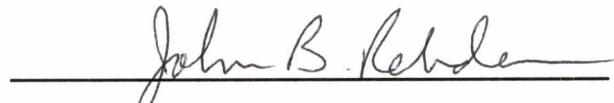
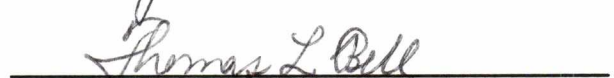


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A MODEL FOR THE SPATIAL EXAMINATION OF
ELECTRIC POWER DISTRIBUTION CAPACITIES:
The Office of Economic Assessment Decision Support System

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Fred Eugene Latham

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ABSTRACT

This research attempts to develop a means by which policy makers who are charged with formulating a national energy plan can utilize power plant operational data to visualize the spatial extent of power generating capacities. The methods developed here allow the analyst to synthesize statistics from a large archival database into the more manageable environment of a Decision Support System, which is an integrated collection of custom programs and standard office software and hardware. The system gives the decision maker the capability of creating various analytical scenarios by re-selecting (re-sampling) data elements, usually by geographic extent (state or group of states) and/or the type of fuel consumed by the power plants within those extents. The decision maker can then create contour maps and statistical surface models.

These procedures provide a mechanism by which data collected to perform one specific function of government, that of regulation, can be used to perform far different functions, those of formulating and planning for future energy needs.

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1. INTRODUCTION AND PURPOSE

Government regulators who oversee the electric utility industry require the collection of certain information and statistics. This information is collected primarily to monitor compliance with environmental and safety standards. Examples include information about the location, type, fuel requirements, emissions, generating capacity, and other characteristics of generating plants. Such information is invaluable for monitoring compliance, but it also offers insight into present generating capabilities by the decision-makers who are charged with formulating a national energy policy. The information however, must be made available in a form that is usable by these analysts, and with which they are comfortable. Currently, one of the best approaches is to use a decision support system (DSS), an integrated collection of custom programs and standard office software and hardware.

This thesis describes an effort to disseminate data that characterize the regional capacity for electricity generation to policy makers. The Energy Information Agency of the Department of Energy requires all electric utilities to supply data regarding the annual performance of each generating unit. Such reports include for each unit: the number of kilowatt hours generated, the type of fuel utilized, the construction date and proposed retirement

date, the locational coordinates expressed in latitude and longitude, and the generating capacity. These data are currently maintained in a large, mainframe database in SAS at the Oak Ridge National Laboratory.

As is often the case with a large, archival database, the data are, for the most part, inaccessible to most researchers. Their inaccessibility is due to a lack of an infrastructure, such as an on-line metadata, or card catalog type, file within government to facilitate the dissemination of spatial data. When the data are available, they are often difficult to interpret.

In a project commissioned by the Office of Environmental Assessment (OEA) of the Department of Energy (DOE), I demonstrate that data which are collected for the purpose of monitoring power plant operations can become more than simple statistics, but genuine information useful for making policy decisions.

In formulating a national energy plan, DOE is required to provide supporting documentation that conveys possible impacts of various scenarios on different regions of the country, much as other agencies must provide environmental impact statements. The spatial analysis techniques described here convey the magnitude of some variable, in this case, electric generating capacity, and general spatial distribution at the same time. The techniques allow for a quick visualization of types of capacity and they give the

decision-maker additional insight in making or eliminating choices.

The intended audience of this effort is the OEA department head who is engaged in policy decisions concerning a national energy strategy. One of the missions of the OEA is to evaluate the impact of environmental legislation on energy issues and the impact of the use of various forms of energy on the environment. The capability described here allows the decision maker to create various analytical scenarios and gain visual spatial perspectives of their results. Such simulations might include envisioning the effect that a potential Congressional mandate to burn only low sulfur coal might have on the supply of electricity in the Tennessee Valley, or the effect of the loss of Florida's three nuclear plants on that state's ability to meet demand. The techniques also convey the regional predominance of various types of fuel, for example, the great number of coal fired plants in the Tennessee Valley, or of oil fired plants in Florida. Included in this capability will be the means to juxtapose the supply capacity with current or projected demand figures, compiled from DOE publications.

To transform the archival data into useful information, a software system for analyzing the effects of various policy alternatives was developed. The software was developed for generally available office computers because the office is the typical environment where such decisions

are made. The software consists of the integration of commercial software packages that are commonly found in the office environment and custom software that was written specifically for this system.

The attributes of the system are:

- (1) a simple database of relevant generating capability data;
- (2) the ability to allow interactive data selection, to perform simulations;
- (3) the ability to allow statistical surface type and contour type modeling, although in keeping with the design of a modular system, other modeling techniques can and should be added later; and
- (4) a user interface, to facilitate ease of operation.

These attributes coincide with many of the characteristics of the subset of Management Information Systems known as Decision Support Systems, or, more precisely, situation-specific decision support systems (Sprague and Watson 1986, Densham and Rushton 1988, and Densham, 1991).

The system will be applied to the Southeastern Electric Reliability Council (SERC) region. The SERC region includes the states of Florida, Georgia, Alabama, South Carolina, North Carolina, all of Tennessee except metropolitan Memphis, and parts of Mississippi, Kentucky, and Virginia.

The following section describes data and the steps necessary to prepare them for inclusion in a Decision Support System.

2. THE ENERGY INFORMATION AGENCY DATABASE

The Energy Information Agency (EIA) of the Department of Energy collects and validates monthly operating data from utility companies and stores the information in various computer files. The files that contain information of particular interest for this research project are Forms 423, 759, and 767. In this section the files are described, as are the steps needed to put this information in the form needed by the software system.

One of the difficulties with analyzing these data is that the files contain information at different levels of detail. Data collected at the plant level include figures for generating units at a particular location; with the plant identification code being a standard Office of Regulatory Information (ORIS) code. Data collected at the unit level include figures for the generating components of each plant. The term "unit", however, is more of a concept than a defined structure. Ideally, a generator-boiler combination should be termed as a unit. Some plants, however, group various configurations of boilers and generators into what they classify as a unit. The three configurations of generators and boilers are listed below.

(A) One boiler to one generator, the preferred configuration due to its design simplicity.

(B) Two or more boilers to one generator; another simple configuration, where the boiler statistics can be summed to represent "unit" information.

(C) One or more boilers to two or more generators. With this configuration, boiler statistics are aggregated to unit level by a series of allocation matrices. Ninety-six percent of the generating capacity in the United States comes from the first configuration, 2.8 per cent comes from the second configuration, and 1.2 per cent comes from the third configuration.

Form 423 is a plant level file that contains data concerning the types and quantities of fuel delivered to a location. Included is information identifying the quality of the fuel, such as BTU and the sulfur and ash content, and the source of the fuel. Form 759 contains plant level information on stocks of fuel, deliveries by fuel type, and the monthly electric generation figures. Form 767 includes monthly boiler level data on fuel use and generating unit level information on power generation (see Figure 1). Although data are available at the resolution of the boiler level, this form's usefulness is somewhat limited because it is required only from power plants with a generating capacity of over 100 megawatts (MW). This excludes about half of the country's generating plants, but only about 2% of the generating capacity.

Source	Media	Level	Data
Form 423	Digital	Plant	Fuel quality Fuel source
Form 759	Digital	Plant	Deliveries by fuel type Amount of fuel on hand Monthly generation figures
Form 767	Digital	Boiler	Generation figures Fuel consumption
Pub. 0214	Paper	State	Residential electricity consumption

Figure 1. Sources of data.

Some of the data from these files, along with data from other EIA forms and various industry publications are synthesized and collected in a database called the Generating Unit Reference File (GURF) (see appendix A), a unit level database. Included in the GURF file are data specifying the location of the unit, the unit type, the designed generating capacity and the actual generating capacity (usually about 20 per cent lower), ownership, the year the unit came on line, and the year of planned retirement. Information about both existing and planned units is included in this file. The file is maintained on EIA's mainframe computers and is kept current as new information is made available. The Oak Ridge National Laboratory (ORNL) owns a copy of the GURF file and maintains it as a Statistical Analysis System (SAS) database on its IBM mainframe computers (Alvic 1984).

Information stored in SAS format can be read only by SAS software. In order to be downloaded to a microcomputer database, the SAS database must be rewritten as an Extended Binary Coded Decimal (EBCDIC) mainframe file (see appendix B). Subsets can then be extracted.

In addition to data from the GURF files, figures for the total kilowatt hours generated by each unit were gathered from various other DOE sources and included in the DSS data file. These data give the analyst still more information to be used in assessing power generation capability. The code for summation of monthly totals and creation of an IBM data file is found in appendix C.

The data fields of interest for inclusion in this DSS from GURF are plant name; generating capacity; latitude; longitude; plant status; primary fuel; FIPS Code (state and county identifier); a plant identifier code; alternate fuel; planned retirement year; the type of nuclear unit; if applicable; a unique unit identifier; and the total kilowatt hours generated in a base year. The code to create such a subset is found in appendix D.

For analysis of locational data over a large geographical area, the ability to aggregate the generating capacity of all units at a particular location is often desirable. In order to extract the necessary information at the proper scale, a program consisting of three modules was written. The first module inputs the results of the code in appendix

C, the yearly kilowatt hours generated by each unit, and sums the figures to obtain generation figures for a plant site. The second module selects the plants that are relevant to this study, those that are currently active and which are located in the Southeastern Reliability Council (SERC) region. The third module of this program assigns the predominant fuel type of the largest generator to the entire location. For example, the program classifies the Turkey Point site in Florida as a nuclear site, even though auxiliary oil generators are associated with the location. The generating capacity of the auxiliary generators is aggregated to that of the predominant generator. The fuel type reported by the utility designates fuel oil by weight (ie. fuel oil #1, or fuel oil #6); coal by type, and gas by type (e.g. liquid propane or natural gas). If analysis requires aggregation of fuel type to the more generic oil, gas and coal, that capability is also available in this program.

The original concept of this model included an electric power demand file to facilitate comparison between supply capabilities and demand. State level residential consumption figures are available in Department of Energy, Energy Information Agency publication 0214. Commercial consumption can be estimated as a factor of residential consumption. However, during the time it took to construct this model, industrial consumption figures did not become available.

Preliminary analysis with residential data was performed with mainframe software, and with the personal computer software described above. But lack of corresponding industrial data makes any attempt at demand analysis almost meaningless. Therefore, the available demand data were not incorporated into this version of the pc model.

The task of incorporating complete demand data, should it become available, can be accomplished with little effort by an analyst whose interests include examining the relations between consumption and generation (also see the Database Management portion Section 3). The capability is provided here by the FORTRAN code found in appendix E. The first module inputs county population figures from the 1980 Census of Housing and Population file, calculates each county's percentage of the state's total population, and applies that percentage to the state residential consumption figure. The results are assigned to each county. The second module reads data from a national database of county center locations and assigns the appropriate geographic coordinates to the calculated residential demand figure.

In order to perform comparative analysis between demand and supply, the data need to be at common units of resolution, e.g. the county level. Therefore, generating capacity from all sources within a county are aggregated, assigned to the county center, and written to an output file. The code is in appendix F.

The data manipulation described above is best incorporated into the capabilities of the decision support system and would greatly enhance the flexibility of the system. However, due to time and budget constraints, and because the DSS is a demonstration of display capabilities rather than a working system, the data are pre-processed.

3. THE DECISION SUPPORT SYSTEM

The term "decision support system" (DSS) is frequently used in contemporary geographic literature when referring to computer assisted geographic analysis. Cowan (1988) implies that any Geographic Information System (GIS) is a DSS when he defines GIS as "a decision support system involving the integration of spatially referenced data in a problem-solving environment". Honea, Hake and Durfee (1991) are all inclusive when they describe a DSS as "any device ... used by humans to better understand the information necessary to make a decision ... anything from the back of an envelope used for scribbling ideas to a sophisticated GIS running on a CRAY XMP". Such statements overlook the substantial body of literature characterizing decision support systems that was initiated by Gorby and Morton's paper in 1971. That treatise described the evolution of DSS from information systems of the late 1960s and early 1970s and depicted shortcomings of Information Systems of the day (Densham 1991). Viewpoints such as Cowan's and Honea et al tend to treat the concept of the decision support system as a vague ideal rather than the well defined genre in operations research and the business world that it is.

Most definitions of DSS in the established literature include Geoffrion's (1983) six distinguishing characteristics:

1. They are explicitly designed to solve ill-structured problems where the objectives of the decision maker and the problem itself cannot be fully or precisely defined.
2. They have a user interface that is both powerful and easy to use.
3. Such systems enable the user to combine analytical models and data in a flexible manner.
4. They help the user explore the solution space (the options available) by using the models in the system to generate a series of feasible alternatives.
5. They support a variety of decision-making styles and are easily adapted to provide new capabilities as the needs of the user evolve.
6. Such systems allow problem solving to be both interactive and recursive - a process in which decision making proceeds by multiple paths, perhaps involving different routes, rather than a single linear path.

Other observed characteristics are:

1. the focus on a limited problem domain;
2. the use of analytical and statistical modeling capabilities;
3. the reliance on graphic displays to convey information to decision-makers; and
4. adaptability to various decision making styles (Armstrong and Densham 1990).

The value of a DSS to the decision making process comes from its attribute as an iterative, integrative, and participative process. The process is iterative because a set of alternative solutions is presented for the decision-maker's evaluation. Insights gained are integrated into the definition of further analysis. It is participative because the decision-maker combines his or her expert knowledge and value judgements with the insight gained from alternate scenarios to redefine the problem, conduct analysis and evaluate outcomes (Densham 1991).

The descriptions of structures of DSS usually reflect, to greater or lesser extent, the framework defined by Ralph Sprague (Sprague 1980; Sprague and Carlson 1982). That framework exhibits three levels of technology. First is the DSS toolbox. This includes the software and hardware components that can be assembled to build the appropriate system modules. Second is the DSS generator, a set of compatible hardware and software modules that can be configured to produce the final level, a specific DSS. A specific DSS is used to address a particular problem by using some or all of the modules in the DSS generator. As the nature of the problem or the needs of the decision-maker change, other modules can be added to the specific DSS from the generator or from components of the toolbox (Densham 1991).

The classic DSS generator consists of five integrated software modules, providing functionally related capabilities. The modules are for (a) database management, (b) model management, (c) display, (d) report generation, and (e) a user interface (Densham 1991).

Database Management

The database management module of a DSS must be able to store and manipulate both locational and non-locational data that are pertinent to the analysis. Locational data include spatial primitives such as latitude and longitude or county and state identifiers. Non-locational, or thematic data relevant to this thesis include electric generating capacity, the number of kilowatt hours generated, fuel type, construction date and planned retirement date. The type of database management system varies with the application. Relational data models such as dBASE and FoxPro are widely available commercial packages that are easily integrated into decision support systems. The extended network model is extolled by some researchers as especially effective for representing many forms of spatial relationships (Armstrong and Densham 1990).

For many applications however, a less elegant data structure is sufficient. A simple database, one without relational features, is any computerized list of information. Daniel Gasteiger claims that the world's most popular

PC database management system is Lotus 1-2-3 (1990). Irrespective of the claim, Lotus 1-2-3 was selected as the database component for this DSS for the following reasons:

1. A simple database was suitable for the specified task.
2. Lotus 1-2-3 is a familiar product to many managers.

2a. Two characteristics of a DSS are flexibility and ease of use. Because this software was conceived as a demonstration project, it is not assumed that all desired scenarios are foreseen by the designer. It is assumed that the user will modify and update the database or introduce complementary data, such as projected power demand or industrial consumption figures. Lotus 1-2-3's near ubiquity and the simplicity of its macro language were major considerations for its inclusion in this system.

3. Lotus 1-2-3 allows fast search and extract functions from RAM.
4. Surfer, the modeling software, accepts Lotus 1-2-3 spreadsheets as an input format.

The top row of the spreadsheet contains field names; plant name, state name, OEA assigned plant identification number, FIPS code, latitude, longitude, generating capacity

(megawatt hours), number of kilowatt hours generated (1985), and primary fuel type. Each record falls within a single row and each field falls within a single column. The database for the SERC region contains 304 records, or 304 aggregated generating sites (see Figure 2).

The database is initialized by typing "123". The /fr¹ (file retrieve) command displays the names of all available worksheets. A response of SERCPP (for SERC power plants) imports the proper data file.

ACTIVE (1988) SERC STATES POWER PLANTS								
Plant Name	State	Plant ID	FIPS	Lon	Lat	Capacity (mw)	KWH Generated (1985)	Fuel
GANTT	AL	53	1039	-86.3728	31.4097	40	No Data	COAL
BARRY	AL	3	1097	-87.9992	31.0083	1599	8512438272	COAL
TOMBIGBEE	AL	56	1129	-87.9055	31.5028	520	2334810368	COAL
MILLER	AL	6002	1073	-86.968	33.6269	1333	4792410112	COAL
E C GASTON	AL	26	1117	-86.4469	33.243	1932	11826806784	COAL
GADSDEN NEW	AL	7	1055	-85.9731	34.013	135	815843840	COAL
WIDOWS CREEK	AL	50	1071	-85.7544	34.8839	1794	5370015744	COAL
COLBERT	AL	47	1033	-87.8486	34.7439	1672	7371022336	COAL
GORGAS NO 2	AL	8	1127	-87.1919	33.7653	1272	7052238848	COAL
GREENE COUNTY	AL	10	1063	-87.7864	32.6014	509	3364342528	COAL
BANKHEAD DAM	AL	2	1125	-87.4486	33.3139	93	No Data	HYDR
WEISS DAM	AL	20	1019	-85.6433	34.2828	78	No Data	HYDR
LAY DAM	AL	15	1021	-86.6992	32.8708	255	No Data	HYDR
HENRY DAM	AL	11	1015	-85.8411	33.7639	72	No Data	HYDR
HARRIS	AL	6188	1111	-85.4447	33.3019	147	No Data	HYDR
WHEELER	AL	49	1079	-87.3089	34.5528	363	No Data	HYDR
WILSON	AL	6440	1077	-87.6986	34.8764	629	No Data	HYDR
Point A	AL	55	1039	-86.4556	31.2714	5	No Data	HYDR
MARTIN DAM	AL	14	1121	-86.1442	33.4081	139	No Data	HYDR
SMITH DAM	AL	18	1127	-87.2858	33.7653	185	No Data	HYDR
MILLERS FERRY	AL	38	1131	-87.2617	32.0533	77	No Data	HYDR

Figure 2. Example of the Lotus 1-2-3 database.

¹Bold typeface indicates menu functions.

All of the necessary database functions are available from the /data menu, which allows for sorting, searching and extracting subsets. Several macros are provided to do these functions by predetermined criteria. For example, the procedure to select all power plants within specified states by a specified fuel type is described in a macro labeled "\F" (see Figure 3). A similar macro, "\S", selects all generating plants within one selected state. Also included are macros to sort the data by state and fuel type and to sort the data by FIPS code. It should be stressed, however, that since DSS is an iterative, participative process, these macros are not intended to preclude any that evolve from the insights gained by the decision-maker.

Macros are started by simultaneously pressing the alt key and the letter key representing the name of the macro. Data can be selected for modeling by extracting them to a new worksheet. A macro "\X", is provided for this purpose. The user is prompted for a descriptive name for the new worksheet, then the pointer returns to the front of the database. The procedure can be repeated as many times as necessary for various scenarios.

The /data menu allows the user to search for specific information and copy selected records to another area of the worksheet. This process is controlled through the Criterion Range. A Criterion Range is the area of the worksheet that 1-2-3 references when it processes queries against the

database; much like the query-by-example function of a conventional database manager.

```

\F {GOTO}AA3
  {GETLABEL "Select 1st state ",AA3}~ Select first state
  {GETLABEL "Select 2nd state ",AA4}~ Select second
state
  {GETLABEL "Select 3rd state ",AA5}~ Select third state
  {PANELOFF}{WINDOWSOFF}          Suppress redraws
  /D                               Data
  Q                               Query
  I                               Input
  A3.I307~                        Range
  C                               Criterion
  AA2.AA5~                        Range
  O                               Output
  O6.W312~                        Range
  E                               Extract
  Q
  {GOTO}AB3~                      Now select by
fuel
  {PANELON}{WINDOWSON}
  {GETLABEL "Select by fueltype ",AB3}~
  {PANELOFF}{WINDOWSOFF}          Suppress redraws
  /D                               Data
  Q                               Query
  I                               Input
  O6.W312~                        Range
  C                               Criterion
  AB2.AB3~                        Range
  O                               Output
  AA6.AI312~                      Range
  E                               Extract
  Q~                              Quit
  {GOTO}AB5~
  {GOTO}AB5~

```

Figure 3. A macro to select states and plants by fuel type.

The Model Base

Three approaches can be used to accommodate modeling within a DSS. The first is to use the macro programming capabilities built within the database management system. These capabilities simplify the manipulation and querying of the database. The second approach is to construct libraries of appropriate models selected from the previously mentioned toolbox. This approach allows a large number of models to be assembled. The models can then be addressed through a standard interface (Densham 1991).

Both of these approaches are implemented in the DSS described in this thesis. The third approach is known as a model based management system (MBMS). This approach is that of embedding components of algorithmic models in the DSS. Since many algorithmic solution methods are common among a number of analytical models, redundancy is almost eliminated. To employ a particular algorithm, the MBMS combines the required components in the necessary sequence, determined by specific formulae. However the scope of this thesis precludes detailed description of MBMS.

A recurring dissatisfaction among policy analysts appears in the literature concerning the failure of mathematical models to capture important aspects of spatial problems. This dissatisfaction is attributed to the practice of computer analysts and systems builders defining the dimension of the problem to be modeled. They define the

problem by their very selection of analytical capabilities provided to decision-makers (Densham and Goodchild 1989; Honea, Hake and Durfee 1991; Densham 1991; Dobson 1992). Rather, these commentators contend, the problem should be defined by the decision maker. The modeling technique defined by the decision-makers who funded this research is the statistical surface. The purpose of this thesis is not to pre-suppose the selection of that analytical method, but to describe the system integration required to accomplish the capability. Nonetheless, a subsequent section (section 4) documents the validity of the technique as a spatial analytical model.

The components selected from the DSS toolbox to accomplish a statistical surface are the modules of the software package named Surfer, from Golden Software. Surfer consists of three primary menu driven modules plus ancillary plotting and viewing programs. TOPO is a contouring program. SURF is an interactive graphics program that produces three dimensional surface representations to a screen, printer, or plotter. Both programs model gridded files created by the GRID module.

GRID's menu prompts include **Random**, **Function** and **Modify** (see Figure 4). Included in **Random** are the options for creating a regularly spaced grid from irregularly spaced data with x,y, and z coordinates.

[GRID] Random Function Modify Environ
Input data consists of irregularly spaced XYZ data points

GRID Version 4.03
Copyright (C) Golden Software Inc. 1989

F1=Help F3=Main F4=StoreAll F5=Directory Esc=Backup Arrow keys=Move pointer

Figure 4. Grid's main menu.

Among the sub-menus in **Random** are **Input**, **Output**, **Duplicate**, **Gridsize**, and **Methods**. The **Input** option will accept data as delimited ASCII or in Lotus 1-2-3 format. **Output** exports the completed grid either as a binary file or an ASCII file. It also assigns a name to the output file. **Duplicate** has options for handling data points with identical x,y coordinates. **Gridsize** specifies the resolution of the final grid. **Method** allows the choice of one of three gridding methods; Inverse distance, Kriging, and Minimum curvature. Inverse distance uses a weighted distance averaging interpolation technique. The weights are inversely proportional to the distance to the grid node. Data points closer to a given grid node are given more influence. Also, weights may be increased exponentially to increase the effect of the weighting function. Kriging is described in a separate

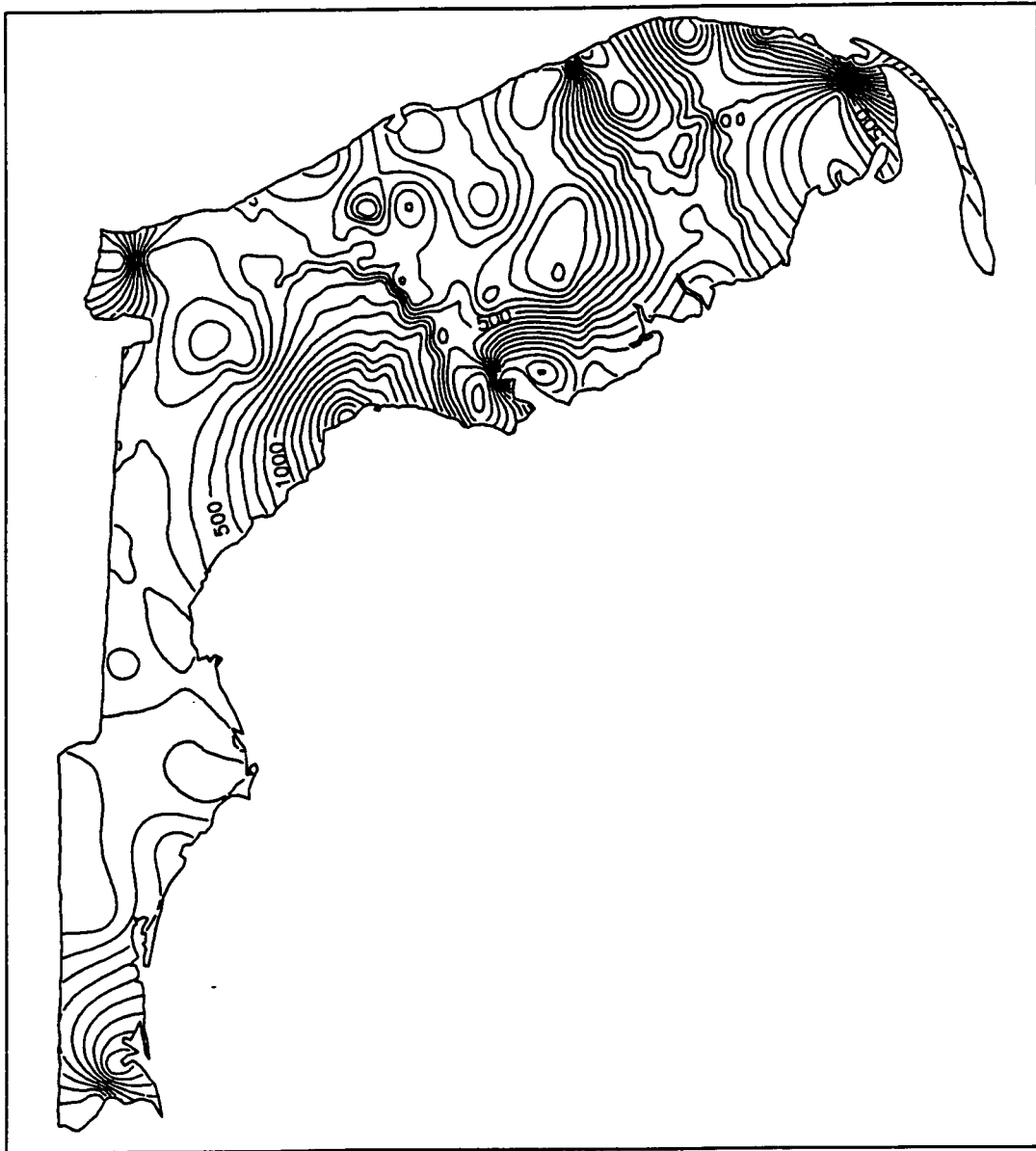
section. Minimum curvature is designed to produce exact replications of digitized contour lines and for high-density data collected along widely spaced transects (Hodler 1988). **Function** is for the creation of a grid from a user specified function of two variables in the form $z=f(x,y)$.

The **Modify** menu has provisions for smoothing a grid, blanking a portion of a grid, and performing mathematical operations between two existing grid files of the same size. Smoothing eliminates irregularities in the surface to produce a more visually pleasing plot. Two smoothing techniques are available. Spline smoothing fits a cubic spline to the input grid and interpolates additional values for the output grid. This produces a denser grid but preserves the original data points. The other technique, Matrix smoothing, uses a user defined matrix to weigh and average the values of the original matrix. The averaging process results in a smaller grid with lower highs and higher lows. The technique known as blanking allows the values in specified portions of a grid to be set to zero, resulting in flat regions in surface plots and the suppression of contour lines in contour maps. The technique is also used to create a defining mask, such as a state outline. The **Math** menu allows the user to mathematically combine two grids to form a third grid.

TOPO is a menu-driven program that produces contour maps on a computer screen, on a plot file, or on an in-

stalled plotter. A contour map is a representation of x,y, and z values, where the z value is defined by lines of equal values. The area between two neighboring contour lines contains only values within the range of the two contours. TOPO accepts as input a previously created grid in ASCII or binary format. The values of the contour lines are determined by defining the minimum, maximum, and interval values, or by reading a data file that contains specified contour levels. Scale (size of the plot) is determined by specifying either the length of the longest side of the plot or the number of data units per inch. TOPO calculates the length of the shorter side to maintain proportion. Contour lines can be labeled or unlabeled, dashed or continuous, smoothed or not, and differentiated by color zones (see Figures 5-7). Each contour lying within a color zone will use the color specified by a predetermined color zone file.

Like the other modules in Surfer, SURF is menu-driven. It is an interactive program that produces statistical surface output to a computer screen or plotting device. Input is previously gridded data in ASCII or binary format. SURF supports two projections. Orthographic is more suitable when measurements are needed from the surface, as parallel lines remain parallel. Perspective looks more natural to the human eye because parallel lines appear to converge at a distance. The surface can be rotated along the x axis or tilted along the y axis. Hidden lines also



Florida's Total Generating Capacity

Figure 5. TOPO representation of Florida's electric power generating capacity.



Generating Capacity w/o Nuclear

Figure 6. TOPO representation of Florida's generating capacity without nuclear plants.

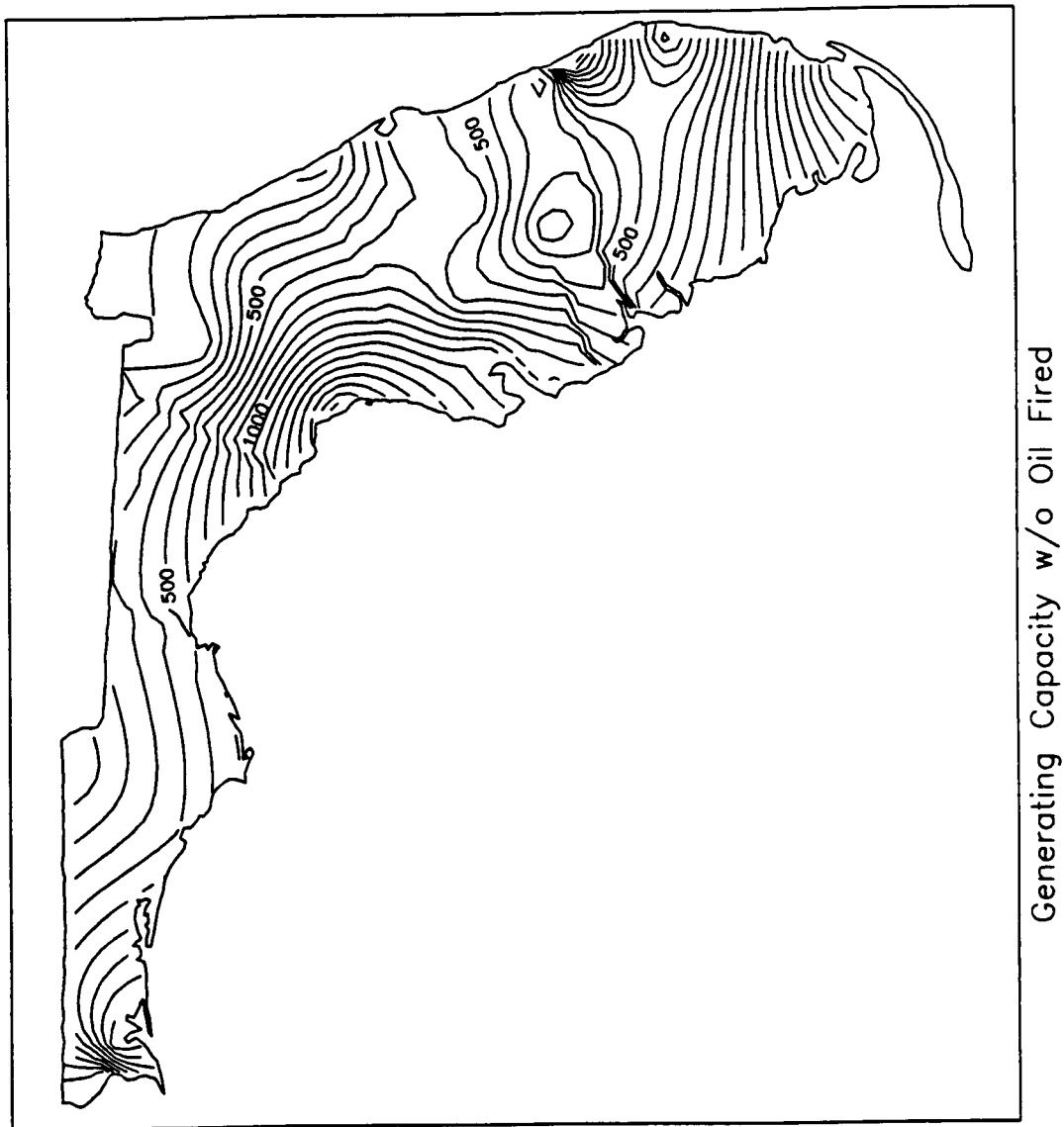


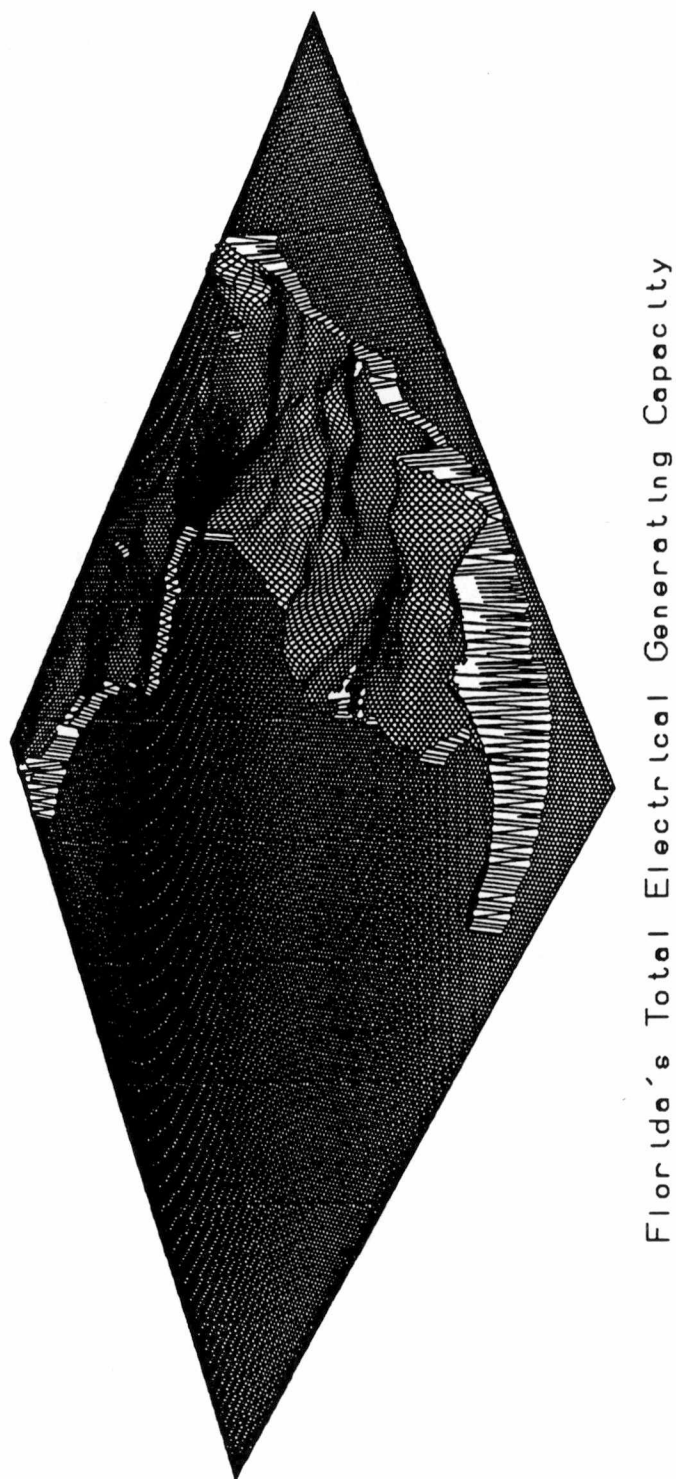
Figure 7. TOPO representation of Florida's generating capacity without oil fired plants.

can be removed (see Figures 8-10). As with TOPO, a color zone file can be created, allowing data within user defined ranges to be displayed in different colors. Thus, a continuum can be created, with, for example, reds as highs and blues as lows (Surfer 1989).

Display and Graphic and Tabular Reports

The traditional visualization tool for spatial data is the paper map, however maps are limited to the two dimensions of a sheet of paper. But just as spatially referenced data are no longer stored primarily in analog form, they no longer have to be presented or viewed solely in analog form. The advances in computer technology provide the ability to easily present spatial data as three-dimensional representations, or even animated data. Battenfield and Mackaness (1991) argue that the application of geographic visualization should provide additional insight with respect to geographic data analysis, presentation and decision making.

The files created by the modeling software Surfer (see The Model Base in this chapter) can be viewed on the computer monitor by Surfer's VIEW program. VIEW has menu features that allow the plot to be seen enlarged, reduced, or enlarged in sections. VIEW will display plot files that can be made from one or more contour maps or surface plots. VIEW divides the screen into four sections; the viewing area, the command menu, the line number display, and the message line.



Florida's Total Electrical Generating Capacity

Figure 8. SURFER representation of Florida's electric power generating capacity.

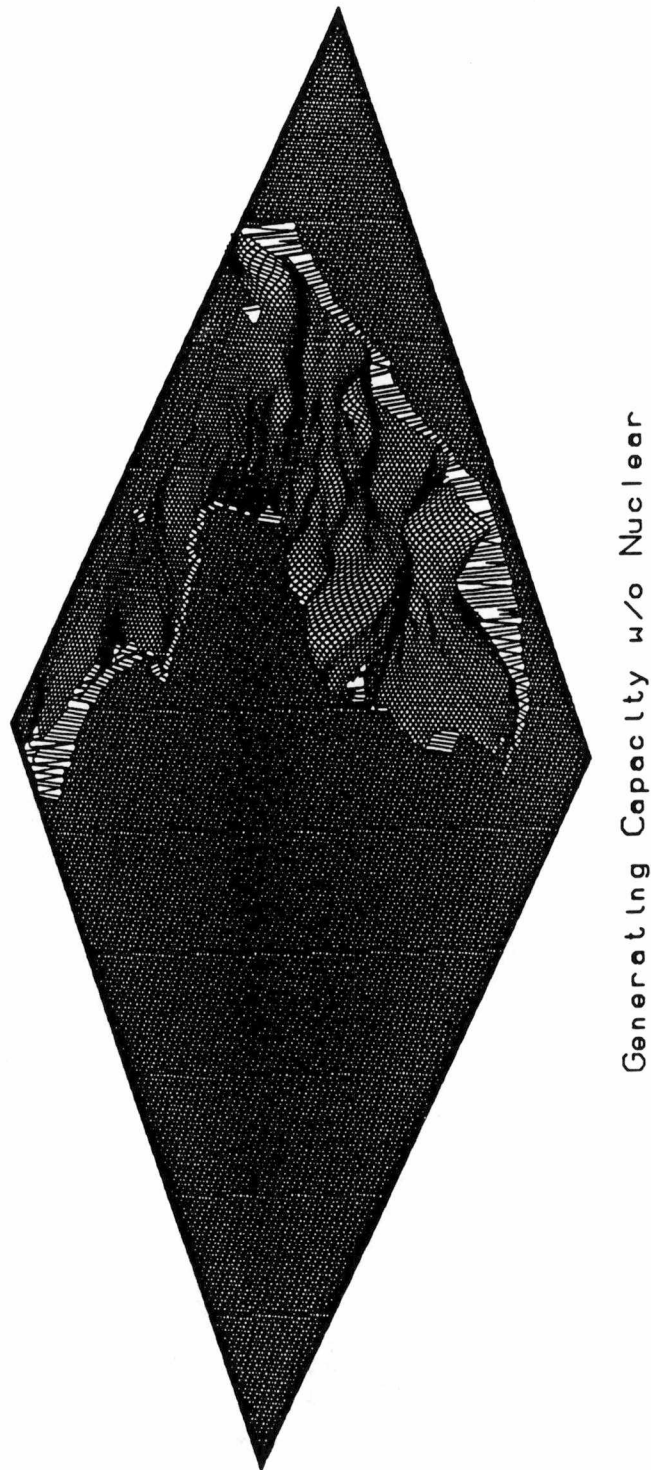


Figure 9. SURFER representation of Florida's electric power generating capacity without nuclear plants.

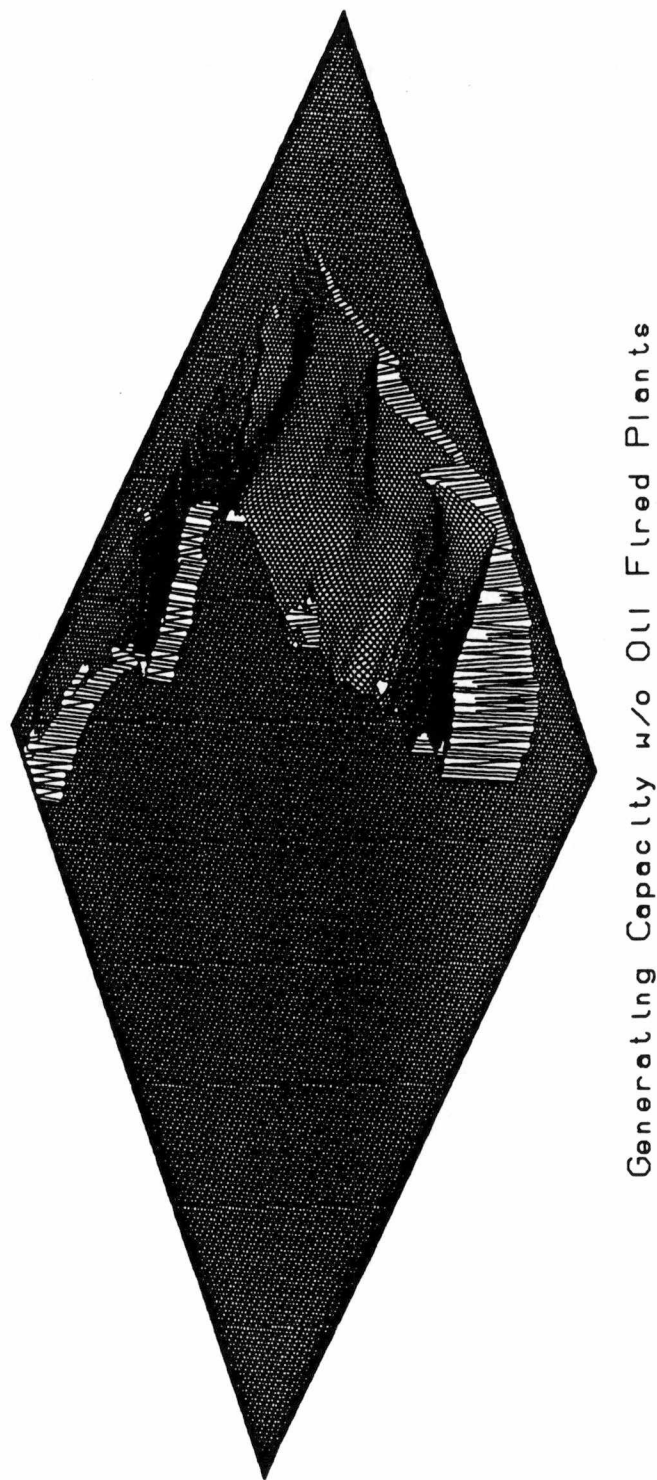


Figure 10. SURFER representation of Florida's electric power generating capacity without oil fired plants.

The command menu is a vertical menu of available commands on the left side of the screen. The line number display, in the lower left corner, indicates how far VIEW has progressed through the file at a given time. The message line, on the bottom of the screen, lists the available options.

The user can interrupt the progress at any time, alter the viewing parameters, and VIEW will begin redrawing the file from the beginning with the new parameters. This allows the user to reposition rapidly or scale a plot without waiting for a drawing to finish or without redrawing the entire plot each time. The user also can use the arrow keys to pan the plot while it is being drawn. VIEW includes a **trace** command to allow stepping through a plot one line at a time. This is useful for debugging purposes.

VIEW supports five graphics adapters:

1. IBM Color Graphics Adapter (640 x 200),
2. IBM Enhanced Graphics Adapter (640 x 350),
3. Hercules Monochrome Graphics Adapter (720 x 348),
4. Olivetti Graphics Adapter (640 x 400), and
5. IBM Video Graphic Array (640 x 480).

Contour maps and surface plots can also be plotted on a variety of printers and plotters by the PLOT program. Like the VIEW program, the PLOT program allows the user to shift or scale the plot.

Output can also be produced in AutoCad .DXF, Lotus .PIC and Hewlett Packard HPGL .PGL file formats. This allows for

easy importing into computer assisted design (CAD) and desktop publishing packages (Surfer 1989). These file formats also serve as exchange mediums with software that has no direct means of data exchange.

Reports can be obtained from the database by using Lotus 1-2-3's /p (print) command (see Database Management in this chapter). This command allows access to several levels of print options that allow the user to print worksheet data and graphs for draft review. The /p command allows data to be sent directly to a printer or saved in an ASCII file so that they can be transferred to other software, such as Surfer, or a word processor (Desposito 1992).

The User Interface

The user interface is the means by which the user communicates with the various modules of the decision support system. Because this decision support system is, in large part, an integration of stand-alone software products, each module is supplied with an interface, most often in the form of pull down menus. The interface for each individual module is described in the appropriate section.

The bridge between the various modules is the Batch Enhancer facility of Norton Utilities. The Batch Enhancer is a set of commands that allows, along with other functions, the capacity to create drop down windows (Elliot 1992). Through a series of drop down windows the user can enter the interface

of the desired module and return to the Batch Enhancer when finished. He is then positioned to request the next module (see Figure 11).

Demonstration of the DSS

Assume that the OEA is preparing for the contingency of a repeat of the 1974 oil embargo of the United States by petroleum producing countries. Assume also that the immediate analysis focuses on the effect that such an embargo would have on Florida's electric generating capacity if all oil fired plants were shut down. An analyst might wish to gain perspective of the state's capacity without the oil fired plants contrasted with the total present capacity.

The analyst first examines the database by initializing the user interface by typing "oea" and selecting "lotus123" from the menu. The SERC database now appears. Scrolling across the screen reveals the plant name, state, plant id number, FIPS code, longitude, latitude, generating capacity, the reported kwh generated in 1985, and the primary fuel type. An initial examination shows that Florida has fifty-one plants in the file, of which thirty-three, or almost sixty-five per cent, are oil fired. Further examination shows that, of the total generating capacity of 25,879 megawatts, 13,249, or slightly more than fifty-one per cent, comes from oil fired plants. Therefore, two subsets would

```

echo off
be cls
:start
be sa NORMAL
be window 0,0,24,79 bri whi on blue
be rowcol 0,23 "OEA Power Generation Model" bri white
be menus.scr
rem be ask " " bri white
be ask " " 123456 bri white
if errorlevel 6 goto end
if errorlevel 5 goto surf
if errorlevel 4 goto topo
if errorlevel 3 goto grid
if errorlevel 2 goto states
if errorlevel 1 goto lotus123
goto start
:states
states.exe
goto start
:topo
topo.exe
goto start
:grid
grid.exe
goto start
:surf
surf.exe
goto start
:lotus123
be cls
123
goto start
:end
BE SA NORMAL
be cls
rem menus.scr
rem open window
window 4,14,20,65 bri white on green zoom shadow
rowcol 6,31 "=====MAIN MENU=====" BRI YEL
ROWCOL 8,22 " 1 - Determine criteria with LOTUS 123" BRI
WHITE
ROWCOL 9,22 " 2 - Build State outline mask" bri white
rowcol 10,22 " 3 - Calculate matrix with GRID" bri white
rowcol 11,22 " 4 - Create isarithmic map with TOPO" bri
white
rowcol 12,22 " 5 - Create surface with SURF" bri white
rowcol 13,22 " 6 - Quit" bri white

```

Figure 11. Sample commands to drive Batch Enhancer

likely be extracted from the SERC database; one with Florida's total capacity, and one with the oil plants excluded. A subset spreadsheet is generated by the "/f" macro, which prompts the user to select the states and fuel types of interest by following these instructions (see appendix H):

While depressing the "alt" key, press "f" --
You will be prompted to select three states (use postal abbreviations). If fewer than three states are desired, reply "return" to the prompts. The entire SERC region can be selected by replying "~all" (tilde all) to the first prompt.

Next, you will be asked to select a fuel type. Again, "~all" (tilde all) will select all types, otherwise, type either "oil", "gas", "hydr", "coal", or "nucl". One fueltype can be excluded from the choice set by replying "fuel", (tilde fuel), (e.g. ~nucl). Data for the states and fuel types that you have selected have now been move to another section of the worksheet.

To save the subset for modeling, it must be extracted to a new worksheet. To do this, while depressing the "alt" key, press "X". You will be prompted to choose a descriptive file name for your new worksheet (e.g. FLGAS for Florida gas). The pointer now returns to the front of the worksheet. You can repeat the procedure for other scenarios, or exit.

To exit, type /QY

The modeling software requires a bit of housekeeping on extracted worksheets. Failure to do so will require a power down boot if you try to import your new worksheet into GRID, the interpolation package. Again, type "123" if you have exited Lotus. When the "ready" light appears, type /FR (file retrieve) then press "return". Type the new file name (e.g. FLGAS)
Press "home"
Press "F9" (calc)
Type /FS then press return
Type "R" (replace old file with new)
Type /QY (exit Lotus)

Recap of keystrokes:

```

to initialize:
    select lotus123
to select:
    alt F
    first state
    second state (or return)
    third state (or return)
    fuel type

to extract:
    alt X
    new file name

housekeeping:
    123 (if not active)
    /FR new filename
    home
    F9
    /FS return
    R
    /QY

```

The subsets are ready to be imported by the modeling software.

The modeling software will use an outline of the selected states as a mask during both interpolation and display. This outline is known as a blanking file, thus, it has an extension of .bln.

To create a .bln file, at the DOS dot prompt, the user selects "states" from the user interface. A menu of SERC state names will appear. The arrow keys allow the user to move through the menu, after which, he presses "return" to select states and "esc" when finished with the selection. The next prompt asks for a descriptive name, ie ALGA (Alabama, Georgia) or a return for the default (states.bln).

The modeling software consists of three modules: GRID, which interpolates x, y, & z data values to a grid: TOPO,

which displays the output of GRID as a contour plot, and SURF, which displays the same output as a 3-D surface representation.

To create the matrix for interpolation, the user follows these instructions:

Select GRID from the user interface.

- At the menu, highlight "random" or enter "r" and return.
- At the menu, highlight "input" or enter "i" and return.
- At the menu, highlight "xternal" or enter "x" and return.
- At the menu, highlight "wk1" or enter "w" and return.

Type the file name extracted from Lotus.

Respond with "return" to the next three prompts.

Press "esc" to return to the main menu.

- At the main menu, highlight "limits" or enter "l" and return.

GRID interpolates between data points, but does not extrapolate to the edge of the edge of the map. To accomplish this, reset the minimum and maximum x & y values of the grid to correspond to the extremes of the state boundaries that you have selected. See the table at the end of appendix H.

- At the menu, highlight "begin" or enter "b" and return.

The next steps are to smooth and mask the grid.

Theoretically, GRID will allow these steps now, but, due to limitations with the package, memory allocations become exceeded. Therefore, the user must exit and reenter GRID.

- Press "esc".
- Press "esc".
- Reply "yes" to exit.
- Type GRID
- At the menu, highlight "modify" or enter "m" and return.
- At the menu, highlight "smooth" or enter "s" and return.
- At the menu, highlight "spline" or enter "s" and return.

Input the grid file:

- Type the output file name from interpolation (e.g. FLGAS).
- Press "return" for the remaining prompts in this window.
- At the prompt "BEGIN CREATING GRID" type "yes" or return.
- At the prompt, press "esc".
- At the menu, highlight "blank" or enter "b" and return.
- Press return until prompted for an output file. Choose a descriptive name (e.g. FLGAS.GRD). This will be the final grid. At the .bln prompt, enter the name of the file that was created with program "states". At the prompt "BEGIN CREATING GRID" type "yes" or return.
- Press "esc"
- Press "esc"
- Press "yes"

The grid is now complete.

The user may now choose to create a contour map or a 3-D surface representation.

To create a contour map, the user follows these instructions:

- Select TOPO from the user interface.
- Select "input"
- Type the name of the grid file
- Press "return" to the next four prompts
- Select "XYLine"
- Type the name of the blanking file
- Press "return" or select a new color (see color table)
- Press F2 to view

To create a 3-D surface representation, the user follows these instructions:

- Select SURF from the user interface.
- Select "input"
- Type the name of the grid file
- Press "return" to the next four prompts
- Select "view"
- Type either "O" or "P" for projection
- Select viewpoint in relation to zero (due east) or return for default.

"Tilt after rotation" is the imagined altitude. Adjust to fit the situation or return to accept the default.

- Return
- Return
- Return
- Select "xyline"

- At the main menu, press F2 to view.
- Press "esc".
- Reply "yes" to exit.

Hard copy black and white versions of these displays are presented in figures 5, 7, 8, and 10.

The isarithmic and perspective models and the interpolation methods used to create them are discussed in the following sections.

4. ISARITHMIC AND PERSPECTIVE MAPS

AS MODELS

Statistical data can be represented in various ways. Common among analytical techniques are tabular reports, bar charts, and pie diagrams. Statistical data that have associated areal characteristics can be referred to as statistical surfaces, or quantitative geographical volumes. These spatially referenced data can be represented, in addition to the methods mentioned, as maps. Arthur Robinson states that "in order to comprehend any geographical volume, it is necessary to visualize it, actually or imaginatively, and the usual way is to think of it as varying vertically over area with reference to some smooth datum." Robinson goes on to say that "the major purpose of such maps is to present the totality of the data in such a way that the variation from place to place of the surface formed by it is evident..." (Robinson 1961).

Any type of data that changes in magnitude and exists either actually or hypothetically in continuous fashion over area constitutes a statistical surface. The surface need not be an actual tangible surface, such as land. It can be assumed to exist for any distribution that can be conceived of as being continuous and measured on an ordinal, interval, or ratio scale. Whenever the values assigned to areal units are conceived to have a vertical dimension, the values can

be visualized as forming a three-dimensional surface. The x and y values refer to the horizontal axis, and the z values refer to the assumed relative heights above a horizontal datum, an assumed surface of zero z values. To display overall interrelation of the magnitudes of data, the total mass is commonly conceived of as forming a volumetric distribution. The continuous statistical surface of that volume is usually portrayed by means of isarithms, or contours. In much the same way that a contour map shows the relief of the land, the patterns of the isarithms show the gradients, troughs and ridges of abstract statistical data.

According to Robinson, Sale, and Morrison (1978), there are two classes of z values that differ in terms of the precision with which they can specify a statistical surface; actual or derived values that can occur at points, and actual or derived values that cannot occur at points. Examples of the former are elevation, the actual depth of precipitation, a mean monthly temperature, or, as in the current interest, the kilowatt hours of electricity generated from a specific location. Examples of the latter class are people per square mile, the ratio of one race of people to the total population of an area, or the total kilowatt hours generated in a utility district. In order to symbolize the undulations of a statistical surface with this type of data, it is necessary to assign the z values to specific points.

An isarithm is a generic term describing any trace of the intersection of a horizontal plane with a statistical surface. It is also called an isoline or isogram. Isarithms that show the distribution of actual or derived quantities that can exist at points are called isometric lines. Isarithms that display the distribution of quantities that cannot exist at points, and are thus less likely to indicate positional precision, are called isopleths.

The isarithmic approach assumes a continuous and smoothly undulating distribution of values. An assumption is necessary as to the magnitude of gradients that exist between known z values. The procedure for estimating the value of intermediate values in a series is known as interpolation. "... when no evidence exists to indicate a non-linear gradient between control points, interpolation becomes merely a matter of estimating linear distances on the map in proportion to the differences between the control point values." In contemporary computer routines interpolation usually consists of two steps; first, a primary, not necessarily linear, interpolation from the irregularly spaced data points to a square or rectangular grid of interpolated values, second, a usually linear interpolation of the preliminary matrix (Robinson, Sale, and Morrison 1978).

5. SPATIAL INTERPOLATION

The generation of contour maps and three dimensional surface representations requires that the data exist in a regularly spaced format, a grid, rather than in the irregularly spaced pattern which they are most often found in nature. A number of methods are available for converting irregularly spaced data to a regularly spaced configuration. This section introduces several interpolation procedures and discusses those found in the software provided for this decision support system.

Spatial interpolation is the process of inferring values for the areas between sites where known values exist. The value of the property is almost always an interval or scaled value. The use of interpolation in spatial analysis follows from the first law of geography, which is an observation that near points in space are more likely to have similar attributes or values than points that are far apart.

Spatial interpolation procedures are classified in several different ways:

Areal interpolations transfer data from one set of areas to another. An example is the interpolation of population counts to voting districts. This is a simple problem if the target zone is an aggregation of the source zone, but is more complex if the zonal boundaries are not

coincident. The concern of this thesis, however, is with point based interpolation.

Point based interpolation consists of approximate methods and exact methods. Approximate methods include (a) trend surface analysis, (b) Fourier series, and (c) distance weighted average methods.

Trend surface analysis is characterized by an output data structure that is a polynomial function that can estimate grid point values at any point in a matrix. The z value at any point is determined by various powers of x and y . A trend surface is a global interpolator, that is, it determines a single function which can be mapped across an entire region (Goodchild and Kemp 1990). Trend surface analysis fit polynomials or trigonometric functions by least square regression on spatial coordinates. Major shortcomings are; (a) variation in values in one part of the matrix affects the fit of the surface elsewhere; (b) the complexion of an entire surface can change due to outlying variables or when enough values are included in the function to retain local detail, a characteristic of all global interpolators; and (c) smoothing tends to cause a lack of detail (Oliver and Webster 1990).

A Fourier series is a global interpolator that approximates a surface by overlaying a series of sine and cosine waves. It is rarely used in spatial analysis and is mentioned here only for completeness.

Distance weighted average estimates are the averages of z values at a given number of known points. The formula is $z = \sum w_i z_i / \sum w_i$, where w is some distance function.

Variations on this widely used method include diverse distance functions, variations on the number of points, and changing the direction from which they are selected.

Exact interpolators honor the given data points, that is, the surface passes through all points. Exact point based methods include (a) proximal interpolation, (b) B-splines, and (c) Kriging. A Proximal interpolator is a local interpolator, one that applies an algorithm repeatedly to a small part of the set of points. All values are assumed to be equal to the nearest known point. Thiessen polygons, formed by the perpendicular bisector of the distance between each pair of points, constitute the output data structure.

B-splines are local interpolators that produce a continuous surface with minimum curvature. B-splines are best for very smooth surfaces (Goodchild and Kemp 1990). A B-spline interpolator is included in the Surfer software package, described elsewhere in this thesis.

Kriging is an interpolation method that is becoming widely used in spatial analysis because it is based on a model of stochastic spatial variation rather than the purely mathematical methods of other interpolants. The random distribution of points more nearly reflects geographical

distribution (Oliver and Webster 1990). Kriging is based upon the rate at which the deviation, or variance between points changes over distance. This is expressed by showing how the average difference between values at locations changes with distance between locations by a device called a variogram.

A variogram is derived by inputting data from irregularly spaced sample points and dividing the range of distance into a set of discrete intervals. The distance for every pair of points is computed, along with the squared difference in the z values. Each pair of points is assigned to a distance range, and the total variance in each range is accumulated. The variance at each distance range is then computed, and the value is assigned to the midpoint distance of each range. The variogram is then used to estimate distance weights for interpolation. The interpolated values are the sum of unbiased weighted values of the known points, with the weights determined by the distance between known and interpolated points (Goodchild and Kemp 1990). A Kriging interpolator is included in the Surfer software package.

6. DISCUSSION AND CONCLUSION

A trend of thought exists among certain theorists in spatial analysis that advocates the broad dissemination of spatially referenced data. Edward Wenk once argued that the survival of democracy rests upon reducing disparities in access to information (National Science Foundation 1986). He urged colleagues to give great consideration to methods of enhancing wisdom, in the form of better decision-making, by making information available to individuals outside the existing 'college of cardinals'. Wenk observed that society needs people who can facilitate communication between the information-producing and the decision-making communities.

The undercurrent of discussion at the 1986 conference that preceded the formation of the National Center for Geographic Information and Analysis concerned the distribution of data to the user community (National Science Foundation 1986).

Administrators and policy makers are to be commended for seeking innovative ways to understand the spatial problems with which they are presented. However, those seeking to understand the geographic distribution of a particular phenomenon must constantly be aware of the dangers of making complex issues too simple. Incumbent upon the knowledge users rest the responsibility to interpret data in a manner that reveals their true nature. It is the

responsibility of the knowledge users to recognize that, although the use of statistical surfaces and isarithmic maps in the manner described in this research yields a certain insight to the geographical distribution of data, the use of these methods in isolation can lead to the misinterpretation of the values being examined.

Specifically, it must be recognized that the values being examined here are discrete values that are associated with particular locations, or points. Cartographic practice often allows for discrete data to be displayed in a continuous representation if it can be assumed that the phenomenon exists everywhere on the map, both at and between observation points. This practice can be easily justified for many phenomena, such as temperature or rainfall. But, the practice requires the assumption that the value exists everywhere, not just at the points of measurement (Barber 1988). This is clearly not the case with the distribution of electrical power, which must by necessity, flow along highly constrained pathways in non-uniform quantities (transmission lines, with varying carrying capacities).

To allow a more balanced perspective of the nature of electric generating capacity, I recommend that the capabilities of the OEA Decision Support System be expanded. The capabilities should include the traditional methods of displaying magnitude at a point; a three-dimensional, isometric portrayal of a dot map (see Figure 12), and/or

graduated circle representations of the values (see Figure 13).

The procedures described in this thesis reflect the sentiments of those who argue that decision support capabilities be defined by the decision maker rather than the system designer. They are based upon a recognized need for the broad dissemination of data within the Federal community. Finally, they define a mechanism by which data collected to perform one specific function of government, that of regulation, can be used to perform far different functions, those of formulating policy and planning for future needs.

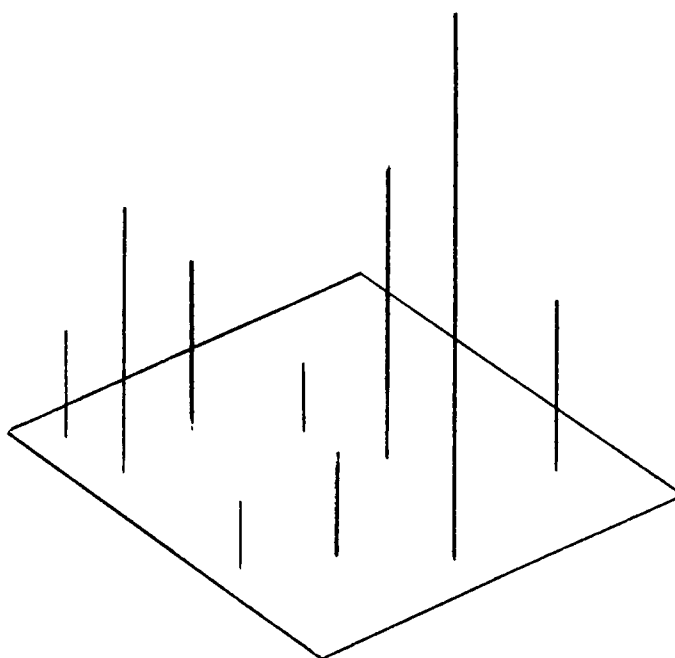


Figure 12. Example of a 3-dimensional representation of a dot map.

Florida Electric Power Generating Capacity and
Transmission Line Network

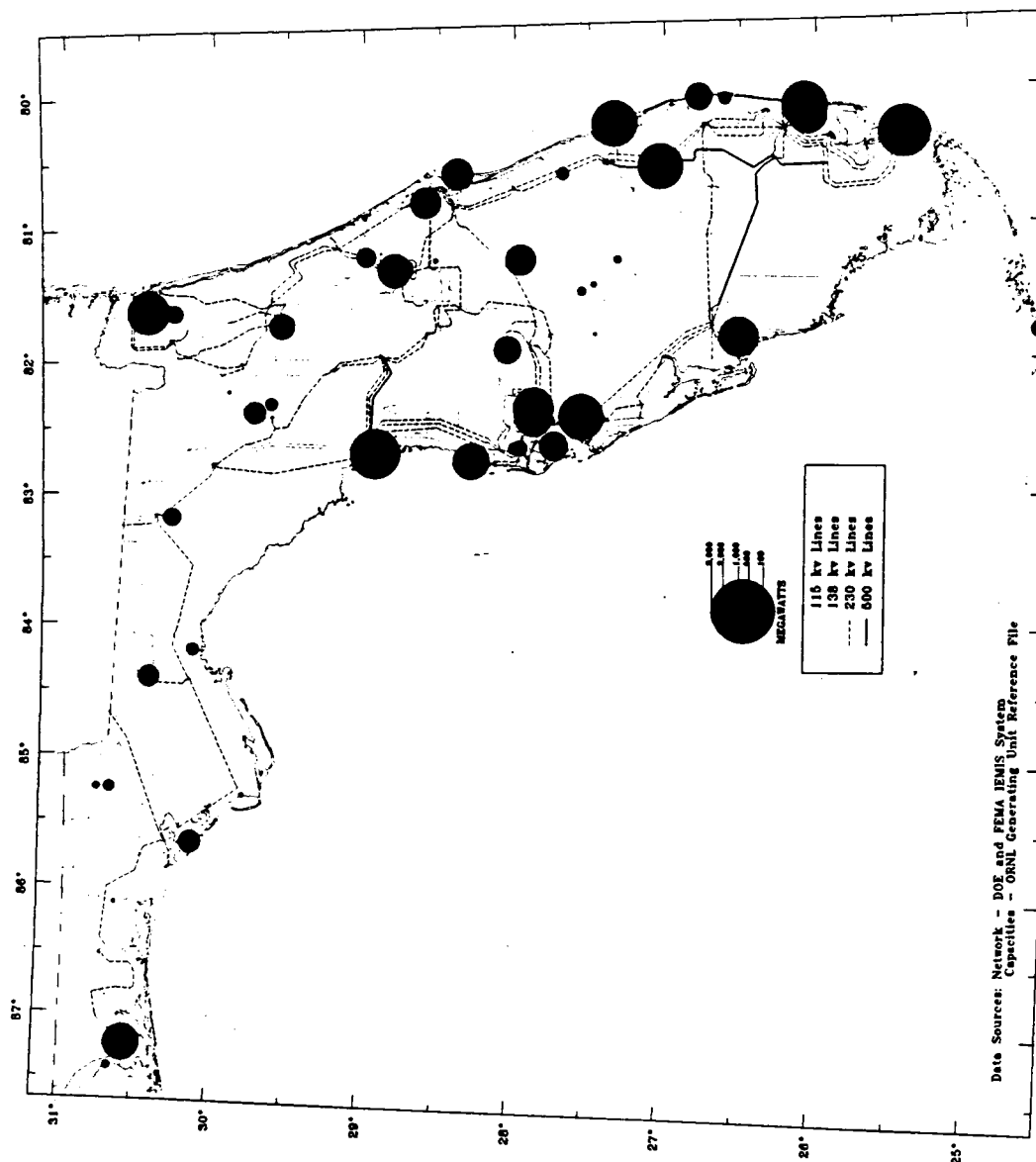


Figure 13. A graduated circle representation of Florida's electric generating capacity.

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APPENDIXES

APPENDIX A The Generating Unit Reference File (GURF)

AS11510000	DSNAME='A.D.FEL50489.NENGURF'	15	ST	12025	25	80	KEY WEST PLANT	19	2123	FO6	6583	S	1	5	0	0	CENT	1966	
NON	17 KEY WEST UTILITY BOARD	51503		12025	25	80	KEY WEST PLANT		2123		6583	S	8	6	0	0	CENT	1978	
	23 KEY WEST UTILITY BOARD	51503		12025	25	80	KEY WEST PLANT		2123	FO6	6584	S	1	1	0	0	HALF	1972	
NON	37 KEY WEST UTILITY BOARD	51503	37	ST	12025	25	80	STOCK ISLAND	37	2123	FO6	6584	S	7	IC1	0	0	HALF	1965
NON	2 KEY WEST UTILITY BOARD	51503	2	IC	12025	25	80	STOCK ISLAND	2	2123	FO6	6584	S	7	IC2	0	0	HALF	1965
NON	2 KEY WEST UTILITY BOARD	51503	2	IC	12025	25	80	STOCK ISLAND	2	2123	FO6	6584	S	7	IC3	0	0	HALF	1965
NON	2 KEY WEST UTILITY BOARD	51503	2	IC	12025	25	80	STOCK ISLAND	2	2123	FO6	6584	S	7	IC3	0	0	HALF	1965
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G1	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G2	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G3	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G4	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G5	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G6	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G7	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G8	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G9	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G10	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G11	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G12	0	0	NEDS	1970
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G13	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G14	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G15	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G16	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G17	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G18	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G19	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G20	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G21	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G22	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G23	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G24	0	0	NEDS	1972
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	613	S	8	G25	0	0	NEDS	1971
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	617	S	8	G1	0	0	NEDS	1971
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	617	S	8	G2	0	0	NEDS	1971
NG	37 FLORIDA POWER & LIGHT	51006	36	GT	12011	26	80	LAUDERDALE	34	1048	FO2	617	S	8	G3	0	0	NEDS	1971

APPENDIX B

A program to read the SAS GURF
dataset and rewrite it as an OS file.

```
//FELGURF JOB (50489),'LATHAM XCSD H-29',TIME=1,REGION=2048K
//OUT1 OUTPUT DEFAULT=YES,JESDS=ALL,DEST=RM057
//* gurf to os
// EXEC SAS,OPTIONS='PAGESIZE=52'
//OLD DD DSN=DRA.GURF.SAS.UPD29,DISP=SHR
//NEW DD DSN=A.D.FEL50489.NEWGURF,UNIT=DISK,
// SPACE=(TRK,(900,1),RLSE),
// DCB=(RECFM=FB,LRECL=247,BLKSIZE=32604),
// DISP=(NEW,CATLG,DELETE)
DATA XX;
SET OLD.TEST2;
PROC SORT;
BY LAT LONG;
DATA ZZ;
SET XX;
FILE NEW;
PUT AFUEL $ 1-3 ALT_USE $ 5 ALTER 7-14 CAPACITY 16-23 CO_NAME
$ 25-55 COMPANY 57-64 COOLING $ 66-68 DEPEND 70-77
DOE_PART $ 79-82 DOETY $ 84-85 FIPS 87-94 JOINT 96-103 LAT
105-112 4 LONG 114-121 4 NAME $ 123-142 NMPLT 144-151
ORCOM 153-160 PFUEL $ 162-164 PLANT 166-173 RETIRE 175-182
RTYPE $ 184-187 STATUS $ 189 TYPE 191-198 UNIT $ 200-202
UPCAPY 204-211 UPDATE 213-220 WATER $ 222-233 WHERELAT $
235-238 YEAR 240-247;
/*
//
```

APPENDIX C

A program to total the monthly
generation figures by plant ID, in
preparation for inclusion in model database.

```
//FELTOTAL JOB (50327,I2),'LATHAM XCSD H-29',TIME=(,15)
/*ROUTE PRINT RMT57
// EXEC SAS,OPTIONS='PAGESIZE=52'
//IN DD DSN=A.D.FEL50054.SAS.GEN85,DISP=SHR
//NEW DD DSN=T.FEL50054.SEMITOT.KWH,UNIT=SPDA,
// SPACE=(TRK,(20,5),RLSE),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=12960),DISP=SHR
DATA XX;
SET IN.GEN;
TOTKWH=SUM(GENKW01,GENKW02,GENKW03,GENKW04,GENKW05,GENKW06,
GENKW07,GENKW08,GENKW09,GENKW10,GENKW11,GENKW12);
DATA YY;
SET XX;
PROC SORT;
BY PLANT;
DATA ZZ;
SET YY;
FILE NEW;
PUT NAME $ 1-20 PLANT 22-29 TOTKWH 31-50;
PROC PRINT;
VAR NAME PLANT GENCNT NAMEPLT TOTKWH;
/*
//
```

APPENDIX D
A FORTRAN-SAS program to extract the
Appropriate data from the GURF file

```
//FELGURF8 JOB (50327,I5),'LATHAM XCSD H-29',TIME=(,50)
/*ROUTE PRINT RM57
/* * Power plant selection programs .....
// EXEC FORTHCLG
//FORT.SYSIN DD *
C.. This module sums the total 1985 output for all
C.. generators at a site..
C.. Input is the summation of monthly counts provided by
C.. program TOTKWH.SAS
      LOGICAL FIRST/.TRUE./
      XTOT=0.0
      ICOUNT=0
      IDX=0
10     CONTINUE
      ICOUNT=ICOUNT+1
      READ (20,15,END=40) ID,TOTKWH
15     FORMAT (24X,I5,10X,F11.0)
C     IF (ICOUNT.LE.50) PRINT 15, ID,TOTKWH
      IF ((.NOT.FIRST).AND.(ID.NE.IDX)) GO TO 30
      FIRST=.FALSE.
      XTOT=TOTKWH+XTOT
      IDX=ID
      GO TO 10
30     CONTINUE
      WRITE (6,35) IDX,XTOT
35     FORMAT (1X,I5,F20.0)
      WRITE (26,37) IDX,XTOT
37     FORMAT (I5,F20.0)
      IDX=ID
      XTOT=TOTKWH
      GO TO 10
40     CONTINUE
      STOP
      END

/*
//GO.FT26F001 DD DISP=(NEW,PASS),UNIT=SYSDA,
// DSN=&&TOTKWH,SPACE=(TRK,(500,3),RLSE),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=12960)
//GO.FT20F001 DD DISP=(SHR),
// DSN=T.FEL50054.SEMITOT.KWH
/*
// EXEC SAS,OPTIONS='PAGESIZE=52'
```

```

/* This module extracts selected power plant data for SERC
/* states from the ORNL GURF file
/*
//OLD DD DSN=DRA.GURF.SAS.UPD29,DISP=SHR
//NEW DD DSN=A.D.FEL25295.SERC.POWER.PLANTS,UNIT=3330V,
// SPACE=(TRK,(20,5),RLSE),
// DCB=(RECFM=FB,LRECL=87,BLKSIZE=12963),
// VOL=SER=VFEL02,DISP=(SHR)
DATA VV;
SET OLD.GURF;
PROC SORT;
BY PLANT;
DATA XX;
SET VV;
**** SELECT ONLY SERC POWER PLANTS;
IF FIPS GT 12000 AND FIPS LT 14000 OR FIPS GT 21000 AND FIPS
LT 22000 OR FIPS GT 28000 AND FIPS LT 29000 OR FIPS GT 37000
AND FIPS LT 38000 OR FIPS GT 45000 AND FIPS LT 46000 OR FIPS
GT 47000 AND FIPS LT 48000 OR FIPS GT 51000 AND FIPS LT 52000
OR FIPS GT 01000 AND FIPS LT 02000;
DATA YY;
SET XX;
**** SELECT ONLY ACTIVE POWER PLANTS ;
IF RETIRE LT 1 OR RETIRE GT 1988 ;
IF STATUS EQ 'S';
GENCAP=DEPEND;
IF DEPEND LT .01 THEN GENCAP=CAPACITY;
**** SORT BY COUNTY, IN PREPARATION FOR AGGREGATION;
PROC SORT;
BY FIPS LAT LONG;
DATA ZZ;
SET YY;
FILE NEW;
PUT NAME $ 1-20 GENCAP 22-29 1 LAT 32-39 4 LONG 41-48 4
STATUS $ 50 PFUEL $ 52-54 FIPS 56-60 PLANT 62-66 AFUEL
$ 68-70 RETIRE 72-78 RTYPE $ 80-83 UNIT $ 85-87;

/*
// EXEC FORTHCLG,PARM.FORT='LINECNT=52',
// REGION.GO=900K
//FORT.SYSIN DD *
C=====
C
C A PROGRAM TO SELECT THE PREDOMINANT FUEL TYPE AT A
C POWER PLANT SITE AND SUM CAPACITIES FOR A SITE....
C DATA IS FROM THE ORNL GURF FILE
C
C=====
C LOGICAL*1 FUEL1(3),FUEL2(3),STAT,STATUS
C LOGICAL*1 NAME1(20),NAME2(20)

```

```

        LOGICAL  PFUEL,  PFUEL1,  PFUEL2,  OTHR
        XDMS(A) = ((AMOD(A,1E2)/60.+INT(AMOD(A/1E2,1E2)))/60.+
&          INT(A/1E4))
        INTEGER ID(2100)
        RND(A)=IFIX(A+0.5)
        REAL*4 TOTKWH(2100),LAT1,LON1,LAT2,LON2
C..  Fill the ID array
        INDEX=701
        DO 4 I=1,INDEX
            READ (30,5,END=9) ID(I),TOTKWH(I)
5          FORMAT (I5,F20.0)
4          CONTINUE
9          CONTINUE
C          PRINT 666,(ID(I),I=1,INDEX)
666        FORMAT (1X,12I10)
600        CONTINUE
C..
        READ (20,15)
+          NAME1,CAP1,LAT1,LON1,STAT,FUEL1,FIPS,IPLANT
15         FORMAT
+          (20A1,1X,F8.1,1X,2F9.4,1X,A1,1X,3A1,1X,F5.0,I6)
C..  Change d.m.s. to decimal degrees
        LON1=XDMS(RND(LON1*1.E4))
        LAT1=XDMS(RND(LAT1*1.E4))
C..
        PRINT 16,
+          NAME1,CAP1,LAT1,LON1,STAT,FUEL1,FIPS,IPLANT
16         FORMAT
+          (1X,20A1,1X,F8.1,1X,2F9.4,1X,A1,1X,3A1,1X,F5.0,I6)
        TOTCAP=0.0
        IF (ICOMPA(STAT,'S',1).EQ.0) TOTCAP=CAP1
        CALL COMPAR(FUEL1,PFUEL1)
        CAP=CAP1
        PFUEL=PFUEL1
        ICOUNT=0
C..
C... Sum the generating capacity for a site
20        CONTINUE
        ICOUNT=ICOUNT+1
        READ (20,15,END=80) NAME2,CAP2,LAT2,LON2,
+          STATUS,FUEL2,FIPS2,IPLAN2
C..  Change d.m.s. to decimal degrees
        LON2=XDMS(RND(LON2*1.E4))
        LAT2=XDMS(RND(LAT2*1.E4))
        IF (ICOMPA(STATUS,'S',1).NE.0) GO TO 30
        CALL COMPAR(FUEL2,PFUEL2)
        IF ((LAT2.NE.LAT1).OR.(LON2.NE.LON1)) GO TO 32
        TOTCAP=TOTCAP+CAP2
        IF (CAP2.GT.CAP) PFUEL=PFUEL2

```

```

        IF (CAP2.GT.CAP) CAP=CAP2
30      CONTINUE
        GO TO 20
32      CONTINUE
C..
C....    Fetch the yearly generation totals
        CALL SEARCH(IPLANT,ID,INDEX,LOCN)
        IF (LOCN.GT.0) GO TO 46
C      PRINT 45,IPLANT
45      FORMAT (1X,'PLANT # ',I6, ' IS NOT IN THE KWHGEN
           FILE')
        LOCN=INDEX+1
        TOTKWH(LOCN)=0.0
46      CONTINUE
47      CONTINUE
C..
C..
C      PRINT 49,IPLANT,ID(LOCN),LOCN
49      FORMAT (1X,'IPLANT = ',I8, ' ID(LOCN) = ',I8,'
+          LOCN = ',I8)
        IF (PFUEL.NE.OTHR) WRITE (6,55)
+      NAME1,FIPS,TOTCAP,LAT1,LON1,
+      FUEL,IPLANT,ID(LOCN),TOTKWH(LOCN)
55      FORMAT (1X,20A1,2F6.0,2F9.4,2X,A4,2I5,F30.0)
        IF (PFUEL.NE.OTHR) WRITE (26,65)
+      NAME1,IPLANT,FIPS,LON1,LAT1,
+      TOTCAP,TOTKWH(LOCN),PFUEL
65      FORMAT (20A1,I5,F6.0,2F9.4,F6.0,1X,F30.0,A4)
C..    RESET VARIABLES
        TOTCAP=CAP2
        PFUEL1=PFUEL2
        PFUEL=PFUEL1
        CAP1=CAP2
        CAP=CAP1
        LAT1=LAT2
        LON1=LON2
        FIPS=FIPS2
        IPLANT=IPLAN2
        DO 70 I=1,20
           NAME1(I)=NAME2(I)
70      CONTINUE
        GO TO 20
80      CONTINUE
        CALL SEARCH(IPLANT,ID,INDEX,LOCN)
        IF (LOCN.GT.0) GO TO 86
C      PRINT 45,IPLANT
        LOCN=INDEX+1
        TOTKWH(LOCN)=0.0
86      CONTINUE

```

```

      IF (PFUEL.NE.OTHR) WRITE (26,65)
+     NAME1,IPLANT,FIPS,LON1,
+     LAT1,TOTCAP,TOTKWH(LOCN),PFUEL
      STOP
      END
C=====
C=====
C=====
C...
      SUBROUTINE COMPAR(FUEL,PRFUEL)
      LOGICAL*1 FUEL(3)
      LOGICAL OIL/'OIL '/, COAL/'COAL'/, HYDR/'HYDR'/,
+     NUCL/'NUCL'/
      LOGICAL GAS/'GAS '/,OTHR/'OTHR'/, PRFUEL
      PRFUEL=OTHR
      IF (ICOMPA(FUEL,'FO1',3).EQ.0) PRFUEL=OIL
      IF (ICOMPA(FUEL,'FO2',3).EQ.0) PRFUEL=OIL
      IF (ICOMPA(FUEL,'FO4',3).EQ.0) PRFUEL=OIL
      IF (ICOMPA(FUEL,'FO5',3).EQ.0) PRFUEL=OIL
      IF (ICOMPA(FUEL,'FO6',3).EQ.0) PRFUEL=OIL
      IF (ICOMPA(FUEL,'OIL',3).EQ.0) PRFUEL=OIL
      IF (ICOMPA(FUEL,'KER',3).EQ.0) PRFUEL=OIL
      IF (ICOMPA(FUEL,'BIT',3).EQ.0) PRFUEL=COAL
      IF (ICOMPA(FUEL,'ANT',3).EQ.0) PRFUEL=COAL
      IF (ICOMPA(FUEL,'COL',3).EQ.0) PRFUEL=COAL
      IF (ICOMPA(FUEL,'SUB',3).EQ.0) PRFUEL=COAL
      IF (ICOMPA(FUEL,'LIG',3).EQ.0) PRFUEL=COAL
      IF (ICOMPA(FUEL,'WAT',3).EQ.0) PRFUEL=HYDR
      IF (ICOMPA(FUEL,'NG',2).EQ.0) PRFUEL=GAS
      IF (ICOMPA(FUEL,'GAS',3).EQ.0) PRFUEL=GAS
      IF (ICOMPA(FUEL,'LPG',3).EQ.0) PRFUEL=GAS
      IF (ICOMPA(FUEL,'UR',2).EQ.0) PRFUEL=NUCL
C      IF (PRFUEL.EQ.OTHR) WRITE (6,25) FUEL
25     FORMAT (1X,'FUEL IS OTHER ,FUEL= ',3A1)
      RETURN
      END
C=====
C=====
C=====
C...
C...     BINARY SEARCH SUBROUTINE
C...
      SUBROUTINE SEARCH(ARG,TABLE,TABSIZ,LOCN)
C
C      Table lookup of 'ARG' in 'TABLE', by binary search
C      process of successively halving the table until the C
      desired argument is found, or the table is exhausted C
C      Input arguments:
C      ARG      Value searched for

```

```

C      TABLE   Array in which to search for the value
C      TABSIZ   Array size
C
C      LOCN     Location at which 'ARG' was found, or 0 if
C              not found
C
C      Variables:
C      LOW      Lowest subscript in currently active table
C              portion
C      HI       Highest subscript in currently active table C
C              portion
C      MID      Midpoint of currently active table
C      SIZE     Size of currently active table
C
C      INTEGER ARG, LOCN, TABSIZ, TABLE(TABSIZ)
C      INTEGER LOW, HI, MID, SIZE
C
C
C      LOW=1
C      HI=TABSIZ+1
C      SIZE=TABSIZ
C      LOCN=0
C
C      Main loop
C
C      10      CONTINUE
C              IF (SIZE.LE.0) GO TO 150
C              Halve the table, compute the midpoint
C              SIZE=SIZE/2
C              MID=(LOW+HI)/2
C              IF (ARG.LT.TABLE(MID)) HI=MID
C              IF (ARG.GT.TABLE(MID)) LOW=MID
C              IF (ARG.NE.TABLE(MID)) GO TO 10
C
C      Entry is found
C      LOCN=MID
C      150     CONTINUE
C              RETURN
C              END
C
C      //GO.FT26F001 DD DISP=(SHR),UNIT=3330V,
C      // DSN=A.D.FEL50327.SERC.PPLANTS.BY.FUELTYPE,
C      // SPACE=(TRK,(500,3),RLSE),
C      // DCB=(RECFM=FB,LRECL=90,BLKSIZE=12960)
C      //GO.FT20F001 DD DSN=A.D.FEL25295.SERC.POWER.PLANTS,DISP=SHR
C      //GO.FT30F001 DD DSN=&&TOTKWH,DISP=SHR
C      /*
C      //

```

APPENDIX E

A program to proportion a state's residential electric energy consumption to counties based upon county population. The program then assigns the estimate to county center points.

```
//FELPERCT JOB (50327,I4),'LATHAM XCSD H-29',TIME=(,20)
/*ROUTE PRINT RMT73
//STEP1 EXEC FORTVCLG,PARM.FORT='LINECOUNT(52),LANGLVL(66)',
//  CLSIZE=1500K,GOSIZE=1000K
//FORT.SYSIN DD *
    INTEGER STFIP
10    CONTINUE
    READ (20,15,END=30) STFIP,STPOP
15    FORMAT (I5,20X,F8.0)
    IF (STFIP.NE.12000) GO TO 10
    CALL PERCNT(STFIP,STPOP)
30    CONTINUE
    STOP
    END
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
    SUBROUTINE PERCNT(STFIP,STPOP)
C... Determine the percentage of total population (1980) in
C... each county, then proportion the total residential
C... electric energy consumption to each county, based upon
C... percentage of population.
    INTEGER CTYFIP,STFIP
    REAL*4 KWH
    LOGICAL*1 CTYNAM (20)
C.. Total residential electric energy consumption for
C.. Florida for
C.. 1984 -- 48831 Million kilowatt hours or 595.1 trillion
C.. BTU
C.. (DOE/EIA 0214(84)
    DATA TOTKWH /48831.0/ ,    TOTBTU /595.1/
C.
    TOTKWH=TOTKWH*1000000
    TOTBTU=TOTBTU*1E12
    NXTFIP=STFIP+1000
    KWH=0.0
    BTU=0.0
    TOTPCT=0.0
10    CONTINUE
    READ (20,15,END=40) CTYFIP,CTYNAM,CTYPOP
15    FORMAT (I5,20A1,F8.0)
    IF (CTYFIP.GE.NXTFIP) GO TO 40
```

```

PCTPOP=CTYPOP/STPOP
USEKWH=TOTKWH*PCTPOP
USEBTU=TOTBTU*PCTPOP

C.
C.   Verification variables
      KWH=KWH+USEKWH
      BTU=BTU+USEBTU
      TOTPCT=TOTPCT+PCTPOP

C.
      WRITE (30,25)
+      PCTPOP,USEKWH,USEBTU,CTYFIP,CTYNAM,CTYPOP
25   FORMAT (F8.5,2F16.1,I5,20A1,F8.0)
      WRITE (6,35) PCTPOP,USEKWH,USEBTU,CTYFIP,CTYNAM,CTYPOP
35   FORMAT (1X,'% OF POP. ',F8.5,2X,'USE (KWH)',F12.1,2X,
+   'USE (BTU)',F12.1,3X,'FIPS ',I5,1X,'CNTY ',20A1,
+   'CNTY POP ',F8.0)
      GO TO 10
40   CONTINUE
      WRITE (6,45) TOTPCT,STPOP
45   FORMAT
+   (1X,'TOTAL PERCENT = ',F10.6,3X,
+   'TOTAL STATE POPULATION = ',F9.0)
      WRITE (6,55) BTU,KWH
55   FORMAT
+   (1X,'TOTALED BTU = ',F12.6,3X,'TOTALED KWH = ',F12.3)
      RETURN
      END

/*
//GO.FT20F001 DD DSN=A.D.FEL50054.CENPOP.HOU7080,DISP=SHR
//GO.FT30F001 DD DISP=(NEW,CATLG,DELETE),UNIT=SPDA,
// DSN=T.FEL50054.FLA.POP.PERCENT,SPACE=(TRK,(500,3),RLSE),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=2400)
/*
//STEP2 EXEC FORTVCLG,PARM.FORT='LINECOUNT(52),LANGLVL(66)',
// CLSIZE=1500K,GOSIZE=1000K
//FORT.SYSIN DD *
C=====
C
C   A program to assign county residential electricity
C   demand to county centers
C
C   Data is from program PERCNT.POP
C
C   --   The program is presently set to consider   --
C
C           FLORIDA   FIPS CODE 12000
C
C=====
      INTEGER JFIPS(2000),JF(3125)

```

```

      REAL*4 XCENR(2000),YCENTR(2000),XC(3125),YC(3125)
C..
C..      Fetch and store county centers
      INDX=1
      DO 100 N=1,3125
100      CONTINUE
      READ (25,END=110) JF(N),XC(N),YC(N)
C..
C..      Select only Florida counties
      IF ((JF(N).LT.12000).OR.(JF(N).GE.13000)) GO TO
+      100
C..      Ignore multiple parts of counties
      IF (JF(N).EQ.JF(N-1)) GO TO 90
      JFIPS(INDX)=JF(N)
      XCENR(INDX)=XC(N)
      YCENTR(INDX)=YC(N)
      INDX=INDX+1
100      CONTINUE
110      CONTINUE
C
C=====
C=====
C..
C..      Do a binary search of county center array to assign
C..      x & y to counties
      WRITE (6,115)
115      FORMAT ('1',5X,'County FIPS Code',12X,'County
+      Center',9X,
+      'Total Annual Resedential Elect. Consumption
+      (kwh)',F20.1)
120      CONTINUE
      READ (26,123,END=140) USEKWH,IFIPS
      CALL SEARCH(IFIPS,JFIPS,INDX,LOCN)
123      FORMAT (8X,F16.1,16X,I5)
      WRITE (6,125)
+      JFIPS(LOCN),XCENR(LOCN),YCENTR(LOCN),USEKWH
125      FORMAT (24X,I8,11X,2F10.4,19X,F10.5)
C      WRITE (27,135)
C      +      JFIPS(LOCN),XCENR(LOCN),YCENTR(LOCN),USEKWH
      WRITE (27,137) XCENR(LOCN),YCENTR(LOCN),USEKWH
135      FORMAT (I8,1X,2F10.4,1X,F16.1)
137      FORMAT (2F10.4,1X,F20.1)
      GO TO 120
140      CONTINUE
      STOP
      END
C=====
C=====
C=====

```

```

C...
C...  BINARY SEARCH SUBROUTINE
C...
      SUBROUTINE SEARCH(ARG, TABLE, TABSIZ, LOCN)

C
C      Table lookup of 'ARG' in 'TABLE', by binary search
C      process of successively halving the table until the
C      desired argument is found, or the table is exhausted
C
C      Input arguments:
C      ARG      Value searched for
C      TABLE   Array in which to search for the value
C      TABSIZ   Array size
C
C      LOCN     Location at which 'ARG' was found, or 0 if
C              not found
C
C      Variables:
C      LOW      Lowest subscript in currently active table
C              portion
C      HI       Highest subscript in currently active table
C              portion
C      MID      Midpoint of currently active table
C      SIZE     Size of currently active table
C
C      INTEGER ARG, LOCN, TABSIZ, TABLE(TABSIZ)
C      INTEGER LOW, HI, MID, SIZE
C
C
C      LOW=1
C      HI=TABSIZ+1
C      SIZE=TABSIZ
C      LOCN=0
C
C      Main loop
C
C 10    CONTINUE
C      IF (SIZE.LE.0) GO TO 150
C      Halve the table, compute the midpoint
C      SIZE=SIZE/2
C      MID=(LOW+HI)/2
C      IF (ARG.LT.TABLE(MID)) HI=MID
C      IF (ARG.GT.TABLE(MID)) LOW=MID
C      IF (ARG.NE.TABLE(MID)) GO TO 10
C
C      Entry is found
C      LOCN=MID
C 150   CONTINUE
C      RETURN

```

END

```
/*  
//GO.FT25F001 DD DSN=PRC.CNTYDATA,LABEL=(,,,IN),DISP=SHR  
//GO.FT26F001 DD DISP=SHR,DSN=T.FEL50054.FLA.POP.PERCENT  
//GO.FT27F001 DD DISP=(NEW,CATLG,DELETE),UNIT=SPDA,  
//DSN=T.FEL50054.FLA.KWHUSE.BY.CNTYCNTNTR,  
// SPACE=(TRK,(20,3),RLSE),  
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400)  
/*  
//
```

APPENDIX F

```

C=====
C
C      A program to aggregate the electric power generating
C      capacities of power plants within a county and
C      assign that capacity to a county center.
C
C=====
      CHARACTER*1  STAT,STATUS
      INTEGER JFIPS(2000),JF(3125)
      REAL*4  XCENTR(2000),YCENTR(2000),XC(3125),YC(3125)
      WRITE (6,7)
7      FORMAT
+      (9X,'Total Electric Generating Capacity',9X,'County
FIPS Code')
      READ (20,15) CAP1,STAT,IFIPS1
15      FORMAT (21X,F8.1,20X,A1,5X,I5)
      TOTCAP=CAP1
      CAP=CAP1
      ICOUNT=0
20      CONTINUE
      ICOUNT=ICOUNT+1
      READ (20,15,END=80) CAP2,STATUS,IFIPS2
      IF (ICOMPA(STATUS,'S',1).NE.0) GO TO 30
      IF (IFIPS2.NE.IFIPS1) GO TO 50
      TOTCAP=TOTCAP+CAP2
      IF (CAP2.GT.CAP) CAP=CAP2
30      CONTINUE
      GO TO 20
50      CONTINUE
C..... Store capacity per county on a temporary file
      WRITE (6,55) TOTCAP,IFIPS1
55      FORMAT (22X,F8.1,30X,I5)
      WRITE (26,65) TOTCAP,IFIPS1
65      FORMAT (F10.1,I5)
C..      RESET VARIABLES
      TOTCAP=CAP2
      CAP1=CAP2
      CAP=CAP1
      IFIPS1=IFIPS2
      GO TO 20
80      CONTINUE
C..... Store capacity per county on a temporary file
      WRITE (6,55) TOTCAP,IFIPS1
      WRITE (26,65) TOTCAP,IFIPS1
C=====
C=====
C..

```

```

C..      Fetch and store county centers
          INDX=1
          DO 100 N=1,3125
190        CONTINUE
          READ (25,END=110) JF(N),XC(N),YC(N)
C..      Select only SERC counties
          ISTATE=JF(N)/1000
          IF ((ISTATE.NE.12).AND.(ISTATE.NE.13).AND
+           (ISTATE.NE.47).AND.(ISTATE.NE.21).AND.
+           (ISTATE.NE.51).AND.(ISTATE.NE.45).AND.
+           (ISTATE.NE.37).AND.(ISTATE.NE.01).AND.
+           (ISTATE.NE.28))
+           GO TO 100
C..      Ignore multiple parts of counties
          IF (JF(N).EQ.JF(N-1)) GO TO 90
          JFIPS(INDX)=JF(N)
          XCENTR(INDX)=XC(N)
          YCENTR(INDX)=YC(N)
          INDX=INDX+1
100      CONTINUE
110      CONTINUE
C=====
C=====
C..
C..      Do a binary search of county center array to assign
C..      x & y to
C..      generating capacities
          REWIND 26
          WRITE (6,115)
115      FORMAT
+           ('1',18X,'County FIPS Code',12X,'County
+           Center',9X,'Total Electric Generating
+           Capacity (Megawatts)')
120      CONTINUE
          READ (26,65,END=140) TOTCAP,IFIPS
          CALL SEARCH(IFIPS,JFIPS,INDX,LOCN)
          WRITE (6,125) JFIPS(LOCN),XCENTR(LOCN),
+           YCENTR(LOCN),TOTCAP
125      FORMAT (24X,I8,11X,2F10.4,19X,F10.1)
          WRITE (27,135)
+           JFIPS(LOCN),XCENTR(LOCN),YCENTR(LOCN),TOTCAP
135      FORMAT (I8,1X,2F10.4,1X,F10.1)
          GO TO 120
140      CONTINUE
          STOP
          END
C=====
C=====

```

```

C=====
C...
C...   BINARY SEARCH SUBROUTINE
C...
C       SUBROUTINE SEARCH(ARG, TABLE, TABSIZ, LOCN)
C
C       Table lookup of 'ARG' in 'TABLE', by binary search
C       process of successively halving the table until the C
C       desired argument is found, or the table is exhausted C
C       Input arguments:
C       ARG       Value searched for
C       TABLE    Array in which to search for the value
C       TABSIZ     Array size
C
C       LOCN      Location at which 'ARG' was found, or 0 if not
C       found
C
C       Variables:
C       LOW       Lowest subscript in currently active table
C                portion
C       HI        Highest subscript in currently active table C
C                portion
C       MID       Midpoint of currently active table
C       SIZE      Size of currently active table
C
C       INTEGER ARG, LOCN, TABSIZ, TABLE(TABSIZ)
C       INTEGER LOW, HI, MID, SIZE
C
C
C       LOW=1
C       HI=TABSIZ+1
C       SIZE=TABSIZ
C       LOCN=0
C
C       Main loop
C
C 10    CONTINUE
C       IF (SIZE.LE.0) GO TO 150
C       Halve the table, compute the midpoint
C       SIZE=SIZE/2
C       MID=(LOW+HI)/2
C       IF (ARG.LT.TABLE(MID)) HI=MID
C       IF (ARG.GT.TABLE(MID)) LOW=MID
C       IF (ARG.NE.TABLE(MID)) GO TO 10
C
C       Entry is found
C       LOCN=MID
C 150   CONTINUE
C       RETURN

```

END

```
/*  
//GO.FT20F001 DD DSN=A.D.FEL25295.SERC.POWER.PLANTS,DISP=SHR  
//GO.FT25F001 DD DSN=PRC.CNTYDATA,LABEL=(,,IN),DISP=SHR  
//GO.FT26F001 DD DISP=(NEW,CATLG,DELETE),UNIT=SYSDA,  
// DSN=&&TEMP,SPACE=(TRK,(500,3),RLSE),  
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400)  
//GO.FT27F001 DD DISP=(NEW,CATLG,DELETE),UNIT=SPDA,  
// DSN=T.FEL25295.PPLANTS.CNTY.CENTERS,  
// SPACE=(TRK,(20,3),RLSE),  
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400)  
/*  
//
```

APPENDIX G

Macros used in the Lotus 1-2-3 Database

	<pre> \F {GOTO}AA3 {GETLABEL "Select 1st state ",AA3}~ Select first state {GETLABEL "Select 2nd state ",AA4}~ Select second stat {GETLABEL "Select 3rd state ",AA5}~ Select third state {PANELOFF}{WINDOWSOFF} Suppress redraws /D Data Q I A3.I307~ C AA2.AA5~ O O6.W312~ E Q {GOTO}AB3~ fuel {PANELON}{WINDOWSON} </pre>	
		<pre> Query Input Range Criterion Range Output Range Extract Now select by </pre>
redraws	<pre> {GETLABEL "Select by fueltype ",AB3}~ {PANELOFF}{WINDOWSOFF} /D Q I O6.W312~ C AB2.AB3~ O AA6.AI312~ E Q~ {GOTO}AB5~ {GOTO}AB5~ </pre>	<pre> Suppress Data Query Input Range Criterion Range Output Range Extract Quit </pre>
st	<pre> \O /D{PANELOFF}{WINDOWSOFF} S D A6.J307~ P B6~ A~ </pre>	<pre> Order (sort) by Sort Data Range Primary Key (State) Ascending </pre>

Type)	S	Secondary Key
	I6~	(Fuel
	A~	Ascending
	G~	Go
	{HOME}{PANELON}{WINDOWSON}	
	{DOWN}~	
	\S {GOTO}AA4	Select by state
	(GETLABEL "Select the state ",AA4)~	
	{PANELOFF}	Data
	/D	Query
	Q	Input
	I	Range
	A3.I307~	Criterion
	C	Range
	AA3.AA4~	Output
	O	Range
	O6.W312~	Extract
	E	
	Q	
	{GOTO}O5~	
by	\R /D	Reorder (sort)
	{PANELOFF}{WINDOWSOFF}	
	S	Sort
	D	Data Range
	A6.J307~	
	P	Primary Key
	D6~	(FIPS)
	A~	Ascending
	G~	Go
	{HOME}~	
	{PANELON}{WINDOWSON}	
	{DOWN}~	
selected d	\X {GOTO}BK5~	Extract
Input new file nam	/f	
X		xtract
V {?}~		value or
formula ?	AE7.AG308~	
range		
R~		replace files
with	{HOME}	

APPENDIX H

INSTRUCTIONS TO SELECT AND MODEL ELECTRIC POWER GENERATING CAPACITIES

Prepared by Geographic Data Systems Section of
Computing & Telecommunications, in association
with the Energy Division, ORNL, for DOE/OEA

The surface/contouring capabilities for SERC electric power generating capacities consist of the software packages Lotus 123, v2.01; Surfer, v4; and several custom programs and data files. The SERC power plant data are maintained and manipulated in Lotus 123; surface and contour modeling are accomplished with Surfer.

To manipulate the database, initialize Lotus 123 --

Type '123'

When the 'ready' light appears, type '/FR' (file retrieve), then press 'return'.

Type SERCPP (SERC power plants), then press 'return'.

The SERC database now appears. By scrolling across the screen, you will see that the file contains plant name, state, plant id number, FIPS code, longitude, latitude, generating capacity, the reported kwh generated in 1985, and the primary fuel type. The developers are less than satisfied with the completeness of the reported 1985 generation column, so its suggested that you ignore this data at present, or use it with caution.

You can now create a subset of the SERCPP worksheet for generating capacity data by selecting combinations of adjoining states, grouped by fuel type.

While depressing the 'alt' key, press 'F' --

You will be prompted to select three states (use postal abbreviations). If fewer than three states are desired, reply 'return' to the prompts. The entire SERC region can be selected by replying '~all' (tilde all) to the first prompt.

Next, you will be asked to select a fuel type. Again, '~all' (tilde all) will select all types, otherwise, type either 'oil', 'gas', 'hydr', 'coal', or 'nucl'. One fueltype can be excluded from the choice set by replying '~fuel', (tilde fuel), (e.g. ~nucl). Data for the states and fuel types that you have selected have now been moved to another section of the worksheet.

To save your subset for modeling, it must be extracted to a new worksheet. To do this, while depressing the 'alt' key, press 'X'. You will be prompted to choose a descriptive file name for your new worksheet (e.g. FLGAS for Florida gas). The pointer now returns to the front of the worksheet. You can repeat the procedure for other scenarios, or exit.

To exit, type /QY

The modeling software requires a bit of housekeeping on extracted worksheets. Failure to do so will require a power down boot if you try to import your new worksheet into GRID, the interpolation package. Again, type '123' if you have exited Lotus. When the 'ready' light appears, type /FR (file retrieve) then press 'return'. Type the new file name (e.g. FLGAS)

Press 'home'

Press 'F9' (calc)

Type /FS then press return

Type 'R' (replace old file with new)

Type /QY (exit Lotus)

Recap of keystrokes:

to initialize:

123
at ready /FR return (file retrieve)
SERCPP return

to select:

alt F
first state
second state (or return)
third state (or return)
fuel type

to extract:

```
alt X
new file name
```

housekeeping:

```
123 (if not active)
/FR new filename
home
F9
/FS return
R
/QY
```

The modeling software will use an outline of the selected states as a mask during both interpolation and display. This outline is known as a blanking file, thus, it has an extension of .bln.

To create a .bln file, at the DOS dot prompt, type 'STATES'. A menu of SERC state names will appear. Use the arrow keys to move through the menu, press 'return' to select states. Press 'esc' when finished. Respond to the next prompt with a descriptive name, ie ALGA (Alabama, Georgia) or return for the default (states.bln).

The modeling software consists of three modules: GRID, which interpolates x, y, & z data values to a grid: TOPO, which displays the output of GRID as a contour plot, and SURF, which displays the same output as a 3-D surface.

GRID --

Type GRID

At the menu, highlight 'random' or enter 'r' and return.

At the menu, highlight 'input' or enter 'i' and return.

At the menu, highlight 'external' or enter 'x' and return.

At the menu, highlight 'wk1' or enter 'w' and return.

Type the file name extracted from Lotus.

Respond with 'return' to the next three prompts.
Press 'esc' to return to the main menu.
At the main menu, highlight 'limits' or enter 'l' and return.

GRID interpolates between data points, but does not extrapolate to the edge of the edge of the map. To accomplish this, reset the minimum and maximum x & y values of the grid to correspond to the extremes of the state boundaries that you have selected.

See the accompanying table.

At the menu, highlight 'begin' or enter 'b' and return.

Allow 5 to 10 minutes on an 8mhz machine with a math co-processor.

The next steps are to smooth and mask the grid.
Theoretically, GRID will allow these steps now, but, due to limitations with the package, memory allocations become exceeded. Therefore, we must exit and reenter GRID.

Press 'esc'.

Press 'esc'.

Reply 'yes' to exit.

Type GRID

At the menu, highlight 'modify' or enter 'm' and return.

At the menu, highlight 'smooth' or enter 's' and return.

At the menu, highlight 'spline' or enter 's' and return.

Input the grid file:

Type the output file name from interpolation (e.g. FLGAS).

Press 'return' for the remaining prompts in this window.

At the prompt 'BEGIN CREATING GRID' type 'yes' or return.

At the prompt, press 'esc'.

At the menu, highlight 'blank' or enter 'b' and return.

Press return until prompted for an output file.
Choose a descriptive name (e.g. FLGAS.GRD). This will be your final grid. At the .bln prompt, enter the name of the file that you created with program states. At the prompt 'BEGIN CREATING GRID' type 'yes' or return.
Press 'esc'
Press 'esc'
Press 'yes'

Your grid is now complete.

TOPO:

Type TOPO
Select 'input'
Type the name of the grid file
Press 'return' to the next four prompts
Select 'XYLine'
Type the name of the blanking file
Press 'return' or select a new color (see color table)
Press F2 to view

SURF:

Type SURF
Select 'input'
Type the name of the grid file
Press 'return' to the next four prompts
Select 'view'
Type either 'O' or 'P' for projection
Select viewpoint in relation to zero (due east) or return for default.
'Tilt after rotation' is the imagined altitude. Adjust to fit the situation or return to accept the default.
Return
Return
Return
Select 'xyline'
If you desire the state outline to be drawn, as in TOPO, insert the name of the blanking file. However, in SURF, the blanking outline assumes the 'z' value of the nearest cell. The result is not as aesthetically pleasing as it is in TOPO. At the main menu, press F2 to view.
Press 'esc'.
Reply 'yes' to exit.

SERC STATE WINDOWS

	East Lon	West Lon	North Lat	South Lat
AL	-84.80	-88.55	37.20	30.15
GA	-80.82	-85.70	35.20	30.30
FL	-80.00	-87.70	31.20	24.30
KY (SERC)	-83.65	-89.70	37.00	36.30
MS (SERC)	-88.00	-90.45	35.20	30.15
NC	-75.30	-84.35	36.70	33.65
SC	-78.50	-83.55	35.35	32.00
TN	-81.50	-90.35	36.70	34.82
VA (SERC)	-75.00	-81.50	39.50	36.30

VITA

Fred Eugene Latham was born in Phoenix, Arizona, on April 10, 1945. He attended public schools in Phoenix and Los Angeles County, California, with his senior year of high school in Oak Ridge, Tennessee, where he was graduated in 1963. From 1963 to 1967 he served in a military intelligence unit of the U.S. Army. In 1967 he entered the University of Tennessee and in 1973 received the degree of Bachelor of Arts in Political Science. He has worked in a geographical analysis section at the Oak Ridge National Laboratory since 1977. In March, 1987 he reentered the University of Tennessee and in May, 1993 received a Master of Science degree in Geography.