate of the site-specific cost vector listing the direct cost of developing and operating the site can then be established.

Characterization of the proposed plant and the inventory of regional attributes, coupled with pollution transport, health and environmental impact,

Fig. 1. Flow Diagram of SITE Methodology for Candidate Site Selection

Table 1. Elements of Analysis for
Candidate Site Selection

GEOCODED REGIONAL ATTRIBUTES

Geophysical Attributes

Meteorology and Climatology
Hydrology
Geology/Seismology
Topography
Fossil Fuels
Minerals

Socioeconomic Attributes

Land Use and Ownership
Demography
Economic Activity
Labor Force
Archeological and Historical

Ecological Systems and Biota

Terrestrial
Aquatic
Sensitive Species
Sensitive Ecological Systems

Environmental Quality and Emissions Without
Proposed Facility

Air Quality
Water Quality
Background Radiation
Noise
Waste Heat

Accessibility Attributes

Air
Rail
Barge
Highway
Pipelines
Transmission Line Corridors

SITING CONSTRAINTS

Regulatory Constraints

Emission Standards
Ambient Quality Standards
Operational and Safety Standards
Water Use Regulations

Table 1. (Contd.)

SITING CONSTRAINTS (Contd.)

Physical and Engineering Constraints

- Construction Standards
- Performance Constraints
- Materials Properties
- Geological Properties

Health and Environmental Constraints

- Chronic and Acute Dose Response
- Ecological Systems and Biota Conservation

Land Use Constraints

- Exclusion Zones
- Buffer Zones
- Emission Density Limits
- Right-of-way Availability

Socioeconomic Constraints

- Natural Resource Depletion or Destruction
- Public Perception
- Regional Economics
- Aesthetics
- Political
- Historical

FACILITY CHARACTERIZATION

Resource Requirements

- Land
- Transmission Corridors
- Capital Costs
- Operational and Maintenance Costs
- Site Development Costs
- Site Reclamation Costs
- Fuel
- Water
- Labor
- Control Equipment
- Other Materials

Effects

- Energy Production
- Atmospheric Emissions
- Water Effluents
- Thermal Effluents
- Noise

Table 1. (Contd.)

FACILITY CHARACTERIZATION (Contd.)

Effects (Contd.)

Solid Wastes
Tax Revenues
Occupational Hazards
Radioactive Wastes
Fissionable Fuel Production

IMPACT MODELS

Geophysical Transport

Atmospheric Dispersion, Removal, and Transformation
Radiation Dose
Hydrological Transport, Removal, and Transformation
Pollutant Pathways
Solid Waste Transport
Noise Propagation

Health and Environmental Impact Models

Mortality and Morbidity Rates
Aquatic and Terrestrial Ecosystem Impacts
Sensitive Species Impacts

Socioeconomic Impact Models

Community Services
Taxing Structure
Cultural and Historical
Economics

and socioeconomic models, yields estimates of the impacts imposed on every other site within the region -- the site-specific impact vector.

If the estimated siting impact is not acceptable, additional or alternate plant and site development must be assumed to mitigate these impacts, with a resulting increase in the cost vector. The site-specific impact and cost vectors thus illustrate the tradeoffs between the direct site development and operational costs, and the health, environmental, and socioeconomic impacts, i.e., the indirect social cost resulting from utilization of the site for energy production.

By varying the siting constraints and policies, both the relative and combined values of the impact and cost vectors are subject to studies of technology and engineering design optimization for a specific site, using the analysis framework shown in Fig. 1. The SITE analysis thus leads not only to selection of optimal sites, but also to analysis and assessment of alternative energy production and environmental control technologies and their compatibility with available sites in the region of interest. Extension of this type of analysis leads to application of the SITE methodology to comprehensive assessment of alternative future energy scenarios as is discussed in Sec. 3.

The geocoded attributes and computed cost and impact vectors for each site form elements of the Regional Sites Assessment Matrix, which is the primary data base for selection of candidate sites. These descriptions, either individually or in combination, can be visually displayed on computer-generated maps for the region of interest by shading or color-coding each site in relation to the numerical value of the descriptor for that site. Transparencies of these maps for various parameters can then be overlaid to form a composite showing preferable siting areas. This multiparameter overlay map process is fundamentally a computerized version of the technique described by McHarg.^{3,4}

The site selection process can also be accomplished without the physical use of maps by numerically manipulating the geocoded site parameters. This selection process makes use of decision-analysis techniques in which the various elements of the assessment matrix are weighted with appropriate importance factors and summed to obtain a quantitative evaluation of the potential sites.

The following section is a more detailed description of the attribute descriptors, plant characterizations, impact and cost models, siting constraints and candidate site-selection procedures used in the SITE methodology. The focal point for this description is the application of SITE to Northern Illinois.

2. THE NORTHERN ILLINOIS CASE STUDY AREA

Since 1971, Argonne National Laboratory and other national laboratories have been heavily involved in the evaluation of energy facility siting and the potential impacts of routine or accidental discharges of chemical and radiological wastes on public health and environmental quality. This effort, which is primarily the result of the National Environmental Policy Act (NEPA) and the subsequent Calvert Cliffs Decision, has evolved from a concentration on a retroactive evaluation of existing power plants or plants under construction to the evaluation of proposed plants located in one of several alternative siting areas. The concept of evaluating relative impacts for each siting possibility, from a set of potential sites, is in the spirit of NEPA, which mandates considerations of alternatives for minimization of health, environmental, economic, and social impacts.

The evolution of the impact assessment process has led to the development of the comprehensive computerized SITE methodology for geocoding various attributes for a utility region in which proposed energy facilities being evaluated were to be located. Included in SITE were a set of methodologies for analyzing the potential impact of various types of energy facilities as related to site-specific regional attributes. The intended output of SITE was a predesignated set of preferred siting areas that could then be studied in detail for final site selection. In addition to the environmental benefits, such a predesignation of siting areas is also very useful for expediting the often lengthy licensing procedure for energy facilities.

This section is a detailed description of the SITE methodology and its continuing application to the Northern Illinois area and includes an indication of the ongoing modifications and extensions. The application of SITE to Northern Illinois also provides a unique test of the methodology in that this area represents one of the largest commitments to nuclear power of any utility area in the United States.

2.1 GEOCODED REGIONAL ATTRIBUTES

2.1.1 Data Sources

A broad range of sources are available for providing the data required to evaluate the alternate sites in the region of interest. The

following is a partial list of sources used in the Northern Illinois case study.

Soil Conservation Service, U.S. Department of Agriculture (soil characteristics)

U.S. Department of Housing and Urban Development (land use)

Bureau of the Census, U.S. Department of Commerce (population and economic data)

National Oceanic and Atmospheric Administration, U.S. Department of Commerce (meteorology and climatology)

Bureau of Mines, U.S. Department of the Interior (fossil fuel reserves)

ERTS Multi-Spectral Imagery, U.S. Geological Survey (topographic and land-use features)

National Historical Register (archeological and historical sites)

Federal Power Commission (existing and planned power plants)

National Emission Data System, U.S. Environmental Protection Agency (atmospheric emissions)

National Pollution Discharge Elimination System, U.S. Environmental Protection Agency (waterway effluents)

Army Corps of Engineers (hydrology)

STORET, U.S. Environmental Protection Agency (water quality)

U.S. Geological Survey, Department of the Interior (topography)

Currently two methods are used to geocode all data that will be needed. One is simply to punch the data on cards, with the card images carrying the value for each x,y grid unit, and the x and y coordinates of the unit itself. Alternatively these coordinates can be given as latitude and longitude. Another system, useful in some cases, is to overlay a map that already contains appropriate values onto a digicoder and to make use of the digicoder's ability

to enter integer values simply by a touch of the pen. This system is most useful where the parameter being entered is easily expressed in a small scale of integers. Yet a third method, which is just developing, will have an image-scanning computer, such as the ALICE system at Argonne,⁵ read the data directly and code it automatically. In any case, the final input to the program is then arranged and presented back to the coder both as a density map and as a formatted table. In this way, the coder can quickly and relatively easily verify the large number of values that go into each parameter matrix.

For representational purposes, it is convenient to output the variable on the density map in a number of logarithmic increments. Each of these can correspond to a gray scale, or a color, on the output map. Ordinarily seven logarithmic increments are sufficient, although the program will handle as many as 256.

2.1.2 Geophysical Attributes

SITE is not limited to any particular region and could just as easily be applied to areas of city size or state size. Extensions to multi-state areas are discussed in the following section. In each case, the underlying geometry is the same. A rectangular grid is defined within which the proposed facility will be located, and to include the interregional effects of the facility, a surrounding region is also defined. The southwest corner of this extended area is taken as the coordinate origin, the x-axis generated eastward and the y-axis generated northward. Each unit area then can be designated either by the relative position of its southwest corner, or by the integer values of its x and y coordinates.

The version of the SITE program documented in the appendix is based on square unit areas. In the examples, these are assumed 2 kilometers on a side, partly because review of current fossil and nuclear plants showed that most occupied at least the approximately 1000 acres represented by such a square. However, for subsequent extensions to SITE, the awkwardness of reducing measures to a metric grid when working with available cartography has led to the addition of data management techniques using unit areas defined by one minute of angle in latitude and 2 minutes in longitude. Such "squares," often called Marsden squares, cover nearly the same area as the 2-kilometer squares (about 1200 acres in most of the United States).

In future applications of SITE to other utility areas or regions of interest, the suggested procedure is initially to use a larger grid size to identify candidate areas and subsequently a smaller grid size, equivalent to the actual plant siting area for detailed evaluation. However, for the Northern Illinois test case in a more conservative approach, the smaller grid size was used throughout the region. This approach was considered essential in the initial case study to provide criteria and guidelines for future candidate area selections.

In the Northern Illinois study used as an example, the coordinate origin was taken at a point on the border of Henderson and McDonough counties, as shown in Fig. 2. A grid of 150 horizontal divisions and 95 vertical divisions (2 km/division) was employed to encompass the potential construction area permitted the Commonwealth Edison Company. However, as mentioned above, in order to allow impact assessment of sites right up to the border of this grid, consideration was extended to a region 15 divisions farther out in each direction. This additional area resulted in 160 x 125 (20,000) divisions covering 320 x 250 (80,000) square kilometers.

This area is shown in Fig. 3 as geocoded into the computer. The region of Northern Illinois potentially available to Commonwealth Edison for construction is shown in yellow, with peripheral areas of Iowa to the west, Wisconsin to the north, and a small border of Indiana to the east, shown in red. Chicago and other cities are visible as a light green coloring and Lake Michigan and major waterways are shown in dark blue. This type of minimum-detail, base map, has, in these studies, formed the most useful orientation figure for the remaining geocoding and evaluation efforts. Following the base map, more detailed geographic figures are coded into the program for each of the parameters likely to have some bearing on environmental impact.

Metcorology/Climatology. For all power plants, major consideration must be given to airborne wastes. NOAA data is used to determine the annual average dispersion characteristics of the site and the probabilities and nature of local pollution episodes, inversions, and those similar conditions that are calculated to affect the removal and dispersion of airborne wastes. In addition, the nature and type of cloud cover and of precipitation phenomena

Fig. 2. The Northern Illinois Case Study Area and Site Selection Grid

Fig. 3. Base Map for Northern Illinois

are also coded to permit prediction of the deposition and scavenging of airborne pollutants from the local atmosphere onto local lands. These same parameters also affect the dispersion and deposition of spray and salt from cooling towers, which when employed, constitute an additional source of airborne waste.

Means and extremes of rainfall, temperature, and relative and absolute humidities as they affect evaporation are appropriate to more detailed consideration of the optimum cooling system. If a cooling pond is being considered as a possibility, the concatenation of these values with other vector values, such as land costs, developed during the site optimization analysis will produce a set of costs for the various alternative types of cooling pond utilization; e.g., a 1-acre/megawatt pond, a 2-acre/megawatt pond, a spray pond, or a pond with spray canal. If wet cooling towers are envisioned, dry bulb and wet bulb means and extremes become critical. These values generally determine, by themselves, whether a natural draft or mechanical draft tower is appropriate for a given site. As a general rule, a cool, wet climate, the sort found in most of the northern parts of the United States, favors natural draft towers. A hot, dry climate tends to favor mechanical draft towers. Nonetheless, for fairly large areas in the United States, the choice is not quite that easily made and will depend to a considerable extent on the peculiarities of microclimate of the area. If a dry cooling tower is envisioned, then the major parameters to be geocoded from the NOAA tapes are the air temperature means and extremes, and the means, extremes, and directions of wind velocities.

In addition to the normal meteorology, serious attention must always be given to such meteorological extremes as tornados, hurricanes, and, near the sea coast, waterspouts. Such severe natural phenomena not only affect the desirability of a given site, but also add to the construction and engineering costs that must be incurred to strengthen the facility against these ravages. It is well known that tornados tend to move along "tornado alleys," and it is strongly suspected that they avoid such major heat islands as the city of Chicago. In addition, there appears to be a 45-year cycle of severity and frequency for tornados in middle America. All of these factors are combined from NOAA data tapes and a series of geocoded values is produced for each site, giving probability as a function of severity. An example of one of these is shown in Fig. 4.

Fig. 4. Frequencies for Tornadoes in Northern Illinois

Similar computations are in progress for hurricanes and waterspouts in other regions. Although the areas under consideration are markedly larger than those of interest for tornados, the probabilities of severe short-term precipitation events are also geocoded to permit cost estimates for protection against flash floods, snow overloading, or hail and electrical storm damage. The latter, in particular, has been responsible for at least a dozen hydrogen explosions in BWR off-gas delay lines. A similar phenomenon can be anticipated for radiolytically produced hydrogen in waste tanks at fuel processing facilities and for the hydrogen-forming gas used in fuel production plants. Such phenomena can also be expected to bring about electrical and communication outages, and accordingly, affect the design of the plant with respect to emergency facilities for these services.

Hydrology/Water Quality. In theory each of the grid squares can be evaluated separately for cooling water availability, impact, and alternatives. In practice, a 1000-MWe plant will require about 3000 cubic feet/second (cfs) for once-through cooling, about 50 cfs when evaporative cooling is utilized, and about 1.5 cfs when dry cooling towers are used. Since current legislative postures in this area are distinctly inimical to once-through cooling for future plants, the option was abandoned in this example study. Only those waterways were coded that showed some likelihood of supporting evaporative cooling. These are shown in Fig. 5. Annual average flow rates along each of these and other secondary waterways were coded at each of the reporting stations and superimposed on Fig. 5.

Available flow rates from Fig. 5 along the waterways were interpolated by the program between each of the reporting points. At the same time total dissolved solids readings, and other water quality parameters, were geocoded into the matrix. Water availability from ground aquifers was not specifically coded, because study of the groundwater draw-down capabilities of Northern Illinois by the Illinois Water Survey showed that any part of Northern Illinois was capable of supporting a withdrawal of 1.5 cfs.

Also coded is the probability and severity of floods for the major waterways, which can impact on engineering and construction costs and impose restrictions on location to avoid flood plains.

Fig. 5. Major Waterways in Northern Illinois and 1973 Annual Average Flow Rates

Geology/Seismology. Underlying geological strata are obtained from the local state geological survey, and are coded in such a way as to indicate where plants should not be built because of their proximity to seismic faults and similar geological instabilities. At the same time the entire earthquake history of the United States is used to produce a density map of earthquake probability and seismicity for the area.

For more detailed evaluations the U.S. Soil Conservation Service maps indicating soil characteristics, including slope, can be used to evaluate compatibility of specific sites to power plant construction.

Topography. Figure 6 shows the topography of Northern Illinois. Because Northern Illinois is relatively flat, the total range involved is only a few hundred feet, and the importance of topography is relatively small. In mountainous regions, however, topography is important, both in the feasibility of plant siting, and in establishing atmospheric dispersion patterns. A narrow valley is a poor place to locate a plant, for its relatively channeled meteorology will inhibit the dispersion of airborne pollutants. A mountain top is equally undesirable for reasons of construction difficulty and cost. Because the program codes areas of only 1000 acres or so, it is relatively easy to locate sites that are on plateaus, high enough to benefit from good dispersion patterns and sufficiently well chosen to lie above major centers of population. In mountainous regions the major centers of population are almost always found in valleys. By lying above them, the plant benefits not only from the improved meteorology of being on a plateau, but from the lowered concentrations that arise from the large vertical distance between its emitting stacks and the population center.

Fossil Fuels/Minerals. Information on the spatial location of fossil fuel resources, as provided by the Bureau of Mines, is available for access by SITE. This information can be related to fuel transportation costs as a function of site location for fossil-fueled power plants. Similar information for other mineral resources could be used to evaluate costs of a proposed site in terms of the value of minerals at that location.

2.1.3 Socioeconomic Attributes

For almost any siting analysis, consideration must be given to the population distribution about the site. The first step is the geocoding of

Fig. 6. Topographical Map of Northern Illinois

populations for each of the grids in the region of interest. SITE uses the census tapes to produce the population and other socioeconomic characteristics for each census tract, block group, or block. A partial sample of the information obtained is shown in Fig. 7. In addition to the parameters shown in Fig. 7, data on the labor force and unemployment, commuting, stability and turnover, public assistance and social security, and the like are obtained from the census information. A coded example of population density is shown in Fig. 8. Chicago is visible on the lake. Then Kankakee, Joliet, Aurora, and Elgin can be seen in a clockwise arc about Chicago; and Peoria, Quad Cities, Galesburg, and Rockford in a larger arc starting at the bottom of the map. Small towns and villages are visible as small, dark areas scattered very nearly uniformly throughout Northern Illinois. The same sort of geocoding analysis is performed for each of the other population variables of interest. Nonhuman entry is made in the same way, e.g., cow populations for the computation of milk pathway doses from reactor releases or biotic populations for the computation of ecosystem disruption.

In addition to the population directly available from census tapes, information is also available as to growth and growth rate. The number of telephone households per tract for each year from 1970 onwards was obtained from telephone books and the number of households per tract that have newly registered automobiles, from automobile registration records. From national planning data is acquired the land area for each tract as well as the percentage of land available for population expansion, which has not been taken over by cemeteries, federal institutions, and the like. Additional tract estimates for a number of cities and land areas are also acquired from local planning offices, and the growth change between the 1960 and 1970 census is factored in. Not only current populations but also a fair forecast of future populations can be obtained and geocoded into the program, as were the estimates of 1974 population shown in Fig. 7.

Also coded are zoning and planning restrictions, and the existence and availability of wastelands of potential utility to plants. In the process of this particular study, data from earth satellite and aerial views were geocoded into the program, along with data from local and county records as to land use. From these, it was possible to identify land that had lost its previous utility for various reasons. These included historical abandonment (e.g., the retired Illinois-Michigan Canal), land that had become

POPULATION per 4 km^2

Fig. 8. Population Densities for Northern Illinois

agriculturally inadequate for "corn belt farming," abandoned quarries and mines, abandoned industrial sites, and old gravel pits. These seemed to be eminently suitable for reclamation by a modern power plant. And, indeed, Commonwealth Edison's new Braidwood Plant, at least on the basis of its location in the remains of an abandoned strip mine, must certainly rank as the classical case of "doing well by doing good."

In addition to the direct impacts of pollutants on population, there are indirect impacts from locating a plant close to scenic, cultural, public, historical, or archeologically important areas. These too are geocoded into the program from data available from the National Historical Register and the other national, state, and local registries. An example is shown in Fig. 9 where public conservation areas are denoted by a dash and historical sites by an "X."

2.1.4 Ecological Systems and Biota

In much the same way, one may geocode various aspects of the environment and ecosystems about the site. Species range maps are obtained and geocoded, along with special symbols indicating the population and range of critical or endangered species, species of economic or recreational importance, and biological indicators (i.e., species of particular utility in detecting environmental changes), along with the habitat and usage areas associated with each of these. Probable noise impacts are coded in, as well as a history of epidemics or local catastrophes that might have affected the biotic population.

2.1.5 Environmental Quality and Emissions Without Proposed Facility

The monitoring efforts of federal and state networks are included in a special geocoded series of their own, along with monitoring efforts by power stations already in the area. This is done in order to provide an adequate baseline of background biological, chemical, and radiological characteristics against which any future impacts may be measured. An example of this is shown in Fig. 10, where the radiological monitoring stations within a 200-mile radius of a particular plant site are listed, along with symbols indicating the type of measurements that they perform. The actual monthly or quarterly values obtained by these stations are also maintained on a tape file and

== CONSERVATION AREAS
 x HISTORICAL & ARCHEOLOGICAL AREAS

Fig. 9. Public Conservation and Historical Areas in Northern Illinois

FEDERAL AND STATE RADIOLOGICAL MONITORING STATIONS IN MFRP

NUMBER OF STATIONS = 57

VICINITY, I.E., WITHIN 200. MILES

STATION	ST	DIS/DIR	PT	PM	SA	SW	ST	TW	TT	DA	LO
MENASHA	WI	196. N						1			
TWORIVER	WI	195. N						1			
MANITWOC	WI	189. N						1			
OSHKOSH	WI	183. N						1			
NLISRON	WI	198.NNW						1			
MUSKOGON	MI	164.NE						1			
GORAPIDS	MI	173.NE	1					1			1
MADISON	WI	130.NNW			1			1	1		
MILWAUKEE	WI	116. N	1					1		1	
HOLLAND	MI	147.NE						1			
DUBEQUE	IA	146.NNW				1					
SHAVEN	MI	125.NE	1				1				1
KALANZO	MI	152.NE						1			
ROCKFORD	IL	74.NW						1			
DESPLANS	IL	51.NE						1			
STJOSEPH	MI	105.ENE						1			
SAVANNA	IL	107.NNW						1			
FRAKLMPK	IL	44.NNE						1			
ROSEMONT	IL	47.NNE						1			
SCHILPPK	IL	45.NNE						1			
ARGO	IL	42.NE						1			
EEDERDPK	IL	37.NE						1			
CHICAGO	IL	48.NE	1							1	
DOWNRGRO	IL	33.NNE						1			
PLKHART	IN	121. E						1			
IOWACITY	IA	170. W	1	1					1		1
LEMONT	IL	24.NE						1			
MICHICITY	IN	75.ENE						1			
MIDLBERRY	IN	135. E						1			
ORLANDPK	IL	27.NE						1			
GARY	IN	51.ENE				1					
JOLIET	IL	14.NE						1			
MOLINE	IL	115. W					1				
PORTAGE	IN	58.ENE						1			
ROCKILND	IL	119. W						1			
MORRIS	IL	8. W					1				
PERU	IL	45. W						1			
NORTHEST	IN	164. E	1								1
NORTHWEST	IN	8. ESE	1								1
BURLGTON	IA	159.WSW				1		1			
LOGNPORT	IN	109.ESE						1			
PEORIA	IL	84.SW				1		1			
LAFAFETE	IN	93.SE						1			
WLAFFETE	IN	95.SE						1			
CENTRAL	IN	165.ESE	1								1
DANVILLE	IL	93.SSE						1			
MUNCIE	IN	172.ESE						1			
BERDTOWN	IL	147.SW						1			
QUINCY	IL	191.WSW						1			
DECATUR	IL	112.SSW						1			
HANNIBAL	MO	200.SW					1				
INDAPOLS	IN	158.SE	1	1				1	1	1	
SPRINGFIELD	IL	131.SW			1			1	1		
VANDALIA	IL	173.SSW						1			
ALTON	IL	169.SSW						1			
WOODRIVER	IL	198.SSW						1			
WASHGTON	IN	197.SSE						1			

Fig. 10. Sample Listing of Radiological Monitoring Stations in the Vicinity of the Midwest Fuel Reprocessing Plant (MFRP)

included in the geocoding matrix. Similar monitored data for nonradioactive pollutants is also available from the U.S. Environmental Protection Agency and state environmental agencies. In addition to measurements of existing air quality, data is also available on location and rates of emission for radioactive and nonradioactive pollutant sources. This data, in conjunction with appropriate pollutant transport models, can provide estimates of ambient concentrations to supplement monitored values. Sources of this emission data include the EPA National Emissions Data Systems (NEDS) for nonradioactive atmospheric emissions, the National Pollutant Discharge Elimination System permits for water effluents, Federal Power Commission data for power plant emissions, and the power plant environmental data base being developed at Argonne as discussed below.

2.1.6 Accessibility Attributes

The availability of transportation routes and their proximities to sites are coded in, as in Fig. 11. This figure shows the major highways of Northern Illinois. Similar maps are made up for the other major forms of transportation, e.g., railroad, barge, and airports in the case of Northern Illinois. Also coded are transmission line corridors and their associated costs and routes for solid waste disposal.

2.2 THE PLANT

At the same time that one is encoding the regional attributes, one must characterize the potential plants that may be sited. In order to do this, model nuclear and fossil plants are established, and their noise, thermal, solid, liquid, and gaseous wastes estimated. So far this has been done for PWR, BWR, HTGR, and LMFBR nuclear plants, as well as for coal, oil, gas, and coal-gasification fossil plants. The fuel cycle aspects, transportation, water, and air needs, sanitary needs, construction and transmission needs, accidents and accidental impacts, economic and social effects have been estimated and entered. This has been done very largely by a survey of existing plants, along with some extrapolation based on present orders, options, and letters of intent. An example of the data obtained by this kind of survey is shown in Fig. 12. This particular figure was taken from a recently completed survey at Argonne of 72 nuclear reactors.⁶ It is part of an ongoing

Fig. 11. Major Highways in Northern Illinois

ID: BRAIDWOOD 1&2, COMMWLTH EDISON, COUNTY OF WILL, STATE OF IL

MAJOR RIVER BASIN	UPPER MISSISSIPPI	DISRUPTED ONSITE LAND, ACRES	3770
LATITUDE, DEG MIN SEC	041 16 06	DISPL.EXCAVATION SPOIL,MIL CU YRD	DATA NOT AVAILABLE
LONGITUDE, DEG MIN SEC	088 12 48	DREDGE SPOIL, MIL CU YRD	0.5
DOCKET NUMBER	50456	AVG. CONSTRUCTION PERSONNEL	1100
LICENSING ACTION	CP APPLICATION PENDING	OPERATING PERSONNEL	200
DATE OF LICENSING ACTION	09 20 73	NOBLE GAS AIR RELEASE, CURIES/YR	7026
NSSS TYPE	PWR	I-131 AIR RELEASE, CURIES/YR	0.1
NO.NUCLEAR UNITS INFO. APPL	2	LIQ. EFFLUENT(NON-H3), CURIES/YR	0.2
TOTAL THERMAL CAPACITY, MWT	3425	TRITIUM LIQUID RELEASE, CURIES/YR	700
TOTAL ELECTRICAL CAPACITY,MWE	1120	CS-137 LIQ. EFFLUENT, CURIES/YR	0.0092
ADDITIONAL UNITS ONSITE	NO	DIRECT RADIATION AT SITE BOUNDARY,MR/YR	0.01
TALLEST STRUCTURE, FEET	DATA NOT AVAILABLE	MAX. GAS STORAGE, CURIES	200
COOLING SYSTEM TYPE	COOLING POND/CANAL	MAX. LIQUID STORAGE, CURIES	DATA NOT AVAILABLE
PLANT LIFETIME, YEARS	30	RADIOACTIVE SOLID WASTE, CURIES/YR	19000
SOURCE WATERBODY	RIVER, NONTIDAL	RADIOACTIVE SOLID WASTE VOL.,DRUMS/YR	2100
RECEIVING WATERBODY	RIVER, NONTIDAL	MAX. HEAT TO ATMOS.,BBTU/HR	16
LAND ACREAGE OF STATION FACILITIES	3580	MAX. HEAT TO REC. WATER, BBTU/HR	0.43
TOTAL LAND ACREAGE OF SITE	4420	TREATMENT CHEMICALS, LBS/YR	
OFFSITE ACREAGE, TRANSMISSION LINES	2375	BIOCIDES	
OFFSITE ACREAGE, ACCESS RCADWAY	0.0	SODIUM HYPOCHLORITE	69000
OFFSITE ACREAGE, ACCESS RAILWAY	0.0		
MIN. DISTANCE TO SITE BOUNDARY, FT	1800		
MIN. DIST. LARG. DIFFUSION FACTOR,FT	1800		
INTAKE LOCATION	OFFSHORE, SUBMERGED		
COOLING SYSTEM WITHDRAWAL,CU FT/SEC	93	CORROSION AND SCALE INHIBITORS	
SERVICE WATER WITHDRAWAL, CU FT/SEC	0.67	SODIUM PHOSPHATE, ORTHO, ANHYDROUS	210000
APPROACH VELOCITY, FEET PER SECOND	0.5	SULFURIC ACID	30000000
SCREEN VELOCITY, FEET PER SECOND	1		
INTAKE SCREEN MESH, INCHES	DATA NOT AVAILABLE		
COOLING SYSTEM EVAPORATION,CU FT/SEC	47		
SERVICE WATER EVAPORATION,CU FT/SEC	NOT APPLICABLE	CLEANING AND NEUTRALIZING COMPOUNDS	
DRIFT, PERCENT	NOT APPLICABLE	SULFURIC ACID	1600000
DISCHARGE LOCATION	OFFSHORE, SUBMERGED	SODIUM HYDROXIDE	1000000
DISCHARGE TYPE	EFFLUENT PIPE	BORIC ACID	160000
COOLING SYSTEM DISCHARGE, CU FT/SEC	46		
SERVICE WATER DISCHARGE, CU FT/SEC	NOT APPLICABLE		
DISCHARGE VELOCITY, FEET PER SECOND	2	CHEMICAL EFFLUENTS, PPM	
DISCHARGE EFFECTIVE AREA, SQ FT	64	TOTAL RESIDUAL CHLORINE	0.001
COND. COOLING WATER FLOW,CU FT/SEC	3250	FREE AVAILABLE CHLORINE	0.0
RETURN COND. TDS RATIO	2.51	TOTAL CHROMIUM	1.3
NO. CONDENSER COOLING TOWERS	NOT APPLICABLE	TOTAL COPPER	1
COOLING TOWER HEIGHT, FT	NOT APPLICABLE	TOTAL IRON	2
COOLING TOWER EXIT DIAM.,FT	NOT APPLICABLE	TOTAL NICKEL	1
COOLING RANGE, DEG. F	NOT APPLICABLE	TOTAL ZINC	1
COOLING TOWER EXIT VELOCITY, FT/SEC	NOT APPLICABLE	TOTAL PHOSPHORUS (AS P)	0.4
COOLING TOWER DROPLET SIZE, MICRONS	NOT APPLICABLE	SULFATE	588
CONDENSER TEMP.RISE, DEG. F	21	OIL AND GREASE	15
COOLING SYSTEM TRANSIT TIME, MIN.	DATA NOT AVAILABLE	DISSOLVED OXYGEN	DATA NOT AVAILABLE
EFFLUENT TEMP. ABOVE AMBIENT,DEG F	30.2	TOTAL DISSOLVED SOLIDS	967
NOISE AT BOUNDARY, DECIBELS	DATA NOT AVAILABLE	TOTAL SUSPENDED SOLIDS	52
		BOD5 DAY	30

NOTES: THERE ARE NONE.

Fig. 12. Sample Listing from Nuclear Power Plant Environmental Parameter Survey (Braidwood)

survey with a much broader data base, one that encompasses all of the 256 reactors currently operational or planned. When this is completed, similar surveys of fossil plants, coal gasification projects, and the like are anticipated.

Also available for use by SITE is the computerized Matrix of Environmental Residuals for Energy Systems created by Brookhaven,⁷ which quantifies the impacts on land, water, air, solid waste, and occupational health associated with supply and end use of fossil fuels.

2.3 SITE EVALUATION AND IMPACT MODELS

With the various regional and plant characterization inventories in hand, one may proceed to the computation of many of the specific and general costs and impacts of plants at each site. In the simplest possible case, the geocoded information itself is of such a nature that it either inhibits or permits siting. For example, regulatory guides for nuclear power plants generally require exclusion of population within 0.4 miles of the plant, a low population zone within 3 miles, and no densely populated centers (more than 25,000 residents) within 4 miles.⁸ Other restricted areas such as recreation areas, natural preserves, and those over seismic faults can similarly be obtained directly from the geocoded regional inventories.

Cooling System Costs. Since the data base is computerized, the SITE methodology can of course also perform functional analysis. The least complicated type of functional analysis is represented by a determination of the minimum cooling system cost for the site-specific cost vector. An average value of \$12 per installed kilowatt was obtained for all sites for which sufficient water was available for evaporative cooling (50 cfs for a 1000-MWe plant). Detailed study showed that the cost differentials between cooling ponds, spray ponds, spray canals, natural draft, and mechanical draft towers were too small and too variable to be seriously considered as separate alternatives. They were much too dependent on company policies and company histories for clear separation, and they simply merged into one another. This was partly a consequence of land costs in Northern Illinois, about \$1000 to \$2000 per acre, even for land well outside urban areas. Increased land cost for ponds tended to balance the increased construction, equipment, and operating costs for wet towers. In addition to the water cooling requirements

and impacts on local water availability and quality, costs were factored in for transporting water to plant sites not directly located on the waterways by means of canals or large pipes.

For dry towers, the cost was found to be considerably higher at \$30 per installed kilowatt. As a result, in Northern Illinois, the choices for preferable sites based on cooling costs are quite straightforward. The major waterways or Lake Michigan, shown in Fig. 3, were all that could be expected to support a major power plant as the additional smaller waterways shown in Fig. 5 were not effectively available. One could locate within a few kilometers of a major waterway and use any of the well-known methods for evaporative cooling with little cost advantage over use of the other methods. Or, one could locate away from the major waterways and incur the roughly three-fold increase in cooling costs required by dry towers. This situation also quite adequately represented the question of aqueous waste removal and dispersion. The major waterways indicated were generally adequate for dispersion of the relatively small amounts of aqueous waste permitted to modern power plants. And the other waterways were not to be considered, either on the basis of insufficiency of cooling water or on the basis of their inability to disperse aqueous wastes.

Transportation Costs. A similar analysis is used to obtain the transportation-related element of the site-specific cost vector. The major highway routes in Fig. 11 and data for unit trucking costs, on and off major highways, is used by a subprogram of SITE to compute trucking costs associated with a particular site. The population density map in Fig. 8 is also used in conjunction with transportation routes to determine the costs, in time and dollars, for the communication of plant personnel and of construction workers coming and going from the site. In each case the final output is a set of numerical costs associated with each site, as well as visual aids in the form of shaded density maps of these costs, graded logarithmically.

Transmission Costs. Another example of an uncomplicated, one-function site-specific cost analysis is shown in Fig. 13 for electrical transmission costs. Cost values on this particular figure are given in mills/installed kilowatt, and include costs for amortization, operation, and power losses over the life-time of the plant. Data on construction, operation, and load-loss costs were obtained from Commonwealth Edison.⁹ As with many large, urban

TRANSMISSION COST
TRANSMISSION LINE COST , PER COEIAN THESIS.

1.638E 04	TO	3.312E 04	@	8.104E 03	TO	1.638E 04
W 4.009E 03	TO	8.104E 03	X	1.983E 03	TO	4.009E 03
= 9.809E 02	TO	1.983E 03	/	4.852E 02	TO	9.809E 02
- 2.400E 02	TO	4.852E 02				

Fig. 13. Site-specific Electrical Transmission Costs for Northern Illinois (mills/installed kw)

power systems, the transmission line costs prove to be a simple linear function of plant distance from a system load centroid. This function is indicated in the figure by the relatively regular increase of cost with distance from a single blank square very near the eastern boundary of the region. The latter is the locus of the current load centroid for Commonwealth Edison. It lies about 15 miles southeast of the Chicago Loop (Central Business District) and is moving very slowly northwestward. However, the load system is so dominated by the heavy industrial complex at the southern end of Lake Michigan that increased suburban and light industrial growth to the west and north of the Loop have had very little effect on the position of the load centroid, and is likely to have no greater effect in the foreseeable future.

The factors that allow transmission line costs to be estimated in this straightforward manner, essentially independent of previous transmission rights-of-way, are partly economic, partly sociopolitical, and partly electrical. A 1000-MWe plant represents about 10% of the total capacity of even so large a system as that of Commonwealth Edison. Older plants are much smaller, and their lines and rights-of-way cannot merely be expanded to include much larger plants. Thus, in effect, each large, new plant must build its own system, de novo. And, since these are necessarily baseload rather than peaking plants, they must deliver their load as directly as possible to the region about the centroid. The overall needs of the system are such that a baseload plant cannot be dedicated just to the service of its own local region.

Health and Environmental Impacts. This type of analysis is also applicable to the evaluation of the site-specific impact vector involving many human and natural phenomena. Many of these are a function of position only or of relative position (as in the case above) and are handled by one or two sample equations. An example is the algorithmic analysis of radiation from a nuclear plant that varies as the inverse of the square of the distance from the plant. This simple algorithm models direct radiation from reactors, from BWR turbine shine, and from waste storage areas, as well as noise from mechanical cooling towers and, under some circumstances, the esthetic impact of tall plant structures. An example is shown in Fig. 14 in which the density of each square is proportional to the logarithm of the integrated direct radiation annual dose commitment to the entire population surrounding the plant

TOTAL MANREM DOSE FOR EACH SITE
NORTHERN ILLINOIS WITH DOSE INVERSELY PROPORTIONAL TO DISTANCE SQUARED

■	1.054E 04	TO	2.472E 04	●	4.491E 03	TO	1.054E 04
W	1.914E 03	TO	4.491E 03	X	8.159E 02	TO	1.914E 03
=	3.477E 02	TO	8.159E 02	/	1.482E 02	TO	3.477E 02
-	6.317E 01	TO	1.482E 02				

Fig. 14. Site-specific Total Annual Dose Commitment from Direct Radiation for a 1000-MWe BWR in Northern Illinois

if the plant were to be located at the indicated square. For this particular computation, the plant was taken to be a 1000-MWe BWR with unshielded turbines. The values are given in man-millirems. In this computation, as in others, Lake Michigan was not specifically excluded for siting because offshore siting is a possibility, albeit a rather remote one. Clearly, the Chicago area in the northeast corner would be a poor choice on the basis of direct radiation dose, as would other urban areas about the state. However, in much of the state siting would result in dose commitment levels about 1% of those of urban areas, because of the highly rural character of most of Northern Illinois.

More complex functions can be handled in the same algorithmic way, but for quite arbitrary functions, it is more expedient to first generate a function density map about each point, as in Fig. 15, which represents an example of the dose distribution about a nuclear plant from airborne radioactive effluents. For this example the dispersion parameters were based on the meteorology for the Dresden 100-meter effluent stack, averaged over the climatological year. For each site the matrix elements of the function density maps are concatenated with those of the population densities about the site to produce an estimate of the annual total manrem exposure resulting from location of the plant at that site with results as shown in Fig. 16.

From Fig. 16 one can see that, so long as one avoids major urban areas, average annual population dose can be kept quite small. However, to the population living near the plant, that is hardly the question at issue! For them, the dose commitment to the maximum single square in the region of the plant is of vital interest. Most often this will be a small community close to the plant and downwind of it along the path of the local prevailing winds. The maximum annual exposure to any surrounding square is shown in Fig. 17 for each potential site. When this "point dose" is considered, the number of low dose sites diminishes markedly.

In general, one would not use a single meteorological climatic data set ("met set") for so large an area, but would vary the distribution matrix represented by Fig. 14 from square to square as needed. However, as might be anticipated from the relatively flat and featureless terrain of Northern Illinois, the Dresden met set proved to be quite representative of the rest of Northern Illinois.

Fig. 15. Dose Distribution for Gaseous Radioactive Effluents
from a Nuclear Power Plant in Northern Illinois

TOTAL MANREM DOSE FOR EACH SITE
NORTHERN ILLINOIS WITH 100 MTR DRESDEN ANNUAL DOSE

W	3.744E 02	TO	7.876E 02	+	1.780E 02	TO	3.744E 02
=	8.462E 01	TO	1.780E 02	x	4.023E 01	TO	8.462E 01
-	1.912E 01	TO	4.023E 01	/	9.092E 00	TO	1.912E 01
-	4.322E 00	TO	9.092E 00				

Fig. 16. Site-specific Total Annual Dose Commitment from Radioactive Effluents for a Nuclear Plant in Northern Illinois

MAX POINT DOSE FOR EACH SITE
NORTHERN ILLINOIS WITH 100 MTR DRESDEN ANNUAL DOSE

1.898E 01	TO	4.826E 01	0	7.462E 00	TO	1.898E 01
2.934E 00	TO	7.462E 00	0	1.154E 00	TO	2.934E 00
4.537E-01	TO	1.154E 00	0	1.784E-01	TO	4.537E-01
7.015E-02	TO	1.784E-01	0			

Fig. 17. Site-specific Maximum Point Annual Commitment from Radioactive Effluents for a Nuclear Power Plant in Northern Illinois

For specific conditions the annual average met set will hardly be either representative or predictively useful. For such conditions, a matrix is generated for the particular condition of interest. In the case of accidents or pollution episodes for example, one must especially consider the residents of the Low Population Zone (LPZ), i.e., those who live in close proximity to the plant and may be too numerous to evacuate quickly.

Further examples of this sort of concatenation of plant output and population are given in the sample problem in the Appendix along with a more detailed description of the computational procedure.

The same concept holds whether one is speaking of a radiation dose from a nuclear plant or air pollutant doses from fossil plants, particularly such doses as might occur during an air pollution episode. For fossil plants, however, the nomenclature and the units change. The individual radiation dose, given in millirem/year, becomes an average concentration of airborne pollutant (sulfur dioxide, carbon monoxide, carbon dioxide, particulates, etc.), usually expressed in $\mu\text{g}/\text{m}^3$. The concept of dose commitment is not as frequently used for nonradioactive pollution, yet, on epidemiological grounds,¹⁰ it is probable that overall human hazard and impact is just as likely to depend on the time integrated exposure to chemical pollutants as it is to radiation, and man-rem becomes man- $\mu\text{g}/\text{m}^3$. Nor is "dose-commitment" restricted in its interest entirely to man. The home owners of Pittsburgh, Gary, and Lackawanna, for example, will vigorously attest to the importance of exposure levels in their neighborhood property values.

Generalized Impact Modeling. Now, SITE is not itself a modeling program -- at least not beyond those models that can be expressed in the form of simple functions or operations -- but is rather a methodology for combining various available geophysical, environmental, and socioeconomic models with regional attributes to evaluate impacts of facility siting within the region. For many environmental impacts very complex models and model systems are often required. At Argonne these have included: Gaussian, Eulerian, and Monte Carlo systems used to model the dispersion and deposition of airborne pollutants; Okubo-Pritchard and similar models of dispersion for liquid-borne pollutants and for thermal gradients,^{11,12} hydrological models for water use, water tables, and subsurface disposal; probability and severity models for severe natural phenomena (earthquakes, floods, tornados, hurricanes, forest

fires, and other acts of God); geological models for soil formations, faults, and for the transport and buildup of pollutants in the lithosphere; biological and ecological models for effects in the biosphere and their resultant interactions with man and his community; and finally demographic, economic, political, and sociocultural models for effects in the noosphere. Experimenting with these models and with their use in SITE has directed and continues to direct the development of SITE and has brought about a continuous extension of its capabilities so as to encompass the very wide range of impacts that attend the siting of any major human facility.

2.4 CANDIDATE SITE SELECTION

The site-specific cost and impact vectors and other regional attributes in the site assessment matrix form the basis for selection and possible rank ordering of candidate sites within the region of interest. The easiest comparison method is to output the encoded vector elements and attributes as contour maps, produced on a line printer with black-and-white shades of gray signaling logarithmic increments of value. Candidate regions for siting can then be determined by simply holding up mechanical overlays of transparencies of these maps and "looking for the holes" in a computer-aided analog to the methodology of McHarg.⁴

In order to aid this process further, such contour maps can be produced and overlaid directly by the computer on film or on microfiche in either black-and-white or color. An example of one of these done with an automatic, two-level overlay is shown in Fig. 18.

When this technique was employed in the examination of optimum sites for nuclear power plants in the Commonwealth Edison service area in Northern Illinois, it predicted quite well the problems or lack thereof that would characterize the plants then built or under construction, Dresden, Quad Cities, Zion, and LaSalle.^{9,13} It also predicted that optimum future sites for Northern Illinois power plants would lie along the upper Rock River and along the lower Kankakee River.^{9,13} About a year or so later Commonwealth Edison announced its two new nuclear plants, Byron and Braidwood, at precisely these locations. Thus, whatever the process used by the utility for its decision-making and whatever the relative merits of the two methods, they are at least notably similar in their end results.

Fig. 18. Overlay of Major Waterways (Fig. 3) and Maximum Point Annual Dose Commitment for Radioactive Effluents (Fig. 17) in Northern Illinois

In each of the computations given above, the density value is reduced to a scale-of-seven, truncated, logarithmic value for display only. Within the computer matrix, the actual values are all retained and, for more detailed computations, can be compared and concatenated by functional methods within the program. In particular it is useful to express total impacts for a plant located at each square as a weighted sum of individual impacts at that square. This method is discussed elsewhere.⁹

3. REGIONAL ASSESSMENT OF ENERGY DEVELOPMENT OPTIONS

The primary motivation for the development of the detailed regional inventory and site evaluation procedure described in the previous sections and incorporated into the SITE methodology is the identification of likely candidate sites for energy facilities within a utility region, or equivalent area. A further detailed evaluation of these potential sites can then be used to provide a rational consideration of alternatives in the assessment of a new energy facility site as required by NEPA.

A conceptually straightforward extension of the SITE methodology for evaluating the viability of sites is the consideration of alternative future energy development options that may use a combination of those potential sites and an evaluation of the cumulative impacts in a larger region, and ultimately in the entire U.S. The objective of this extension of SITE, which is currently under development at Argonne as part of the ERDA-sponsored Regional Studies Program, is to address the more fundamental questions of the desirability of a particular type of energy development within an area in comparison with other options, such as use of alternate technologies or fuels, balancing of impacts between regions with various import-export policies, or possibly encouraging reductions in energy consumption growth rate. Future energy supply options that are relevant to the Midwest region, for example, and must be evaluated using the extended SITE methodology include use of nuclear fuel, high sulfur coal with flue gas desulfurization, gasification of high sulfur coal, imported low sulfur Western coals, imported electricity generated in the vicinity of low sulfur Western coal mines, solar energy, and others.

The various components included in a regional energy supply impact assessment and their relationships are diagrammed in Fig. 19, which is an extension of Fig. 1. The assessments illustrated are most conveniently carried out for individual states, with subsequent analyses to correlate total effects in a unified policy evaluation for a multistate region, such as the Midwest. The diagram illustrates the use of previous case studies, siting constraints, and regional attributes to obtain a preliminary identification of candidate areas (as opposed to candidate sites as in Fig. 1). For purposes of the statewide assessments, only general siting areas several square miles in size are identified and typical microscale impacts from case studies are assumed.

Fig. 19. Extension of SITE Methodology for Regional Supply Option Impact Assessment

The uncertainties in future population distributions and environmental conditions at the specific sites preclude the use of more specifically defined sites.

For each of the identified siting areas, impacts are modeled using data files that characterize the externalities of the particular energy option and technology projected for utilization at that site.

The impact of locating an energy park with multiple facilities in a siting area relative to dispersed siting is also evaluated within this assessment framework. For total regional assessment, the future impacts of emissions from existing or committed energy facilities and other activities must be included. Projection models for future land use development, time frames for existing or committed facilities, and the availability of new technology then become an integral part of the regional assessment package.

An increasing awareness is developing that many of the more significant environmental and health impacts of energy development may be those related to long-range transport of long-lived pollutants. Examples are long-lived radioactive pollutants contributing to an increase in global radiation exposure, long-range transport, transformation, and deposition of sulfur compounds and hazardous trace elements in coal; and buildup of pollutants in waterways. These effects require a careful development of statewide assessment techniques that will include effects of energy development in neighboring regions.

The evaluations of impacts from energy development for individual potential siting areas are considered, in view of siting constraints and the regional demand for energy, in selecting an array of sites to be used for future energy development. Although not explicitly shown in Fig. 19, the assessment of the energy site utilization requires simultaneous reevaluation of the combined impact of the total siting array because of the nonlinear nature of various impacts. Atmospheric chemical transformation of pollutants is one example of a mechanism that is dependent on the total atmospheric burden of various pollutants.

In addition to the cumulative site-related impact assessment, the final regional energy supply option impact assessment includes site-independent costs such as capital costs, technology development costs, occupational

hazards, global climatic changes, national resource commitments, radioactive waste disposal, and risk of sabotage or nuclear material diversion for weapons. The final output is a concise tabular documentation of various impacts associated with the assumptions that define the energy supply scenario.

The regional impact assessment outlined in Fig. 19 is iterative in the sense that each evaluation of an alternative energy supply option is in itself a case study that serves as an input to guide subsequent studies. The importance of various uncertainties in available data and impact models is also determined by an iterative evaluation of alternate parameters in a sensitivity analysis.

The ultimate output of the process in Fig. 19 is a library of information that allows decision-makers to choose, from a set of alternatives, the energy supply options that will result in a balance of timely energy resource development with a minimization of undesirable side effects.

APPENDIX

Description and User Information for the
SITE2 Computer Program

A.1 GENERAL DESCRIPTION

The main body of this report describes the comprehensive SITE methodology for systematic selection of candidate power plant sites within a utility region and describes results of the ongoing application of that methodology to Northern Illinois. In this appendix is documented a computer program called SITE2, which is an established segment of the software used in the analysis described in the report. Similar documentation of programs used in subsequent extensions of the SITE methodology are planned as they become available.

The SITE2 computer program consists of (1) an algorithm useful in evaluating specific parameters required for determining candidate locations for nuclear or fossil power plants and (2) a general structure that can be exploited for evaluation of additional parameters required in the site-selection process.

In particular, the SITE2 computer program generates the radiological doses resulting from normal or accidental nuclear plant operating releases. Maximum individual point doses and total doses (MANREM) to the regional population are calculated for each potential site. These calculations are accomplished by storing in the computer a dosage pattern (DOSE) that applies to and around each site, multiplying dosages at all points in the vicinity of the site by the corresponding populations (POP) to get individual point doses, and (for total MANREM doses) summing. The dosage pattern is a square array that optionally may be input data, or may be computed by SITE. In the latter case, the computation generates each dosage as being inversely proportional to the distance from the center of the pattern, or to the distance squared, or in fact to any prescribed power (a positive or negative real number) of the distance. A geocoded accounting system moves the DOSE pattern from site to site within the prescribed region. Actually, the pattern to be used need only be a (user-designated) central portion of the computed or input dosage pattern, as in Low Population Zone (LPZ) computations (see Fig. A.1). Output consists of printed and plotted arrays of population (POP), dose (DOSE),

Fig. A.1. Site Optimization Grid Arrays

total population-dose for each site (ROSE), and maximum population-dose per point for each site (BOSE). The plotted arrays may also be output to film. In addition, the total, average, largest, and smallest values for each array are printed.

In the sample problem given below, the dosage patterns that are input to SITE2 were calculated previously in auxiliary computations using the ASSMRD program.¹⁰ Maximum individual dosages and total MANREM doses to the regional population as a result of normal releases were calculated through the use of annual average atmospheric dispersion modeling techniques. The dosages associated with accidental releases were computed by means of short-term peak (episodic) meteorological dispersion analysis. These atmospheric models are based on the "Argonne Steady State Model" (ASSM) that has been used extensively in related EPA environmental studies.¹⁴ For each potential plant site, maximum individual doses, total dose in the low population zone, total dose to the regional population, and maximum point dose are calculated.

These atmospheric models take account of stack height, smoke plume rise, annual, seasonal, and diurnal regional meteorological conditions, and certain temporal or aerochemical transformations of pollutants. They can be used without modification to assess the concentrations and dosages imposed on regional populations exposed to sulfur oxides, particulates, hydrogen sulfide, oxides of nitrogen, and other airborne effluents from fossil-fueled plants, coal conversion plants, or other industrial facilities.

That the DOSE pattern need not consist of radioactive dosages is emphasized. The pattern could, for example, also be made up of noise dosages. The relative aesthetic and noise impacts can also be included because they are functions of distance from a given site and the permanent or transient exposed populations. Similarly, POP need not be a human population matrix. It has been used, for example, to refer to the regional cow population -- a vital pathway for radiological exposure in the human food chain.

For a given power centroid within (or without) the region, SITE2 also generates as a cost attribute (TCOST) the combined expense of electric power transmission. Consistent with utility company data, the transmission cost for each site is taken to be proportional to the distance of the site from the regional load center. Contributing to the site comparison element are the costs

- (a) of setting up high voltage lines and substations between the power plant and the point of connection with the regional service network;
- (b) of operating, maintaining, and replacing transmission and distribution lines, facilities, and equipment; and
- (c) of line losses attributable to heat dissipation and radiation in the transmission and distribution process.

Again, TCOST is quite general; it can represent the cost, say, of transporting oil or gas in a pipeline to a fossil-fueled plant.

SITE2 as described in this appendix can readily be augmented to include a variety of other site attributes and geophysical transport and dispersion models as described in the main text. For example, models of surface and subsurface thermal discharge phenomena in lakes, rivers, and estuaries can be incorporated. Similarly, operational hydrologic and water quality models designed to evaluate the distribution and fate of conservative and nonconservative water pollutants, and the water quality, in lake and river systems can be added to the existing SITE package. Natural site attributes, such as seismic characteristics or susceptibility to exposure to tornadoes, can also be incorporated, either as additional components of the vector of siting costs or as independent indices of site feasibility.

The entire program, consisting of the main SITE2 program and three subroutines (DOSITE, SITMAP, and REFDOS), is written in FORTRAN for the IBM 360. For compilation and execution it requires 480K bytes of core storage. Of this total, about 358K bytes are reserved for data. The rather complete sample program below required about 2-1/2 minutes of CPU time. In addition to normal printed output, there are also density plots on the printer for all input data and all computed output. Optionally, the density plots may also be output to a 2280 (film) output recorder if the computer is so equipped.

A.2 INPUT FOR SITE2

A square grid system is first laid over the region to be considered as in Fig. A.1, with each point of the grid representing a potential site for the projected power plant. Grid points are counted from west to east (left to right), and rows of points are counted from south to north (bottom to top).

Each section of input cards consists of a TYPE card, which may also contain input parameters, followed by other parameter and data cards required by that TYPE. There are seven different TYPE cards: SYMB, POPU, DOSE, DOSD, RUN, TCST, END.

They have the following form:

<u>Variable</u>	<u>Columns</u>	
TYPE	1-4	Alphabetic name of card input type, starting in col. 1.
JM	11-20	JM, KM, LM, MM are right-adjusted integers (positive or zero) giving various grid dimensions.
KM	21-30	
LM	31-40	
MM	41-50	
FILM	60	Film output flag: FILM=1 means there is film output in addition to printed output. FILM=0 means there is no film output for that part.

Some or all of JM, KM, LM, MM, and FILM may be left blank, depending upon the particular TYPE card. The FORTRAN FORMAT for TYPE cards is (A4,6X,4I10,F10.0).

1. Input Card Sections

a. Symbol Control Cards (SYMB)

When an input or computed array (e.g., the input population array) is output as a density map on the printer or in film output, the numbers are grouped on a logarithmic scale with seven divisions, or shades of gray. The

default plot characters in order of increasing output quantities are 1, 2, 3, 4, 5, 6, and 7. Other plot characters may be defined by using a SYMB card followed by the desired characters. These will be the characters used throughout the run unless other characters are introduced later by another SYMB card.

Card 1 (TYPE card)

SYMB in cols. 1-4

Card 2

Graphic symbols in cols. 1-7

To generate nonstandard characters by combining two standard printer characters, put the second (overwriting) characters in cols. 41-47 of Card 2. For example, to generate a theta (θ) for the third character, put a minus sign (-) in col. 3 and a zero (0) in col. 43 of Card 2.

b. Population Parameters and Data (POPU)

The population entries (POP array in the program) are to be for grid points running west to east, and by row from south to north.

Card 1 (TYPE card)

POPU in cols. 1-4

West-to-east population array size (number of horizontal grid points MHP) as an integer ending in col. 20.

South-to-north population array size (number of vertical grid points MVP) as an integer ending in col. 30.

RESTRICTIONS: $MHP * MVP \leq 20000$,
 $MHP \leq 264$.
 For film plot, $MHP \leq 200$, $MVP \leq 180$.

Film Output Flag (FILM)
 (0 or 1) in col. 60.

FILM=1 means there is no film output of population in addition to printed output.
 FILM=0 means there is no film output.

Card 2

Any desired population title (ID) in cols. 1-72. This is the population identification, and is called TITP in the program.

Card 3

FORTTRAN FORMAT (FMTP) for the input of population data in cols. 1-40 (e.g., (10D8.0) for 10 eight-digit numbers per card).

FORMAT (FMTP0) for output of population data in cols. 41-80 (e.g., (' ',20F6.0) for 20 six-digit numbers per line of output).

Card 4 and following cards

Population data (POP) according to the input format in Card 3.

c. Dosage Pattern Parameters and Data When Pattern Is Input (DOSE)Card 1 (TYPE card)

DOSE in cols. 1-4

West-to-east dosage pattern size (number of horizontal grid points MHD) as an integer ending in col. 20.

South-to-north dosage pattern size (number of vertical grid points MVD) as an integer ending in col. 30. Since the dosage pattern is a square array, MVD must equal MHD.

RESTRICTIONS: MVD = MHD,
MVD ≤ 31,
MVD must be odd,
MHD * MVD ≤ 1000.

Reflect Flag (0 or 1) in col. 40. This flag indicates whether DOSE array is to be reflected about the southwest-northeast array diagonal.

Reflect Flag = 0 or blank: Reflect,
Reflect Flag = 1 : Do not reflect.

Film Output Flag (FILM)
(0 or 1) in col. 60.

FILM=1 means there is film output of dosage pattern in addition to printed output.

FILM=0 means there is no film output.

Card 2

Any desired dosage pattern title (ID) in cols. 1-72. This is the dosage pattern identification, and is called TITD in the program.

Card 3

FORTTRAN FORMAT (FMTD) for the input of dosage pattern data in cols. 1-40 (e.g., (13F8.0) for 13 eight-digit numbers per card).

FORMAT (FMTDO) for the output of dosage pattern data in cols. 41-80 (e.g., (' ',13F8.0) for 13 eight-digit numbers per line of output).

Card 4 and following cards

Dosage pattern data according to the input format of Card 3. As with population, the dosage pattern entries (in millirems) are to be for grid points running west to east and by rows from south to north.

d. Dosage Pattern Parameters When SITE2
Computes Dosages in the Pattern

Card 1 (TYPE card)

DOSE in cols. 1-4

West-to-east dosage pattern size (number of horizontal grid points MHD) as an integer ending in col. 20.

South-to-north dosage pattern size (number of vertical grid points MVD) as an integer ending in col. 30. Since the dosage pattern is a square array, MVD must equal MHD.

RESTRICTIONS: MVD = MHD,
MVD $\leq$ 31,
MVD must be odd,
MHD*MVD $\leq$ 1000.

Film Output Flag (FILM)
(0 or 1) in col. 60.

FILM=1 means there is film output of dosage pattern in addition to printed output.

FILM=0 means there is no film output.

Card 2

Any desired dosage pattern title (ID) in cols. 1-72. This is the dosage pattern identification, and is called TITD in the program.

Card 3

FORTTRAN FORMAT (FMTD) for the input of parameters (CDOSE, POWER, and GRID) used in computing the dosage pattern, in cols. 1-40 (e.g., (13F8.1) for the input of parameters with one decimal place).

FORMAT (FMIDO) for the output of computed dosage pattern data, in cols. 41-80 (e.g., (' ',16F8.4/' ',15F8.4) for 16 numbers output on one line and 15 numbers on the next line. All numbers are printed to four decimal places).

Card 4

CDOSE, POWER, and GRID according to the input format (cols. 1-40) of Card 3.

CDOSE is the unit dosage (in millirems); POWER is the exponent applied to the inverse of the distance from the pattern center; GRID is the size of the grid square side (e.g., 2 km). For a point with grid numbers (I,J) with respect to the center of the DOSE pattern, the dosage is computed by SITE2 as:

$$\text{DOSE (I,J)} = \text{CDOSE} / (\sqrt{K^2 + L^2} ** \text{POWER}), \text{ where } K=I*\text{GRID}, L=J*\text{GRID}.$$

e. Execute Population-dose Portion of SITE2 (RUN)

The calculated population-doses (total MANREM doses) are put into a result array (ROSE), and printed and plotted from this array. Another array, BOSE, is used to hold maximum population-doses for each site. It has the same dimensions as ROSE.

Card 1 (TYPE card)

RUN in cols. 1-3

West-to-east total population-dose (result) array size (number of horizontal grid points MHG) as an integer ending in col. 20.

South-to-north total population-dose (result) array size (number of vertical grid points MVG) as an integer ending in col. 30. MHG and MVG define the region of potential sites.

Not all of the DOSE matrix needs to be used in calculating the total population-dose (ROSE) and maximum dose (BOSE) arrays. That centered, square part of DOSE that is to be used is specified in the next two entries on Card 1:

West-to-east dose grid to be used (number of horizontal grid points MHM) as an integer ending in col. 40.

South-to-north dose grid to be used (number of vertical grid points MVM) as an integer ending in col. 50.

RESTRICTIONS: $MHG \cdot MVG \leq 12350$,
 $MHM = MVM$,
 $MVM \leq MVD \leq 31$,
 MVM must be odd.
 For film plot, $MHG \leq 200$, $MVG \leq 180$.

Since the result arrays ROSE and BOSE must be centered in the population array (POP), further restrictions are that:

$$MHG + 2 \left(\frac{MHD-1}{2} \right) = MHP,$$

$$MVG + 2 \left(\frac{MVD-1}{2} \right) = MVP.$$

Film Output Flag (FILM)
 (0 or 1) in col. 60.

FILM=1 means there is film output of total population-doses and of maximum point doses in addition to printed output.

FILM=0 or blank means there is no film output.

Card 2

Any desired title for the program run (ID) in cols. 1-72. This is the program run identification, and is called TITL in the program itself.

Card 3

FORTTRAN FORMAT (FMTR) for the output of the ROSE array of total population-doses for each site, in cols. 1-40.

FORMAT (FMTB) for the output of the BOSE array of maximum point doses for each site, in cols. 41-80. The ROSE and BOSE arrays are the same size.

f. Execute Transmission Cost Portion of SITE2 (TCST)

Transmission costs are calculated and put into an array ROSE. They are not printed but are plotted on the printer, and (if FILM=1 below) on film.

Card 1 (TYPE card)

TCST in cols. 1-4

West-to-east transmission cost array size (number of horizontal grid points MHD) as an integer ending in col. 20.

South-to-north transmission cost array size (number of vertical grid points MVD) as an integer ending in col. 30.

Film Output Flag (FILM)
(0 or 1) in col. 60.

FILM=1 means there is a film plot in addition to a printer plot for transmission costs.

FILM = 0 means there is no film output.

RESTRICTIONS: $MHD * MVD \leq 12350$.

For film plot, $MHD \leq 180$.

Card 2

Any desired transmission cost title (ID) in cols. 1-72. This is the transmission cost identification, and is called TITD in the program.

Card 3

FORTTRAN FORMAT (FMTD) for the input of transmission cost parameters in cols. 1-40 (e.g., (4D10.3) for the input of four double-precision numbers, each with three decimal places).

Card 4

Transmission cost parameters CMX, CMY, GRID, CST according to the input format of Card 3.

CMX is the horizontal grid point number of the region's power center,
 CMY is the vertical grid point number of the region's power center,
 GRID is the size of the grid square side (e.g., 2 km),
 CST is the unit transmission cost (in dollars per km, say).

g. Normal Termination of a Run (END)

Card 1 (TYPE card)

END in cols. 1-3. This is the normal end for a SITE2 program run.

2. Order of Input Card Sections

SYMB	}	Optional, but symbols may be changed at any time.
POPU		
DOSE or DOSD	}	May be repeated for different DOSE patterns with the same population.
RUN		
TCST	}	Should not occur before RUN for previous DOSE.
END	}	Normal ending for a SITE2 run. NORMAL END is the final program printout.

If grid dimensions are improper or the TYPE card is foreign, SITE2 will print one of the five error messages described in Sec. A.3 and then halt.

Fig. A.2. SITE2 Parameter and Data Input Deck

A.3 OUTPUT FOR SITE2

The first card of each input-card section is printed out, both to identify the section and to list the input parameters used. This is always the TYPE card, and has SYMB, POPU, DOSE, DOSD, RUN, TCST, or END in columns 1-4 or 1-3. Ending in columns 20, 30, 40, and 50, respectively, are integer grid dimensions JM, KM, LM, and MM. When these quantities are inappropriate for a particular TYPE, the (blank) input entries appear as zeroes in the output. Finally the Film Output Flag (FILM) is printed as 0. or 1. in column 60. Again FILM does not apply to all TYPE cards. When not used it is printed as 0. in the line of output for TYPE.

The FORTRAN output FORMAT for this first line of output is ('0',A4,6X,4I10,F10.0).

1. SYMB Output

This is the output corresponding to an input section (SYMB) of Symbol Control Cards.

a. Printed Output

Line 1

SYMB in cols. 1-4.

Five meaningless 0's.

Line 2

PLOT SYMBOLS in cols. 1-13.

Seven symbols to be plotted in density maps.

Overwriting plot symbols (if any).

2. POPU Output

This is the output corresponding to an input section (POPU) of Population Parameters and Data.

a. Printed and Printer-plotted Output

Line 1

POPU

MHP, the number of west-east population grid points.

MVP, the number of south-north population grid points.

Two meaningless 0's.

Film Output Flag FILM
(0. or 1.) in col. 60.

FILM=1 for film output of population.

FILM=0 for no film output.

Line 2

The population ID (TITP).

Line 3

FORTTRAN FORMAT for population data input.

FORMAT for population data output.

Line 4 and following lines

Population data (POP) according to the output format in Line 3. Entries are printed from west to east and from south to north, in the order of the input data. Note below that the printer plot and the film output, if any, are from west to east and from north to south as in normal map orientation.

Line 1 after POP output

TOTAL POPULATION, MEAN POP, LARGEST, and SMALLEST as computed by SITE2.

Line 2 after POP output

The population ID (TITP).

Line 3 and following lines

Density plot of the population array POP, from west to east and from north to south. The logarithms of the nonzero POP entries are grouped into seven categories, and the populations are plotted according to the

symbols input in the SYMB section, or (by default) to the characters 1, 2, 3, 4, 5, 6, and 7 for increasing population; zero POP entries are plotted as blanks. Each plotted line corresponds to a row of the POP array unless the horizontal grid dimension MHP is greater than 132. In this case a second printer-plotted line completes the POP row. The characters plotted define a contour map for population. Following the density plot is a legend defining ranges of population for each of the plot symbols.

Last line of POPU output

TIMELEFT in seconds. Whenever the plotting subroutine SITMAP of SITE2 is invoked, it terminates by printing the computer time left in the current SITE2 job.

b. Film Output

If Film Output Flag FILM=1, the printer density plot for population array POP is essentially repeated on the 2280 film output recorder. A title, POPULATION FOR EACH SITE, and the population identification TITP head the film frame. The body of the plot is the density (contour) map for population, together with its associated legend relating population ranges and plot symbols.

RESTRICTIONS: MHP<200,
MVP<180.

3. DOSE Output

This is the output corresponding to an input section (DOSE) of Dosage Pattern Parameters and Data When Pattern Is Input.

a. Printed and Printer-plotted Output

Line 1

DOSE

MHD, the number of west-east grid points in the input dosage pattern (DOSE) array.

MVD, the number of south-north grid points in the input DOSE array.

Reflect Flag (0 or 1).

Reflect Flag=0 to reflect DOSE about the southwest-northeast array diagonal.

Reflect Flag=1 for no reflection.

One meaningless 0.

Film Output Flag FILM
(0. or 1.)

FILM=1 for film output of input or reflected dosage pattern.

FILM=0 for no film output.

Line 2

The dosage pattern ID (TITD).

Line 3

FORTRAN FORMAT for dosage pattern data.

FORMAT for dosage pattern data output.

Line 4 and following lines

Dosage pattern data (DOSE) according to the output format in Line 3. Entries (in millirems) are printed from west to east and from south to north in the order of the input data if Reflect Flag=1, or in the reflected order if Reflect Flag=0. Note that the printer plot and the film output, if any, are from west to east and from north to south as in normal map orientation.

Line 1 after DOSE Output

TOTAL DOSE, MEAN DOSE, LARGEST, and SMALLEST as computed by SITE2.

Line 2 after DOSE Output

The dosage pattern ID (TITD).

Line 3 and following lines

Density plot (in millirems) of the dosage pattern array DOSE, from west to east and from north to south. The logarithms of the nonzero DOSE entries are grouped into seven categories, and the dosage pattern components are plotted according to the symbols input in the SYMB

section, or (by default) to the characters 1, 2, 3, 4, 5, 6, and 7 for increasing dosage; zeros are plotted as blanks. Each plotted line corresponds to a row of the DOSE array. The characters plotted define a contour map for dosage, and hence a dosage pattern.

Following the density plot is a legend defining ranges of dosages for each of the plot symbols.

Last line of DOSE Output

TIMELEFT in seconds. This is the computer time left in the current SITE2 job.

b. Film Output

If Film Output Flag FILM=1, the printer density plot for dosage pattern array DOSE is essentially repeated on the 2280 film output recorder. A title, METEOROLOGICAL DOSE, and the dosage pattern identification TITD head the film frame. The body of the plot is the density (contour) map for the input dosage pattern (in millirems), together with its associated legend relating dosage pattern component ranges and plot symbols.

4. DOSD Output

This is the output corresponding to an input section (DOSD) of Dosage Pattern Parameters When SITE2 Computes Dosages in the Pattern.

a. Printed and Printer-plotted Output

Line 1

DOSD

MHD, the number of west-east grid points in the computed dosage pattern DOSE.

MVD, the number of south-north grid points in the computed array DOSE.

Reflect Flag (0 or 1). Reflect Flag is printed, but is ignored by SITE2 in the processing of DOSD.

One meaningless 0.

Film Output Flag FILM (0. or 1.).

FILM=1 for film output of dosage pattern.

FILM=0 for no film output.

Line 2

The dosage pattern ID.

Line 3

FORTTRAN FORMAT for the input of parameters (CDOSE, POWER, and GRID) used in computing the dosage pattern.

FORMAT for the output of computed dosage pattern data.

Line 4 and following lines

Computed dosage pattern data (DOSE) according to the output format in Line 3. Entries (in millirems) are printed from west to east and from south to north. Note that the printer plot and the film output, if any, are from west to east and from north to south as in normal map orientation. Since the (computed) DOSD pattern is symmetric, however, south-north printing of dosage rows is indistinguishable from north-south printing.

Line 1 after DOSE array output

TOTAL DOSE, MEAN DOSE, LARGEST, and SMALLEST as computed by SITE2.

Line 2 after DOSE array output

The dosage pattern ID (TITD) (repeated from Line 2).

Line 3 and following lines

Density plot of the dosage pattern array DOSE, from west to east and from north to south. The logarithms of the nonzero DOSE entries are grouped into seven categories, and the dosage pattern components (in millirems) are plotted according to the symbols input in the SYMB section, or (by default) to the characters 1, 2, 3, 4, 5, 6, and 7 for increasing dosage; zeros are plotted as blanks. Each plotted line corresponds to a row of the DOSE array. The characters plotted define a contour map for dosage, and hence a dosage pattern.

Following the density plot is a legend defining ranges of dosages for each of the plot symbols.

Last line of DOSE array output

TIMELEFT in seconds. This is the computer time left in the current SITE2 job.

b. Film Output

If Film Output Flag FILM=1, the printer density plot for dosage pattern array DOSE is essentially repeated on the 2280 film output recorder. A title, METEOROLOGICAL DOSE, and the dosage pattern identification TITD head the film frame. The body of the plot is the density (contour) map for the computed dosage pattern, together with its associated legend relating dosage pattern component ranges and plot symbols.

5. RUN Output

This is the output corresponding to a RUN input section. Following printing of the RUN parameters, SITE2 computes, prints, and plots total population-doses and maximum point doses for all potential sites in the prescribed RUN region. All or just part of the (meteorological) dosage pattern may be used in calculating population-doses. Population-doses are calculated in man millirem units, but are scaled down by 1000 for output in manrems.

a. Printed and Printer-plotted Output

Line 1

RUN

MHG, the number of west-east grid points in the population-dose (result) array.

MVG, the number of south-north grid points in the population-dose (result) array. MHG and MVG define the region of potential sites.

MHM, the number of west-east grid points in the dose grid to be used.

MVM, the number of south-north grid points in the dose grid to be used.

MVM must equal MHM and must be odd.

Film Output Flag FIIM (0. or 1.)

FIIM=1 for film plot of total population-doses and maximum point doses.

FIIM=0 for no film output.

Line 2

The program run ID (TITL).

Line 3

FORTTRAN FORMAT for the output of the ROSE array of total population-doses (MANREM doses) for each site.

FORMAT for the output of the BOSE array of maximum point doses for each site.
The ROSE and BOSE arrays are the same size.

Line 4

TIMELEFT AT START of the current program run, in seconds.

Line 5

TIMELEFT AT END of the population-dose computations, in seconds.

(1) Total Population-dose Output

Line 1

TOTAL MANREM DOSE FOR EACH SITE, a heading for the ROSE (result) array of total population-doses for each site.

Line 2

The program run ID (TITL) (repeated from Line 2 of the first page of RUN output).

Line 3 and following lines

Total population-doses computed by SITE2 for each site, printed according to the output format in cols. 1-40 of Line 3, first page of RUN output. Entries in this array (ROSE) are printed from west to east and from south to north. Note below that the printer plot and the film output, if any, are from west to east and from north to south.

Line 1 after ROSE output

SUM OF TOTAL DOSES, MEAN DOSE (of total population-doses), LARGEST, and SMALLEST as calculated by SITE2.

Next Page, Line 1

TOTAL MANREM DOSE FOR EACH SITE

Line 2

The program run ID (TITL) (repeated again).

Line 3 and following lines

Density plot of the total population-dose array ROSE, from west to east and from north to south. The logarithms of the nonzero ROSE entries are grouped into seven categories, and the total population-doses are plotted according to the symbols input in the SYMB section, or (by default) to the characters 1, 2, 3, 4, 5, 6, and 7 for increasing total doses; zeros are plotted as blanks. Each plotted line corresponds to a row of the ROSE array unless the horizontal grid dimension MHG is greater than 132. In this case a second printer-plotted line completes the ROSE row. The characters plotted define a contour map for total population-doses.

Following the density plot is a legend defining the ranges of total doses for each of the plot symbols.

Last line of ROSE array output

TIMELEFT in seconds. This is the computer time left in the current SITE2 job.

(2) Maximum Point Dose Output

This output is very similar to that of the preceding section, but gives maximum point doses for each site instead of total population-doses. The array of maximum point doses is called BOSE.

b. Film Output

If Film Output Flag FILM=1 on the RUN card, the printer density plots for total population-dose array ROSE and for maximum point dose array BOSE are essentially repeated on the 2280 film output recorder. Their respective headings are TOTAL MANREM DOSE FOR EACH SITE plus the program run ID (TITL), and MAX POINT DOSE FOR EACH SITE plus the ID (TITL).

6. TCST Output

This is the output corresponding to a transmission cost (TCST) input section. TCST provides both for the input of transmission cost parameters and for the computation and output of those costs, for each potential site.

a. Printer-plotted Output

Line 1

TCST

MHD, the number of west-east transmission cost grid points.

MVD, the number of south-north transmission cost grid points.

Two meaningless 0's

Film Output Flag FILM (0. or 1.)

FILM=1 for a film plot of transmission costs in addition to a printer plot.

FILM=0 for no film output.

Line 2

The transmission cost ID (TITD).

Line 3

FORTTRAN FORMAT for transmission cost input parameters.

Line 4

Transmission cost parameters CMX, CMY, GRID, and CST.

CMX is the horizontal gridpoint number of the region's power center,

CMY is the vertical grid point number of the region's power center,

GRID is the size of the grid square side,

CST is the unit transmission cost.

Line 5

TOTAL, MEAN, MAX, and MIN transmission costs as computed by SITE2. Note that transmission costs are not printed, although they are printer-plotted and may be output on film.

Line 6

The transmission cost ID (TITD) (repeated from Line 2).

Line 7 and following lines

Density plot of the transmission cost array ROSE, from west to east and from north to south. The logarithms of the nonzero ROSE entries are grouped into seven categories, and the transmission costs are plotted according to the symbols input in the SYMB section, or (by default) to the characters 1, 2, 3, 4, 5, 6, and 7 for increasing transmission cost. Each plotted line corresponds to a row of the ROSE array unless the horizontal grid dimension MHD is greater than 132. In this case a second printer-plotted line completes the ROSE row. The characters plotted define a contour map for transmission costs. Following the density plot is a legend defining ranges of transmission costs for each of the plot symbols.

Last line of TCST output

TIMELEFT in seconds. This is the computer time left in the current SITE2 job.

b. Film Output

If Film Output Flag FILM=1 in the TCST card, the printer density plot for transmission cost array ROSE is essentially repeated on the 2280 film output recorder. A title, TRANSMISSION COST, and the transmission cost ID (TITD) head the film frame. The body of the plot is the density (contour) map for transmission cost, together with its associated legend relating transmission cost ranges and plot symbols.

RESTRICTION: MHD<200.

7. END Output

This is the output corresponding to an END card (normal termination of a run).

Line 1

END This is the normal end for a SITE2 program run.
Meaningless 0's.

Line 2

NORMAL END

8. Abnormal Endings

- a. Printout of TYPE card, followed by UNIDENTIFIED TYPE, when TYPE card is not one of SYMB, POPU, DOSE, DOSD, RUN, TCST, or END.
- b. POPU DIM () MUST BE .LE.20000 when the product of the population array dimensions MHP*MVP is greater than 20000.
- c. DOSE DIM () MUST BE .LE.1000 when the product of the dosage array dimensions MHD*MVD is greater than 1000.
- d. RUN DIM () MUST BE .LE.12350 when the product of the population-dose result array dimensions MHG*MVG is greater than 12350.
- e. MOVING GRID () MUST BE .LE. DOSE GRID () when the product of the moving (dose-to-be-used) grid dimensions is greater than the product of the dimensions of the DOSE array itself.

Abnormal endings b - e cause SITE2 to stop after printing the statement:

RUN ABORTED, CHECK PARAMETERS OR CHANGE DIMENSIONS.

A.4 PROGRAM DESCRIPTION AND EXTENSIONS

The SITE2 computer program consists of 1) seven logical sections of code, each corresponding to one of the seven input TYPES; 2) a switch that directs program control to these sections on the basis of input type; and 3) the three subroutines SITMAP, DOSITE, and REFDOS. The program listing is given in Fig. A.3 and the glossary of variables and arrays is given in Table A.1.

1. The Seven Code Sections

These code sections -- one each for SYMB, POPU, DOSE, DOSD, RUN, TCST, and END -- process the parameters and data discussed above under 'Input Card Sections' and produce related printed, printer-plotted, and film output. Each section corresponds to and is activated by one of the input card types.

2. The TYPE Switch

By means of a DATA statement, the alphameric variables SYMK, POPK, DOSK, DSTK, RUNK, TCSK, and ENDK are initially given the respective values SYMB, POPU, DOSE, DOSD, RUN, TCST, and END. In the TYPE switch these values are successively compared with the input parameter TYPE found in columns 1-4 or 1-3 of the first card for each input section. Switching of program control to the various code sections is done by means of a succession of IF statements at the beginning of the program:

```
IF (TYPE .EQ. SYMK) GO TO 10
IF (TYPE .EQ. POPK) GO TO 20
.
.
.
IF (TYPE .EQ. ENDK) GO TO 50
```

Thus the program is modularized by input type. This feature makes SITE2 readily amenable to extensions for further site attributes.

3. SITE2 Subroutines

a. SITMAP

This subroutine is used by SITE2 to produce density (contour) maps of arrays for population (POP), meteorological dosage (DOSE), total (ROSE)

```

C----- SITE2 PROGRAM ----- SITE2001
C----- SITE2 GENERATES AND DISPLAYS ENVIRONMENTAL IMPACT AND COST ----- SITE2002
C----- ATTRIBUTES FOR ALL POTENTIAL POWER PLANT SITES IN A GIVEN ----- SITE2003
C----- RECTANGULAR REGION. FOR EACH SITE THE PROGRAM COMPUTES TOTAL --- SITE2004
C----- AND MAXIMUM INDIVIDUAL POPULATION-DOSES INCURRED WHEN A ----- SITE2005
C----- PARTICULAR RADIOLOGICAL OR CHEMICAL POLLUTANT DOSAGE PATTERN ---- SITE2006
C----- IS APPLIED TO THE SURROUNDING POPULATION. POWER TRANSMISSION --- SITE2007
C----- COSTS FOR EACH SITE ARE ALSO CALCULATED; THESE COMBINED COSTS OF SITE2008
C----- LINE CONSTRUCTION, MAINTENANCE, AND DISTRIBUTION ARE TAKEN TO BE SITE2009
C----- PROPORTIONAL TO THE DISTANCE OF THE SITE FROM THE REGIONAL LOAD - SITE2010
C----- CENTER. THE PROGRAM IS READILY EXTENDABLE TO OTHER SIMILAR ----- SITE2011
C----- SITE-RELATED ENVIRONMENTAL AND COST EVALUATIONS. ----- SITE2012
C----- PROGRAM WRITTEN BY NANCY CLARK 9/73 AS REVISION FOR IBM 360 OF -- SITE2013
C----- CONTROL DATA 3600 PROGRAM BY NORMAN A. FRIGERIO AND ----- SITE2014
C----- JOSE COBIAN-ROA. TRANSMISSION COST SECTION ADDED BY FRIGERIO --- SITE2015
C----- 1/74. MINOR MODIFICATIONS INCORPORATED BY RICHARD KING 6/75. --- SITE2016
C----- SITE2017
C----- SITE2018
ISN 0002. REAL*8 ROSE, BOSE, POP, DOSE, SOSE, POSE, SDOS, SPOP SITE2019
X, ROSL, ROSS, BOSL, BOSS, ROSM, BOSM, CDOSE, POWER, GRID SITE2020
ISN 0003 LOGICAL*1 LS SITE2021
ISN 0004 DIMENSION ROSE(12350),BOSE(12350),POP(20000),DOSE(1000), SITE2022
X PMTP(10),PMTD(10),PMTPO(10),PMTDO(10),PMTR(10), SITE2023
X PMTB(10),LS(80),TITL(18),TITP(18),TITD(18) SITE2024
COMMON SOSE, POSE, ROSL, ROSS, BOSL, BOSS SITE2025
DATA SYMK/'SYMB'//, POPK/'POPU'//, DOSK/'DOSE'//, RUNK/'RUN'// SITE2026
X , ENDK/'END'//, DSTK/'DOSD'//, TCSK/'TCST'// SITE2027
DATA LS/'1','2','3','4','5','6','7','8','9','A','B', SITE2028
X 'C','D','E','F','G','H'// SITE2029
C----- READ INPUT CONTROL AND PARAMETER CARD ----- SITE2030
2 READ 90, TYPE,JM,KM,LM,MM,FILM SITE2031
ISN 0008 90 FORMAT (A4,6X,4I10,F10.0) SITE2032
ISN 0009 PRINT 96, TYPE,JM,KM,LM,MM,FILM SITE2033
ISN 0010 96 FORMAT ('0',A4,6X,4I10,F10.0) SITE2034
ISN 0011 IF (TYPE .EQ. SYMK) GOTO 10 SITE2035
ISN 0012 IF (TYPE .EQ. POPK) GOTO 20 SITE2036
ISN 0014 IF (TYPE .EQ. DOSK) GOTO 30 SITE2037
ISN 0016 IF (TYPE .EQ. DSTK) GOTO 30 SITE2038
ISN 0018 IF (TYPE .EQ. RUNK) GOTO 40 SITE2039
ISN 0020 IF (TYPE .EQ. TCSK) GOTO 1100 SITE2040
ISN 0022 IF (TYPE .EQ. ENDK) GOTO 50 SITE2041
ISN 0024 PRINT 80, TYPE,JM,KM,LM,MM SITE2042
ISN 0026 80 FORMAT (' ',A4,6X,4I10,' UNIDENTIFIED TYPE') SITE2043
ISN 0027 RETURN SITE2044
ISN 0028 C----- READ IN PLOTTING SYMBOLS ----- SITE2045
ISN 0029 10 READ 99, LS SITE2046
ISN 0030 99 FORMAT (80A1) SITE2047
ISN 0031 PRINT 89, LS SITE2048
ISN 0032 89 FORMAT (' PLOT SYMBOLS ',80A1) SITE2049
ISN 0033 GOTO 2 SITE2050
C----- READ IN POPULATION MATRIX SIZE AND VALUES ----- SITE2051
ISN 0034 20 MHP=JM SITE2052
ISN 0035 MVP=KM SITE2053

```

Fig. A.3. SITE2 Program Listing


```

ISN 0035      J=MHP*MVP
ISN 0037      IF (J .LE. 20000) GOTO 21
ISN 0039      PRINT 94, J
ISN 0040      94 FORMAT ('0 POPJ DIM (' ,I6,' ) MUST BE .LE. 20000')
ISN 0041      GOTO 990
ISN 0042      21 READ 69, TITP
ISN 0043      PRINT 70, TITP
ISN 0044      READ 97, FMTP,FMTPO
ISN 0045      PRINT 98, FMTP,FMTPO
ISN 0046      97 FORMAT (20A4)
ISN 0047      98 FORMAT (' ',20A4)
ISN 0048      READ FMTP, (POP(I),I=1,J)
ISN 0049      PRINT FMTPO, (POP(I),I=1,J)
ISN 0050      C---- FIND TOTAL, MEAN, SMALLEST, & LARGEST POPULATION -----
ISN 0051      FOPS = 7.D75
ISN 0052      POPL = 0
ISN 0053      SPOP = 0
ISN 0054      DO 22 I=1,J
ISN 0055          IF (POP(I) .GT. POPL) POPL = POP(I)
ISN 0056          IF ((POP(I) .LT. POPS) .AND. (POF(I) .GT. 0)) POPS = POP(I)
ISN 0058      22 SPOP = SPOP + POP(I)
ISN 0059      POPM = SPOP/(MHP*MVP)
ISN 0060      PRINT 95, SPOP,POPM,POPL,POPS
ISN 0061      95 FORMAT (' TOTAL POPULATION',F12.0,' , MEAN POP',F8.0,
X ' , LARGEST',F8.0,' , SMALLEST',F8.0)
ISN 0052      C---- PLOT POPULATION MAP -----
ISN 0053      PRINT 70, TITP
ISN 0055      IF (FILM .EQ. 0) GOTO 24
ISN 0056      CALL FTEXT ('POPULATION FOR EACH SITE',24,1,20,2275+10*MVP)
ISN 0057      CALL FTEXT (TITP,72,1,20,2195+10*MVP)
ISN 0068      24 CALL SITMAP (POP,MHP,MVE,LS,POPS,(SPOP/(MHP*MVP)),POPL,FILM)
ISN 0069      GOTO 2
ISN 0069      C---- READ IN METEOROLOGICAL DOSE MATBIX SIZE & VALUES -----
ISN 0070      30 MHD=JM
ISN 0071      MVD=KM
ISN 0072      DO 12 J=1,1000
ISN 0073          DOSE(J) = 0
ISN 0074          J=MHD*MVD
ISN 0076          IF (J .LE. 1000) GOTO 31
ISN 0077          PRINT 74, J
ISN 0078          74 FORMAT ('0 DOSE DIM (' ,I6,' ) MUST BE .LE. 1000')
ISN 0079          GOTO 999
ISN 0080      31 READ 69, TITD
ISN 0081      PRINT 70, TITD
ISN 0082      READ 97, FMTE,FMTDO
ISN 0083      PRINT 98, FMTE,FMTDO
ISN 0085      IF (TYPE .EQ. DSTK) GOTO 35
ISN 0086      READ FMTE, (DOSE(I),I=1,J)
ISN 0088      IF (IM .NE. C) GOTO 33
ISN 0089      CALL REFDOS (DOSE,MHD,MVD)
ISN 0090      33 PRINT FMTE, (DOSE(I),I=1,J)
ISN 0091      C---- FIND TOTAL, MEAN, SMALLEST, & LARGEST METEOROLOGICAL DOSE -----
ISN 0092      DOSS = 7.D75
ISN 0093      DOSL = 0
ISN 0094      SDOS=0

```

```

SITE2054
SITE2055
SITE2056
SITE2057
SITE2058
SITE2059
SITE2060
SITE2061
SITE2062
SITE2063
SITE2064
SITE2065
SITE2066
SITE2067
SITE2068
SITE2069
SITE2070
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SITE2099
SITE2100
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SITE2102
SITE2103
SITE2104
SITE2105
SITE2106
SITE2107
SITE2108

```

Fig. A.3. (Contd.)

```

ISN 0093      DO 32 I=1,J
ISN 0094      IF (DOSE(I) .GT. DOSL) DOSL = DOSE(I)
ISN 0096      IF ((DOSE(I) .LT. DOSS) .AND. (DOSE(I).GT.0)) DOSS = DOSE(I)
ISN 0098      32 SDOS=SDOS+DOSE(I)
ISN 0099      DOSM = SDOS/(MHD*MVD)
ISN 0100      PRINT 75,SDOS,DOSM,DOSL,DOSS
ISN 0101      75 FORMAT (' TOTAL DOSE',F12.3,', MEAN DOSE',F8.3,
      X ' ', LARGEST',F8.3,', SMALLEST',F8.3)
ISN 0102      C---- PLOT METEOROLOGICAL DOSE MAP -----
ISN 0103      PRINT 70, TITD
ISN 0105      IF (FILM .EQ. 0) GOTO 34
ISN 0106      CALL PTEXT ('METEOROLOGICAL DOSE',19,1,20,2275+10*MVD)
ISN 0107      CALL PTEXT (TITD,72,1,20,2195+10*MVD)
ISN 0108      34 CALL SITMAP (DOSE,MHD,MVD,LS,DOSS,(SDOS/(MHD*MVD)),DOSL,FILM)
ISN 0109      GOTO 2
ISN 0110      C---- DETERMINE DOSE AS A POWER FUNCTION OF DISTANCE -----
ISN 0111      35 READ PMTD, CD0SE, POWER, GRID
ISN 0112      CALL DISDOS (DOSE,MHD,MVD,CD0SE,POWER,GRID)
ISN 0113      GOTO 33
ISN 0114      C---- READ IN SITE GRID AND DOSE GRID SIZES FOR RUN -----
ISN 0115      40 MHG=JM
ISN 0116      MVG=KM
ISN 0117      MMH=LM
ISN 0118      MVM=MM
ISN 0119      J = MHG*MVG
ISN 0120      IF (J .LE. 12350) GOTO 41
ISN 0121      PRINT 64, J
ISN 0122      64 FORMAT ('0 RUN DIM (' ,I6,' ) MUST BE .LE. 12350')
ISN 0123      GOTO 999
ISN 0124      41 IF (MMH .LE. MHD) GOTO 44
ISN 0125      PRINT 63, MMH,MHD
ISN 0126      63 FORMAT ('0 MOVING GRID (' ,I6,' ) MUST BE .LE. DOSE GRID (' ,I6,' )')
ISN 0127      GOTO 999
ISN 0128      44 IF (MVM .LE. MVD) GOTO 46
ISN 0129      PRINT 63, MVM,MVD
ISN 0130      GOTO 999
ISN 0131      46 READ 69, TITL
ISN 0132      PRINT 70, TITL
ISN 0133      69 FORMAT (13A4)
ISN 0134      70 FORMAT (' ',18A4)
ISN 0135      READ 97, FMTR,FMTR
ISN 0136      PRINT 98, FMTR,FMTR
ISN 0137      C---- COMPUTE TOTAL & POINT DOSES FOR EACH SITE IN MATRIX -----
ISN 0138      CALL DOSITE (POP,DOSE,ROSE,BOSE,
ISN 0139      X MHE,MVP,MHG,MVG,MHD,MVD,MMH,MVM)
ISN 0140      C---- PRINT TOTAL POPULATION-DOSE FOR EACH POSSIBLE SITE IN MATRIX -----
ISN 0141      PRINT 68
ISN 0142      68 FORMAT ('1 TOTAL MANREN DOSE FOR EACH SITE')
ISN 0143      PRINT 70, TITL
ISN 0144      PRINT FMTR, (ROSE(I),I=1,J)
ISN 0145      ROSM = SOSE/(MHG*MVG)
ISN 0146      PRINT 66, SOSE, ROSM, ROSL, ROSS
ISN 0147      66 FORMAT ('0 SUM OF TOTAL DOSES',1PD12.5,', MEAN DOSE',D12.5,
ISN 0148      X ' ', LARGEST',D12.5,', SMALLEST',D12.5)
ISN 0149      C---- PLOT TOTAL POPULATION-DOSE MAP -----
ISN 0150
ISN 0151
ISN 0152
ISN 0153
ISN 0154
ISN 0155
ISN 0156
ISN 0157
ISN 0158
ISN 0159
ISN 0160
ISN 0161
ISN 0162
ISN 0163

```

Fig. A.3. (Contd.)

```

ISN 0145      PRINT 68                                SITE2164
ISN 0146      PRINT 70, TITL                          SITE2165
ISN 0147      IF (FILM.EQ. 0) GOTO 47                 SITE2166
ISN 0149      CALL FCHSZ (2)                          SITE2167
ISN 0150      CALL FTEXT ('TOTAL MANREM DOSE FOR EACH SITE',31,1,20,2275+10*MVG) SITE2168
ISN 0151      CALL FTEXT (TITL,72,1,20,2195+10*MVG)  SITE2169
ISN 0152      47 CALL SITMAP (ROSE,MHG,MVG,LS,ROSS,BOSM,BOSL,FILM) SITE2170
C----- PRINT POINT POPULATION-DOSE FOR EACH POSSIBLE SITE IN MATRIX ---- SITE2171
ISN 0153      PRINT 67                                SITE2172
ISN 0154      67 FORMAT ('1 MAXIMUM POINT DOSE FOR EACH SITE') SITE2173
ISN 0155      PRINT 70, TITL                          SITE2174
ISN 0156      PRINT PMTB, (BOSE(I),I=1,J)            SITE2175
ISN 0157      EOSM = POSE/(MEG*MVG)                  SITE2176
ISN 0158      PRINT 65, POSE, BOSM, BOSL, BOSS       SITE2177
ISN 0159      65 FORMAT ('0 SUM OF POINT DOSES',1PD12.5,', MEAN DOSE',D12.5, SITE2178
X ' ', LARGEST',D12.5,', SMALLEST',D12.5)          SITE2179
C----- PLOT POINT POPULATION-DOSE MAP ----- SITE2180
ISN 0160      PRINT 67                                SITE2181
ISN 0161      PRINT 70, TITL                          SITE2182
ISN 0162      IF (FILM.EQ. 0) GOTO 48                 SITE2183
ISN 0164      CALL FCHSZ (2)                          SITE2184
ISN 0165      CALL FTEXT ('MAX POINT DOSE FOR EACH SITE ',31,1,20,2275+10*MVG) SITE2185
ISN 0166      CALL FTEXT (TITL,72,1,20,2195+10*MVG)  SITE2186
ISN 0167      48 CALL SITMAP (ROSE,MHG,MVG,LS,BOSS,BOSM,BOSL,FILM) SITE2187
ISN 0168      PRINT 61                                SITE2188
ISN 0169      61 FORMAT ('1')                        SITE2189
ISN 0170      GOTO 2                                  SITE2190
C----- NORMAL END ----- SITE2191
ISN 0171      50 PRINT 59                             SITE2192
ISN 0172      59 FORMAT (' NORMAL END')              SITE2193
ISN 0173      RETURN                                  SITE2194
C----- ABNORMAL END ----- SITE2195
ISN 0174      999 PRINT 998                           SITE2196
ISN 0175      998 FORMAT (' RUN ABORTED, CHECK PARAMETERS OR CHANGE DIMENSIONS') SITE2197
ISN 0176      RETURN                                  SITE2198
C----- TCOST SECTION FOR TRANSMISSION LINE COSTS ----- SITE2199
ISN 0177      1105 FORMAT(' TOTAL=',F15.3,' MEAN=',F15.3,' MAX=',F15.3,' MIN=',F15.3) SITE2200
ISN 0178      1106 FORMAT(' CMX,CMY,GRID & CST = ',4F15.3,/) SITE2201
ISN 0179      1100 READ 69, TITD                      SITE2202
ISN 0180      PRINT 70, TITD                          SITE2203
ISN 0181      READ 97, FMTD,FMTDO                     SITE2204
ISN 0182      PRINT 98, FMTD,FMTDO                   SITE2205
ISN 0183      READ FMTD,CMX,CMY,GRID,CST              SITE2206
ISN 0184      PRINT 1106, CMX,CMY,GRID,CST            SITE2207
ISN 0185      DO 1101 J=1,12350                      SITE2208
ISN 0186      1101 RCSP(J)=0.0                       SITE2209
ISN 0187      MHD=JM                                  SITE2210
ISN 0188      MVD=KM                                  SITE2211
ISN 0189      CMX=CMX*GRID                            SITE2212
ISN 0190      CMY=CMY*GRID                            SITE2213
ISN 0191      DO 1102 JX=1,MHD                       SITE2214
ISN 0192      DX=JX                                   SITE2215
ISN 0193      DX=CMX- (DX*GRID)                      SITE2216
ISN 0194      DO 1102 JY=1,MVD                       SITE2217
ISN 0195      JRS=(JY-1)*MHD+JX                     SITE2218

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Fig. A.3. (Contd.)

ISN 0196	DY=JY	SITE2219
ISN 0197	DY=CMY- (DY*GRID)	SITE2220
ISN 0198	DC=(DX**2)+(DY**2)	SITE2221
ISN 0199	ROSE(JRS)= SQRT(DC)*CST	SITE2222
ISN 0200	1102 CONTINUE	SITE2223
ISN 0201	J=MHD*MVD	SITE2224
ISN 0202	ROSS=7.075	SITE2225
ISN 0203	ROSL=0.0	SITE2226
ISN 0204	SROS=0.0	SITE2227
ISN 0205	DC 1103 I=1,J	SITE2228
ISN 0206	IF(ROSE(I).GT.ROSS) ROSL=ROSE(I)	SITE2229
ISN 0208	IF((ROSE(I).LT.ROSS).AND.(ROSE(I).GT.0)) ROSS=ROSE(I)	SITE2230
ISN 0210	1101 SROS=SROS+ROSE(I)	SITE2231
ISN 0211	ROSM=SROS/(MHD*MVD)	SITE2232
ISN 0212	PRINT 1105, SROS,ROSM,ROSL,ROSS	SITE2233
	C----- PLOT TRANSMISSION MAP-----	SITE2234
ISN 0213	PRINT 70, TITD	SITE2235
ISN 0214	IF(FILM.EQ.C.) GO TO 1104	SITE2236
ISN 0216	CALL FTEXT (' TRANSMISSION COST ',19,1,20,2275+10*MVD)	SITE2237
ISN 0217	CALL PTEXT (TITD,72,1,20,2195+10*MVD)	SITE2238
ISN 0218	1104 CALL SITMAP (ROSE,MHD,MVD,LS,ROSS,ROSM,ROSL,FILM)	SITE2239
ISN 0219	GO TO 2	SITE2240
ISN 0220	END	SITE2241

Fig. A.3. (Contd.)

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ISN 0032		IF (ROSE(NL) .LT. RM) ROSE(NL) = RM	SITE2295
ISN 0034	6	CONTINUE	SITE2296
ISN 0035		ROSE(NL) = ROSE(NL)/SCALE	SITE2297
ISN 0036		ROSE(NL) = ROSE(NL)/SCALE	SITE2298
ISN 0037		SOSE = SOSE+ROSE(NL)	SITE2299
ISN 0038		POSF = POSF+ROSE(NL)	SITE2300
ISN 0039		IF (ROSE(NL) .GT. ROSL) ROSL = ROSE(NL)	SITE2301
ISN 0041		IF (ROSE(NL) .GT. BOSL) BOSL = ROSE(NL)	SITE2302
ISN 0043		IF ((ROSE(NL) .LT. ROSS) .AND. (ROSE(NL) .GT. 0)) ROSS = ROSE(NL)	SITE2303
ISN 0045		IF ((ROSE(NL) .LT. BOSS) .AND. (ROSE(NL) .GT. 0)) BOSS = ROSE(NL)	SITE2304
ISN 0047	7	CONTINUE	SITE2305
ISN 0048		T9 = TLEFT(0)/100.	SITE2306
ISN 0049		IF (T9 .LT. TR) GOTO 9	SITE2307
ISN 0051	8	CONTINUE	SITE2308
	C----	RECORD TIME LEFT AFTER COMPUTATION -----	SITE2309
ISN 0052		PRINT 98, T9	SITE2310
ISN 0053		RETURN	SITE2311
	C----	PRINT MESSAGE WHEN TIME EXCEEDED -----	SITE2312
ISN 0054	9	PRINT 99	SITE2313
ISN 0055		RETURN	SITE2314
ISN 0056		END	SITE2315

Fig. A.3. (Contd.)

ISN 0002	SUBROUTINE SITMAP (ROSE,MHG,MVG,LS,ROSS,ROSM,ROSL,FILM)	SITE2316
	C---- PRODUCE GREY SCALE MAP OF POPULATION DOSE MATEIX -----	SITE2317
	C---- FILM DIMENSION LIMITED TO HORIZ .I.E. 200, VERT .I.E. 180 -----	SITE2318
	C---- SITMAP PRODUCES A PRINTER CONTOUR MAP OF THE ARRAY ROSE. -----	SITE2319
	C---- ROSE IS THE INPUT ARRAY TO BE PLOTTED. ITS ORDER IS ROW WISE -----	SITE2320
	C---- WEST TO EAST AND SOUTH TO NORTH. ITS SIZE IS MHG*MVG. -----	SITE2321
	C---- LS(I) IS THE SYMBOL USED TO REPRESENT VALUES IN ROSE WHICH -----	SITE2322
	C---- FALL IN THE 1/7 TH FRACTION OF THE LOGARITHMIC RANGE. -----	SITE2323
	C---- THE OUTPUT IS PRINTED NORTH TO SOUTH SO AS TO BE SEEN IN ITS -----	SITE2324
	C---- NORMAL ORIENTATION -----	SITE2325
ISN 0003	LOGICAL*1 PA,LS,PR,PO	SITE2326
ISN 0004	REAL*8 ROSE,ROSS,ROSM,ROSL,DLM,DLD,R	SITE2327
ISN 0005	DIMENSION PA(200),ROSS(1),LS(1),PO(200),KEY(6)	SITE2328
ISN 0006	DATA PR/' '	SITE2329
ISN 0007	89 FORMAT (' ',132A1)	SITE2330
ISN 0008	87 FORMAT ('+',132A1)	SITE2331
ISN 0009	88 FORMAT (' TIMELEFT',F3.2,' SECS')	SITE2332
ISN 0010	86 FORMAT (20X,A1,1PE10.3,' TO ',E10.3/'+',10X,A1)	SITE2333
ISN 0011	IF (FILM .EQ. 0) GOTO 2	SITE2334
	C---- OUTLINE SITE RECTANGLE ON FILM -----	SITE2335
ISN 0013	CALL FCHSZ(1)	SITE2336
ISN 0014	CALL FLNSG (10,2115+10*MVG,10+20*MHG,2115+10*MVG)	SITE2337
ISN 0015	CALL FLNSG (10+20*MHG,2115+10*MVG,10+20*MHG,2115-10*MVG)	SITE2338
ISN 0016	CALL FLNSG (10+20*MHG,2115-10*MVG,10,2115-10*MVG)	SITE2339
ISN 0017	CALL FLNSG (10,2115-10*MVG,10,2115+10*MVG)	SITE2340
ISN 0018	CALL FLNSG (10,2080-10*MVG,2760,2080-10*MVG)	SITE2341
ISN 0019	CALL FLNSG (2760,2080-10*MVG,2760,1800-10*MVG)	SITE2342
ISN 0020	CALL FLNSG (2760,1800-10*MVG,10,1800-10*MVG)	SITE2343
ISN 0021	CALL FLNSG (10,1800-10*MVG,10,2080-10*MVG)	SITE2344
	C---- DETERMINE SCALING FOR SEVEN SHADES OF GREY -----	SITE2345
ISN 0022	2 DLM = 0	SITE2346
ISN 0023	IF (ROSS .GT. 0) DLM = DLOG(ROSS)	SITE2347
ISN 0025	DLD = 1.000	SITE2348
ISN 0026	IF (ROSL .GT. ROSE) DLD = DLOG(ROSL)-DLM	SITE2349
	C---- PRINT MAP - ONE PRINT POSITION PER SITE -----	SITE2350
ISN 0028	DO 8 K=1,MVG	SITE2351
ISN 0029	DO 4 I=1,200	SITE2352
ISN 0030	PO(I) = PR	SITE2353
ISN 0031	4 PA(I) = PR	SITE2354
ISN 0032	KS = MHG*(MVG-K)	SITE2355
ISN 0033	DO 6 L=1,MHG	SITE2356
ISN 0034	KS = KS+1	SITE2357
ISN 0035	IF (ROSE(KS) .LE. 0) GOTO 6	SITE2358
ISN 0037	ND = 1.00+6.999999999D0*(DLOG(ROSE(KS))-DLM)/DLD	SITE2359
ISN 0038	IF (ND .GT. 0) PA(L) = LS(ND)	SITE2360
ISN 0040	IF (ND .GT. 0) PO(L) = LS(ND+40)	SITE2361
ISN 0042	6 CONTINUE	SITE2362
ISN 0043	PRINT 89, (PA(I),I=1,132)	SITE2363
ISN 0044	PRINT 87, (PO(I),I=1,132)	SITE2364
ISN 0045	IF (MHG .GT. 132) PRINT 89, (PA(I),I=133,MHG)	SITE2365
ISN 0047	IF (MHG .GT. 132) PRINT 87, (PO(I),I=133,MHG)	SITE2366
ISN 0049	IF (FILM .NE. 0) CALL FTEXT (PA,MHG,1,20,2125+10*MVG-20*K)	SITE2367
ISN 0051	IF (FILM .NE. 0) CALL FTEXT (PO,MHG,1,20,2125+10*MVG-20*K)	SITE2368

Fig. A.3. (Contd.)

ISN 0053	8 CONTINUE	SITE2369
	C---- PRINT KEY CHARACTERS WITH VALUE RANGE REPRESENTED -----	SITE2370
ISN 0054	IF (FIL# .NE. 0) CALL PCHSZ (2)	SITE2371
ISN 0056	R = (POSL/ROSS)**(1.D0/7.D0)	SITE2372
ISN 0057	T1 = POSL	SITE2373
ISN 0058	DO 12 I=1,7	SITE2374
ISN 0059	J = 8-I	SITE2375
ISN 0060	T2 = T1	SITE2376
ISN 0061	T1 = T1/R	SITE2377
ISN 0062	PRINT #6, LS(J),T1,T2,LS(J+40)	SITE2378
ISN 0063	IF (FIL# .EQ. 0) GOTO 12	SITE2379
ISN 0065	CALL CONVO ('(1PE10.3,3H TO,1PE10.3)',KEY,0,L,T1,T2)	SITE2380
ISN 0066	CALL FTEXT (LS(J),1,1,70+((J-1)-((J-1)/2)*2)*1386,	SITE2381
	X 2080-10*MVG-35*I)	SITE2382
ISN 0067	CALL FTEXT (LS(J+40),1,1,70+((J-1)-((J-1)/2)*2)*1386,	SITE2383
	X 2080-10*MVG-35*I)	SITE2384
ISN 0068	CALL FTEXT (KEY,23,1,140+((J-1)-((J-1)/2)*2)*1386,	SITE2385
	X 2080-10*MVG-35*I)	SITE2386
ISN 0069	12 CONTINUE	SITE2387
ISN 0070	IF (FIL# .NE. 0) CALL PADV (4)	SITE2388
	C---- RECORD TIME LEFT AFTER MAP COMPLETED -----	SITE2389
ISN 0072	T9 = TLEFT(0)/100.	SITE2390
ISN 0073	PRINT #8, T9	SITE2391
ISN 0074	RETURN	SITE2392
ISN 0075	END	SITE2393

Fig. A.3. (Contd.)

ISN 0012	SUBROUTINE REFPOS (DOSE,MHD,MVD)	SITE2394
	C---- REFPOS REFLECTS THE DOSE ARRAY OVER ITS DIAGONAL IF NECESSARY ---	SITE2395
	C---- TO CHANGE COLUMNWISE ORDERING TO ROWWISE ORDERING. -----	SITE2396
ISN 0013	DIMENSION DOSE(1, TDOS(*000))	SITE2397
ISN 0014	REAL*8 DOSE,TDOS	SITE2398
ISN 0015	REAL*8 DSO,DOSP,GRID,POWER,CDOSE	SITE2399
ISN 0016	DO 4 K=1,MHD	SITE2400
ISN 0017	KS=(K-1)*MVD	SITE2401
ISN 0018	KJ=K	SITE2402
ISN 0019	DO 4 L=1,MVD	SITE2403
ISN 0020	KS=KS+1	SITE2404
ISN 0021	TDOS(KS) = DOSE(KJ)	SITE2405
ISN 0022	KJ=KJ+MHD	SITE2406
ISN 0023	4 CONTINUE	SITE2407
ISN 0024	KJ = MHD*MVD	SITE2408
ISN 0025	DO 6 K=1,KJ	SITE2409
ISN 0026	DOSE(K)=TDOS(E)	SITE2410
ISN 0027	6 CONTINUE	SITE2411
ISN 0028	RETURN	SITE2412
	C-----	SITE2413
ISN 0019	ENTRY DISPOS (DOSE,MHD,MVD,CDOSE,POWER,GRID)	SITE2414
	C---- COMPUTE DOSE ARRAY AS A (POWER) FUNCTION OF DISTANCE -----	SITE2415
ISN 0020	MHD = ((MHD)/2)*2 - 1	SITE2416
ISN 0021	MVD = MHD	SITE2417
ISN 0022	M = MHD/2 + 1	SITE2418
ISN 0023	N = M-1	SITE2419
ISN 0024	DO 8 K=1,N	SITE2420
ISN 0025	DO 8 I=K,M	SITE2421
ISN 0026	DSO = (GRID*(M-L))**2 + (GRID*(M-K))**2	SITE2422
ISN 0027	DOSP = CDOSE/(DSO**(0.5*POWER))	SITE2423
ISN 0028	I = I + MVD*(K-1)	SITE2424
ISN 0029	DOSE(I) = DOSP	SITE2425
ISN 0030	I = I + MHD*(MHD-K)	SITE2426
ISN 0031	DOSP(I) = DOSP	SITE2427
ISN 0032	I = MHD+I-1 + MHD*(MHD-K)	SITE2428
ISN 0033	DOSP(I) = DOSP	SITE2429
ISN 0034	I = MHD+I-1 + MHD*(K-1)	SITE2430
ISN 0035	DOSP(I) = DOSP	SITE2431
ISN 0036	IF (K.EQ.1) GOTO 8	SITE2432
ISN 0037	I = K + MHD*(I-1)	SITE2433
ISN 0038	DOSP(I) = DOSP	SITE2434
ISN 0039	I = K + MHD*(MHD-L)	SITE2435
ISN 0040	DOSP(I) = DOSP	SITE2436
ISN 0041	I = MHD+I-K+MHD*(MHD-L)	SITE2437
ISN 0042	DOSP(I) = DOSP	SITE2438
ISN 0043	I = MHD+I-K+MHD*(L-1)	SITE2439
ISN 0044	DOSP(I) = DOSP	SITE2440
ISN 0045	8 CONTINUE	SITE2441
ISN 0046	RETURN	SITE2442
ISN 0047	END	SITE2443

Fig. A.3. (Contd.)

Table A.1. Glossary of SITE2 Variables and Arrays

Name	(Maximum Dimension)	Type	Description
BOSE	(12350)	REAL*8	Array of maximum point doses for each site, of dimension MHG*MVG
BOSL		REAL*8	Largest of the maximum point doses (in BOSE array)
BOSM		REAL*8	Mean of the maximum point doses (in BOSE)
BOSS		REAL*8	Smallest of the nonzero maximum point doses (in BOSE)
CDOSE		REAL*8	Unit dosage parameter (in man millirems) when pattern is computed (for input TYPE DOSD)
DOSE	(1000)	REAL*8	Dosage array, input or computed, of dimension MHD*MVD (sometimes called "meteorological dose")
DOSK		Alphanumeric	Template with TYPE value "DOSE" for switch to DOSE section of program
DOSL		REAL*4	Largest of the (meteorological) dosages (in DOSE array)
DOSM		REAL*4	Mean of the dosages (in DOSE)
DOSP		REAL*8	In REFDOS subroutine, ENTRY DISDOSE, computed dosage at current site
DOSS		REAL*4	Smallest of the nonzero dosages (in DOSE)
DSQ		REAL*8	In REFDOS subroutine, ENTRY DISDOS, square of distance from current site to power center
DSTK		Alphanumeric	Template with TYPE value "DOSD" for switch to DOSD section of program
ENDK		Alphanumeric	Template with TYPE value "END" for switch to END section of program
FILM		REAL*4	Film output flag
FMTB	(10)	Alphanumeric	FORMAT for output of maximum point doses (BOSE)

Table A.1. (Contd.)

Name	(Maximum Dimension)	Type	Description
FMTD	(10)	Alphameric	FORMAT for input of dosage data (in TYPE DOSE) or dosage computation parameters (in TYPE DOSD), and later for input of transmission cost parameters
FMTDO	(10)	Alphameric	FORMAT for output of dosage data (DOSE), input or computed
FMTD	(10)	Alphameric	FORMAT for input of population data (POP)
FMTPO	(10)	Alphameric	FORMAT for output of population data (POP)
FMTR	(10)	Alphameric	FORMAT for output of total population-doses (ROSE)
GRID		REAL*8	Grid size parameter when dosage pattern is computed (in DOSD TYPE)
KEY	(6)	Alphameric	In SITMAP, holds successive lines of legend for contour map
LS	(80)	LOGICAL*1	Plot symbols (in bytes 1-7) and overwrite plot symbols (in bytes 41-47)
PA	(200)	LOGICAL*1	In SITMAP subroutine, array of plot symbol characters set up for one line of printing on film output in contour map. Characters are taken from first half of array LS of input (SYMB) or default plot characters
PB		LOGICAL*1	In SITMAP subroutine, blank character for initial clearing of contour map line
PO	(200)	LOGICAL*1	In SITMAP SUBROUTINE, plot symbol characters set up for one overwrite line of printing or film output in contour map. Characters are taken from second half of array LS of input (SYMB) or default plot characters
POP	(20000)	REAL*8	Population array, of dimension MHP*MVP

Table A.1. (Contd.)

Name	(Maximum Dimension)	Type	Description
POPK		Alphameric	Template with TYPE value "POPU" for switch to POPU section of program
POPL		REAL*4	Largest of the population entries (in POP array)
POPM		REAL*4	Mean of the population entries (in POP)
POPS		REAL*4	Smallest of the nonzero population entries (in POP)
POSE		REAL*8	Total of the maximum point doses (in BOSE)
POWER		REAL*8	Power dosage parameter when pattern is computed in TYPE DOSD
R		REAL*8	In SITMAP subroutine, multiplicative length of range for each plotted character
ROSE	(12350)	REAL*8	Array of total (MANREM) population-doses (and later transmission costs) for each site, of dimension MHG*MVG
ROSL		REAL*8	Largest population-dose (and later transmission cost) (in ROSE array)
ROSM		REAL*8	Mean population-dose (and later transmission cost) (in ROSE)
ROSS		REAL*8	Smallest nonzero population-dose (and later transmission cost) (in ROSE)
RUNK		Alphameric	Template with TYPE value "RUN" for switch to RUN section of program
SCALE		REAL*8	In DOSITE subroutine, scale factor (1000) used to convert man-millirems of dosage to manrems of population-dose
SDOS		REAL*8	Total dosage in DOSE pattern
SOSE		REAL*8	Total of all population-doses (in ROSE array)

Table A.1. (Contd.)

Name	(Maximum Dimension)	Type	Description
SPOP		REAL*8	Total population at all sites (in POP array)
SROS		REAL*4	Total of all transmission costs (in ROSE array)
SYMK		Alphameric	Template with TYPE value "SYMB" for switch to SYMB section of program
TC3K		Alphameric	Template with TYPE value "TCST" for switch to TCST section of program
TDOS	(1000)	REAL*8	In REFDOS subroutine, temporary storage array for reflected DOSE pattern
TITD	(18)	Alphameric	Dosage ID (and later transmission cost ID)
TITL	(18)	Alphameric	Run ID
TITP	(18)	Alphameric	Population ID
TYPE		Alphameric	Input parameter used to identify input types SYMB, POPU, DOSE, DOSD, RIJN, TCST, and END

Common Variables:

SOSE, POSE, ROSL, ROSS, BOSL, BOSS

and maximum (BOSE) population-dose, and transmission cost (ROSE). It generates both printer and film plots, and is called once each from the sections POPU, DOSE (or DOSD), and TCST, and twice from RUN.

SITMAP has eight (dummy) parameters: ROSE, MHG, MVG, LS, ROSS, ROSM, ROSL, and FILM. ROSE, with horizontal dimension MHG and vertical dimension MVG, is the array of positive quantities and zeros to be plotted with characters from the symbol array LS. FILM is the Film Output Flag (1 for film, 0 for no film). Nonzero entries in ROSE range from ROSS (smallest) to ROSL (largest), with ROSM being the mean of all ROSE components.

The nonzero quantities are grouped logarithmically into seven categories, or shades of gray, with each group being identified by a specific plot symbol from LS. Although ROSE is a one-dimensional array with entries being grid points from west to east and by row from south to north, SITMAP plots group symbols on the printer (and on film) from west to east and from north to south. Up to 132 characters per line and up to two lines per row of ROSE are plotted on the printer, but only one line of up to 200 characters is allowed on the 2280 film recorder. For film output, MVG cannot exceed 180. At the end of SITMAP, the Argonne built-in function TLEFT is invoked, and time left in the current SITE2 job in hundredths of seconds is converted to seconds and is printed.

Film plotting requires that Argonne's subroutine package FSP¹⁵ be callable. The entries in FSP used by SITE2 are FTEXT (for text), FLNSG (for line segments), FADV (for film advance), and FCHSZ (to change character size). There are also calls to FSP from the main SITE2 program; these affix specific labels for plot types and lines of identification for the particular cases being run. Another Argonne subroutine, CONVO, is used to convert number ranges from machine language to decimal for the range legend.

b. DOSITE

This subroutine, called by the RUN section of SITE2, computes total and maximum population-doses for each potential site. Its parameters are POP, DOSE, ROSE, BOSE, MHP, MVP, MHG, MVG, MHD, MVD, MHM, and MVM. The population array POP is of dimension MHP*MVP, the dosage pattern DOSE is of dimension MHD*MVD, the portion of DOSE to be used in the DOSITE calculations is of dimension MHM*MVM, and the result arrays ROSE (for total population-doses)

and BOSE (for maximum point doses) are both of dimension MHD*MVD. Note, however, that in FORTRAN storage, the arrays POP, DOSE, ROSE, and BOSE are actually of one dimension. Each array is a concatenation of rows of grid points.

DOSITE successively centers the DOSE pattern of dosages at each site of the ROSE (result) array, thus moving through the ROSE grid from west to east and by row from south to north. For a given site, each point dosage of that portion of DOSE being considered is multiplied by the corresponding population to get a point population-dose. The sum of all these is the total population-dose for that site; these sums for each site form the total population-dose array ROSE. The largest of the population-doses for each site constitute the BOSE array of maximum doses, sometimes called the "point doses." In DOSITE all population-doses are divided by SCALE (1000) to be in manrem units rather than the man millirems produced from the DOSE array. DOSITE also computes and places in COMMON storage the sum of all ROSE entries (SOSE) and of all BOSE (POSE), the largest of ROSE and BOSE (ROSL and BOSL), and the smallest (ROSS and BOSS).

The Argonne function TLEFT is utilized in determining and printing the time left in the current SITE2 job both at the start of DOSITE and at the end.

c. REFDOS

This subroutine reflects the square grid array DOSE about its south-west-northeast diagonal to change from south-to-north columnwise ordering of input data to west-to-east rowwise ordering. Its parameters are DOSE, MHD, MVD: the one-dimensional FORTRAN array DOSE to be reflected is of grid size MHD*MVD. Dosage entries are temporarily rearranged and stored in the array TDOS, and then returned to DOSE in the desired order.

Another ENTRY (DISDOS) in REFDOSE generates the elements for DOSE as an inverse power function of distance from the center of DOSE when the dosage pattern is to be computed rather than input. Thus DISDOS is entered from the DOSD section of code in SITE2. In addition to the DOSE, MHD, and MVD parameters of the reflection part of REFDOSE, DISDOS also has parameters CDOSE, POWER, and GRID. CDOSE is the unit dosage, POWER the exponent (any real number) applied to the inverse of the distance from the pattern center, and GRID the grid square size. Only about one-eighth of the point dosages require computation, the others being known by symmetry.

4. Extending SITE2

The TYPE switch near the start of SITE2 and modularization by input type are the keys to extending the program to include other site attributes. First of all, pick a name, say TYPX, for the new attribute type and design the first new input card to have TYPX in columns 1-4. The other possible input parameters on this TYPE card (JM, KM, LM, MM, and FILM) may have any designated or no meaning at all in the new section. Then add a DATA statement setting TYPK equal to TYPX, and to the TYPE switch attach another IF statement:

IF (TYPE .EQ. TYPK) GO TO [address of section X].

Finally add the necessary coding for section X at the end of SITE2. This section should end with a transfer of control to location 2 so that the next TYPE card (possibly END) may be processed. In the new coding, of course, any of the subroutines SITMAP, DOSITE, or REFDOS may be utilized.

A.5 SAMPLE PROBLEM

The region of the sample problem is the Northern Illinois case study described in the main text of this report. For potential power plant sites the coordinate origin is at $90^{\circ}53'$ West and $40^{\circ}38'$ North, a point on the border of Henderson and McDonough Counties, and near the town of La Harpe. The result arrays ROSE and BOSE start at this point, and extend 260 km east and 190 km north. Grid points are every 2 km, so that each point represents a site with an area of about 1000 acres.

Thus there are $130 \times 95 = 12,350$ sites to be considered. The population array POP adds a border of 15 grid points around these sites, and hence requires $160 \times 125 = 20,000$ POP entries. Basic population figures are taken from the 1960 census, with all urban area counts except Chicago's increased by 10%. Rural populations, assumed to be uniformly distributed over each township, are taken to be those of the 1960 census. Chicago populations are also those of 1960.

Two different dosage patterns are used in the sample problem. Both are 31×31 arrays (DOSE) of grid points either input or computed by SITE2. The pattern that is input is based on Dresden meteorological data, with dosages having been separately computed by the ASSMRD version of the ASSM dispersion program.^{10,14} This pattern reflects worst-month conditions (March) and an accidental release at 10 meters, with runs both for the entire dosage pattern area and for the low population zone (9×9 grid).

The other pattern illustrates the DOSD option; computed dosages are inversely proportional to the square of the distance from the site. There is also one transmission cost computation, for a load centroid near Harvey, Illinois, at result grid point (128,55).

The printed output from this sample problem is given in Fig. A.4 and the film-plot outputs are given in Figs. A.5 - A.14.

Fig. A.4. Sample Problem Printed Output

1.5126	1.6429	1.6852	1.8492	2.0136	2.1751	2.3288	2.4682	2.5838	2.7113	2.7723	2.8504	2.8686	2.8180	2.6881	2.6587
2.6130	2.6532	2.6255	2.5392	2.4018	2.3144	2.2268	2.1471	2.0432	1.9239	1.7956	1.6625	1.5284	1.4969	1.3990	
1.4944	1.5223	1.6518	1.8031	1.9391	2.0719	2.1953	2.3031	2.3872	2.4992	2.5490	2.6005	2.6030	2.5496	2.4322	2.4161
2.3693	2.4100	2.5356	2.6334	2.7294	2.8134	2.8476	1.9930	1.9164	1.8228	1.7189	1.6083	1.4958	1.3820	1.3616	

TOTAL DOSE 5167.210, MEAN DOSE 5.377, LARGEST 213.000, SMALLEST 0.765

DRESDEN MARCH 30 DAY WEISSE

[illegible]

(See film plot, Fig. A.6)

B	9.531F	01	TO	2.130E	02
A	4.265F	01	TO	9.531E	01
W	1.908F	01	TO	4.265F	01
X	8.540F	00	TO	1.908E	01
Z	1.321E	00	TO	8.540E	00
F	1.710E	00	TO	1.321E	00
-	7.652F	-01	TO	1.710F	00

TIMELFFT 331.37 SECS

RUN	130	95	31	31	7.
NORTHERN ILLINOIS WITH 10 METER OCCIDENT				DRESDEN MARCH 30 DAY WETSET	
(' ', 13F9.0)				(' ', 13F9.0)	
TIMELEFT AT START	331.37 SECS				
TIMELEFT AT END	109.90 SECS				

Fig. A.4. (Contd.)

NORTHERN ILLINOIS WITH 10 METER ACCIDENT DRESDEN MARCH 30 DAY METSET												
216.	212.	210.	212.	221.	225.	232.	238.	244.	251.	244.	240.	242.
253.	254.	276.	297.	336.	421.	749.	117.	309.	314.	320.	301.	298.
304.	320.	338.	323.	323.	351.	384.	427.	492.	591.	678.	699.	839.
1009.	1124.	1217.	1335.	1479.	1671.	1958.	2390.	2857.	3542.	4524.	5326.	7574.
8511.	8718.	8332.	6172.	4935.	3623.	2882.	2481.	2256.	2010.	1756.	1512.	1360.

2507.	2388.	2233.	2141.	2064.	1610.	1496.	1279.	1162.	1033.	960.	849.	763.
685.	637.	513.	621.	656.	670.	707.	739.	832.	981.	1221.	1676.	1467.
1446.	1327.	1475.	1611.	1806.	1994.	2251.	2246.	2320.	2530.	2734.	2955.	3387.
3414.	3598.	3649.	3603.	3625.	3704.	3833.	4382.	5823.	6682.	7574.	6279.	4977.

SUM OF TOTAL DOSES 2.00884D C7, MEAN DOSE 1.62659D 03, LARGEST 5.95486D 04, SMALLEST 1.81718D 02

NORTHERN ILLINOIS WITH 10 METEF ACCIDENT DRESDEN MARCH 30 DAY *ETSET

[illegible]

(See film plot, Fig. A.7.)

[illegible]

TIMELEFT 307.51 SECS

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8 9

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N
CW
'
MFI

Fig. A.4. (Contd.)

TOTAL HANDED JOSE FOR EACH STIFF												
LOW 0000 ZONE JOSE WIND 10 METERS ACCIDENT DRESDEN MARCH 30 DAY METSET												
44.	48.	45.	46.	60.	62.	66.	73.	75.	77.	70.	63.	62.
57.	47.	107.	127.	165.	249.	167.	120.	100.	98.	85.	91.	90.
96.	99.	109.	78.	69.	79.	140.	166.	216.	305.	390.	256.	185.
160.	147.	133.	135.	184.	255.	404.	714.	953.	1945.	3403.	4541.	6969.

164.	123.	112.	132.	183.	320.	663.	996.	1412.	1848.	2169.	2085.	1937.
1947.	1773.	1499.	1412.	1282.	315.	639.	543.	466.	304.	261.	196.	120.
110.	100.	106.	102.	102.	100.	97.	164.	292.	396.	613.	1017.	785.
699.	526.	627.	672.	781.	970.	1212.	1072.	905.	982.	1039.	1124.	1448.
1470.	1547.	1532.	1352.	1209.	1422.	1253.	2498.	4404.	5233.	5155.	4897.	3659.

SUM OF TOTAL DOSES 7.24139D 06, MEAN DOSE 6.34931D 02, LARGEST 3.67831D 04, SMALLEST 3.91051D 01

[illegible]

(See film plot, Fig. A.9.)

[illegible]

3	1.383F	04	TO	1.678F	04
4	5.201E	03	TO	1.383E	04
5	1.956F	03	TO	5.201E	03
6	7.355E	02	TO	1.955E	03
7	2.766F	02	TO	7.355E	02
8	1.040F	02	TO	2.766E	02
9	3.911F	01	TO	1.040E	02

TIMELEFT 300.53 SECS

Fig. A.4. (Contd.)

LOW POPU ZONE DOSE WITH 10 METER ACCIDENT DPESDEN MARCH 30 DAY METSFT												
6.	7.	7.	6.	15.	17.	23.	29.	32.	34.	27.	19.	15.
8.	22.	33.	55.	93.	185.	103.	49.	29.	18.	14.	17.	18.
23.	40.	56.	29.	14.	9.	52.	73.	117.	202.	282.	144.	70.
45.	34.	20.	26.	32.	51.	63.	117.	117.	139.	426.	430.	1385.

124.	124.	105.	337.	449.	240.	117.	73.	57.	39.	33.	26.	14.
12.	11.	11.	11.	11.	9.	9.	7.	97.	156.	269.	376.	422.
216.	106.	69.	90.	151.	255.	535.	280.	137.	75.	64.	101.	213.
337.	186.	337.	106.	157.	149.	156.	324.	1044.	1044.	1044.	826.	768.

SUM OF POINT DOSES 1.54356D 06, MEAN DOSE 1.24984D 02, LARGEST 6.17701D 03, SMALLEST 2.98200D 00

MAXIMUM POINT DOSE FOR EACH SITE

LOW POPU ZONE DOSE WITH 10 METER ACCIDENT DRESDEN MARCH 30 DAY RESET

[illegible]

(See film plot, Fig. A.10.)

[illegible]

TIMELEFT 294.13 SECS

Fig. A.4. (Contd.)

0.2375	0.2551	0.2740	0.2941	0.3155	0.3378	0.3610	0.3846	0.4082	0.4310	0.4525	0.4717	0.4878	0.5000	0.5076	0.5102
0.5076	0.5000	0.4878	0.4717	0.4525	0.4310	0.4082	0.3846	0.3610	0.3378	0.3155	0.2941	0.2740	0.2551	0.2375	
0.2222	0.2375	0.2538	0.2710	0.2896	0.3077	0.3268	0.3460	0.3650	0.3831	0.4000	0.4149	0.4274	0.4367	0.4425	0.4444
0.4425	0.4367	0.4274	0.4149	0.4000	0.3831	0.3650	0.3460	0.3268	0.3077	0.2896	0.2710	0.2538	0.2375	0.2222	

[illegible]

S	4.178E	01	TO	1.007E	02
9	1.746E	01	TO	4.175E	01
W	7.293E	00	TO	1.745E	01
X	3.047E	00	TO	7.293E	00
=	1.273E	00	TO	3.047E	00
/	5.319E	-01	TO	1.273E	00
-	2.222E	-01	TO	5.319E	-01

```

RUN              139          95          31          31          1.
NORTHERN ILLINOIS WITH DOSE INVERSELY PROPORTIONAL TO DISTANCE SQUARED
(' ',13F8.1)              (' ',13F8.1)
TIMELEFT AT START 270.95 SECS
TIMELEFT AT END   249.21 SECS

```


TOTAL MANHEM DOSE FOR EACH SITE
 NORTHERN ILLINOIS WITH DOSE INVERSELY PROPORTIONAL TO DISTANCE SQUARED

68.4	68.4	68.4	70.1	72.7	75.2	78.4	82.1	85.0	85.7	84.4	84.4	86.4
90.0	94.8	101.9	115.4	149.3	193.5	239.4	287.7	338.4	390.2	442.9	496.6	551.3
101.1	110.2	149.4	126.4	117.4	123.5	147.4	173.3	212.2	306.7	457.9	332.0	273.1
272.0	281.2	298.7	328.2	372.9	440.1	545.8	717.5	980.2	1328.7	1914.1	2397.5	3766.4

1496.5	1342.0	1207.2	1177.5	1278.8	897.9	674.3	573.3	504.2	418.4	352.9	286.7	246.4
218.4	198.1	191.0	192.4	200.1	205.2	214.7	227.2	261.9	336.2	524.3	957.2	905.8
710.1	510.0	524.1	577.7	668.9	795.7	937.5	1106.3	1311.1	1571.3	1888.5	2269.6	2722.9
1220.7	1324.9	1357.7	1331.8	1375.6	1438.6	1525.6	1757.3	2589.5	3324.3	4179.8	5331.4	7539.1

SUM OF TOTAL DOSES 7.27361E 06, MEAN DOSE 5.89956E 02, LARGEST 2.47242E 04, SMALLEST 6.31664E 01

TOTAL MANHEM DOSE FOR EACH SITE
 NORTHERN ILLINOIS WITH DOSE INVERSELY PROPORTIONAL TO DISTANCE SQUARED

```

=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
//=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
//=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
//=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
//=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
  
```

(See film plot, Fig. A.12.)

```

=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
//=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
//=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
//=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
=====XX=====XX=====XXXXXXXXXXXXXXXXXXXX
$ 7.054E 04 TO 2.472E 04
$ 4.491E 02 TO 1.454E 04
$ 1.914E 02 TO 4.491E 03
X 9.159E 02 TO 1.914E 03
= 3.477E 02 TO 6.159E 02
/ 1.482E 02 TO 3.477E 02
- 6.317E 01 TO 1.482E 02
TIMELEFT 296.71 SECS
  
```

Fig. A.4. (Contd.)

NORTHERN ILLINOIS WITH DOSE INVERSELY PROPORTIONAL TO DISTANCE SQUARED

TABLE 1. DISTANCE-DETERMINED PROPORTIONS OF THE 12 CATEGORIES OF CRYSTALS												
PERCENTAGE OF CRYSTALS WITH MOST FREQUENT PROPORTIONS TO DISTANCE SQUARED												
2.9	2.9	3.1	3.5	4.8	6.7	9.2	12.0	13.3	12.0	9.2	6.7	4.9
7.7	8.0	11.0	22.0	55.0	110.0	55.0	22.0	11.0	10.0	20.0	10.0	6.5
12.0	30.0	60.0	30.0	12.2	14.7	17.6	30.0	60.0	150.0	300.0	150.0	60.0
30.0	17.6	11.5	9.2	15.0	24.0	30.0	55.0	55.0	100.0	200.0	200.0	650.0

120.0	75.0	100.0	-250.0	500.0	250.0	100.0	50.0	41.0	31.5	22.8	16.4	12.1
9.1	10.5	12.6	14.8	16.5	17.2	16.5	23.5	40.0	80.0	200.0	400.0	450.0
225.0	90.0	45.0	32.0	60.0	150.0	300.0	150.0	60.0	32.0	30.0	55.0	110.0
200.0	100.0	200.0	100.0	80.0	90.0	80.0	122.5	490.0	490.0	490.0	490.0	490.0

SUM OF POINT DOSES 8.58858D 05, MEAN DOSE 6.95431D 01, LARGEST 2.90000D 03, SMALLEST 2.29592D 00

NORTHERN ILLINOIS WITH DOSE INVERSELY PROPORTIONAL TO DISTANCE SQUARED

[illegible]

(See film plot, Fig. A.13.)

[illegible]

3	1.046E	03	TO	2.400E	03
4	1.769E	02	TO	1.046E	03
W	1.359E	02	TO	3.749E	02
X	4.899E	01	TO	1.359E	02
=	1.766E	01	TO	4.899E	01
/	6.368E	00	TO	1.766E	01
-	2.296E	00	TO	6.368E	00

TIMELEFT 244.72 SECS

TCST 110 95 0 0 1.
 TRANSMISSION LINE COST, PER COPIA THESIS.
 (SD10.3) (' 1,16PB.4' 1,15PB.4)
 CMX,CNY,GRID & CST = 129.000 55.00 2.000 120.000

TOTAL= 209218656.000 MFAN= 16940.781 MAX= 33120.879 MIN= 240.000

TRANSMISSION LINE COST, PER COPIA THESIS.

 #####
 #####
 #####

(See film plot, Fig. A.14.)

 #####
 #####

S 1.538E 04 TO 3.312E 04
 Q 9.104E 03 TO 1.538E 04
 X 4.009E 03 TO 3.104E 03
 Y 1.983E 03 TO 4.009E 03
 = 4.409E 02 TO 1.983E 03
 / 4.852E 02 TO 9.809E 02
 - 2.400E 02 TO 4.852E 02

TIMELEFT 189.23 SECS

END 0 0 0 0 0
 NORMAL END

Fig. A.4. (Contd.)

POPULATION FOR EACH SITE
POPULATION OF NORTHERN ILLINOIS 160 BY 125 TWO KM BLKS

Fig. A.5

METEOROLOGICAL DOSE
DRESDEN MARCH 30 DAY METSET

■	9.531E	01	TO	2.130E	02	●	4.265E	01	TO	9.531E	01
W	1.908E	01	TO	4.265E	01	●	8.540E	00	TO	1.908E	01
=	3.821E	00	TO	8.540E	00	X	1.710E	00	TO	3.821E	00
-	7.652E	-01	TO	1.710E	00	/					

Fig. A.6

TOTAL MANREM DOSE FOR EACH SITE
NORTHERN ILLINOIS WITH 10 METER ACCIDENT DRESDEN MARCH 30 DAY METSET

Fig. A.7

MAX POINT DOSE FOR EACH SITE

NORTHERN ILLINOIS WITH 10 METER ACCIDENT DRESDEN MARCH 30 DAY METSET

■	2.334E 03	TO	6.177E 03	●	8.821E 02	TO	2.334E 03
W	3.333E 02	TO	8.821E 02	x	1.260E 02	TO	3.333E 02
=	4.760E 01	TO	1.260E 02	/	1.799E 01	TO	4.760E 01
-	6.797E 00	TO	1.799E 01				

Fig. A.8

TOTAL MANREM DOSE FOR EACH SITE

LOW POPU ZONE DOSE WITH 10 METER ACCIDENT DRESDEN MARCH 30 DAY METSET

Fig. A.9

MAX POINT DOSE FOR EACH SITE

LOW POPU ZONE DOSE WITH 10 METER ACCIDENT DRESDEN MARCH 30 DAY METSET

■	2.075E	03	TO	6.177E	03	●	6.971E	02	TO	2.075E	03
■	2.342E	02	TO	6.971E	02	×	7.866E	01	TO	2.342E	02
=	2.642E	01	TO	7.866E	01	/	8.877E	00	TO	2.642E	01
-	2.982E	00	TO	8.877E	00						

Fig. A.10

METEOROLOGICAL DOSE
DOSE AS A FUNCTION OF DISTANCE SQUARED

■	4.178E 01	TO	1.000E 02	●	1.746E 01	TO	4.178E 01
W	7.293E 00	TO	1.746E 01	x	3.047E 00	TO	7.293E 00
=	1.273E 00	TO	3.047E 00	/	5.319E -01	TO	1.273E 00
-	2.222E -01	TO	5.319E -01				

Fig. A.11

TOTAL MANREM DOSE FOR EACH SITE

NORTHERN ILLINOIS WITH DOSE INVERSELY PROPORTIONAL TO DISTANCE SQUARED

■	1.054E 04	TO	2.472E 04	●	4.49E 03	TO	1.054E 04
W	1.914E 03	TO	4.491E 03	x	8.159E 02	TO	1.914E 03
=	3.477E 02	TO	8.159E 02	/	1.482E 02	TO	3.477E 02
-	6.317E 01	TO	1.482E 02				

Fig. A.12

MAX POINT DOSE FOR EACH SITE

NORTHERN ILLINOIS WITH DOSE INVERSELY PROPORTIONAL TO DISTANCE SQUARED.

■	1.046E 03	TO	2.900E 03	●	3.769E 02	TO	1.046E 03
W	1.359E 02	TO	3.769E 02	x	4.899E 01	TO	1.359E 02
=	1.766E 01	TO	4.899E 01	/	6.368E 00	TO	1.766E 01
-	2.296E 00	TO	6.368E 00				

Fig. A.13

TRANSMISSION COST
TRANSMISSION LINE COST PER COBIAN THESIS.

1	1.638E 04	TO	3.312E 04	0	8.104E 03	TO	1.638E 04
W	4.009E 03	TO	8.104E 03	X	1.983E 03	TO	4.009E 03
=	9.809E 02	TO	1.983E 03	/	4.852E 02	TO	9.809E 02
-	2.400E 02	TO	4.852E 02				

Fig. A.14

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Regional Studies Program

The Regional Studies Program at Argonne National Laboratory is sponsored by the Division of Biomedical and Environmental Research in the U.S. Energy Research and Development Administration (ERDA). Its primary purpose is to assess the health, environmental, and socioeconomic impacts of energy development options in specific subregions of the country—the Midwest, the Southwest, and the Northern Great Plains states. In conjunction with this program, Argonne is preparing a national impact study of coal development options, based on the research of all the ERDA laboratories.