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PRELIMINARY ASSESSMENT OF
NUCLEAR ENERGY CENTERS
AND ENERGY SYSTEMS COMPLEXES
IN THE WESTERN U.S.

WESTERN INTERSTATE ENERGY BOARD

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PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY AND ENERGY SYSTEM COMPLEXES IN THE WESTERN UNITED STATES

WESTERN INTERSTATE NUCLEAR BOARD

for

OAK RIDGE NATIONAL LABORATORY

Subcontract No. 7272

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FINAL REPORT

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS AND
ENERGY SYSTEMS COMPLEXES
IN THE WESTERN UNITED STATES

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for the

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ABSTRACT

The Nuclear Energy Center siting opportunities in the eleven western states have been systematically examined. The study area has been divided into 10-mile by 10-mile grid cells, and each cell has been evaluated in terms of overall suitability and site-related costs. Composite suitability consists of a weighted sum of ten important nuclear power plant siting issues; the particular weights used for this study were decided by a Delphi session of twenty individuals with energy facility siting expertise, with at least one representative from each of the eleven western states. Site-related costs consist of the additional expenditures required for seismic hardening (in seismically active areas), electric power transmission lines (for sites significantly far from load centers), and wet/dry cooling system costs (limited water availability and/or high summer temperatures).

Zones of highest suitability were identified and displayed on computer-generated maps. Twenty-seven typical site areas (10-mile by 10-mile grid cells) were selected within these zones, and further detailed characteristics were presented. Additionally, eight areas covering specific sites nominated by electric utilities were described in greater detail. The characteristics for each of 15,000 grid cells covering the eleven Western states were also computed as part of the evaluation and comparison, but were not presented in the report.

The weights assigned to the most important issues were varied by up to 35 percent as a sensitivity exercise. This resulted in a shift of less than 10 percent in the designated zones of highest suitability.

The draft final report was circulated to the cognizant agencies in all eleven Western states to identify interest in further investigation of sites within their jurisdiction. The states of Arizona, New Mexico and Utah expressed the desire for further investigation of highest suitability zones within their borders.

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1 INTRODUCTION

1.1 GENERAL BACKGROUND

The siting of central station electric power plants is a major issue in meeting the nation's burgeoning electric energy requirements. Environmental, health, safety, and social impacts must be minimized at a reasonable cost. In recent years, the concept of "energy parks" (the co-location of a number of generating units) has emerged as a possible means of combining construction facilities and confining the impacts of power generation. For nuclear power these objectives could be augmented by the co-location of fuel cycle facilities (particularly reprocessing and high-level radioactive waste disposal) as well.

Co-location opportunities could also be extended to include industrial consumers of process heat or electric power, leading to the concept of a "multipurpose energy systems complex." This report will characterize all of these concepts under the title of Nuclear Energy Center (NEC).

Three years ago the U.S. Nuclear Regulatory Commission was mandated by the Energy Reorganization Act to perform a national generic study of NECs. This study resulted in a comprehensive report entitled, "Nuclear Energy Center Site Survey--1975" (NUREG-0001),⁽¹⁾ hereinafter referred to as NECSS-75. This study examined technical feasibility and practicality issues of NECs

and conducted a "coarse screening" of major regions of the nation for potential sites, but made no recommendations as to specific sites. In addition, NECSS-75 summarized most of the earlier work on the subject including some detailed site evaluation studies of decommissioned military bases which could be used as either coal or nuclear energy centers.^(2,3)

A major recommendation of the NRC study was that other federal agencies (ERDA and/or FEA) concerned with energy research and energy resource development take the lead in further studies and/or development of the NEC concept in cooperation with various state, regional, and industrial organizations.

A study by General Electric Company,⁽⁴⁾ conducted concurrently with NECSS-75, outlined the major environmental and institutional issues. A subsequent study by the National Academy of Public Administration⁽⁵⁾ examined the institutional aspects of energy centers and concluded in part that the tendency of utilities to cluster power plants would likely continue. They also concluded that coherent planning at all levels of government would be required to assure rational growth rather than completely ad hoc centers.

1.1.1 Present Generating Status, Plans and Siting Problems

At present, there are five nuclear power plants in operation in the region covered by the Western Interstate Nuclear Board (WINB)*, with a combined generating capacity of 3,388 MWe. Recent WINB studies⁶ indicate that total nuclear-electric generating capacity may reach 22,000 MWe by 1986. The sites for these plants have already been selected, and the locations are shown on Figure 1.1 together with a few additional sites being considered by utilities where plants could become operational by 1990. The present study is concerned with siting for NECs to meet the additional load growth by 1990 and beyond.

*Now the Western Interstate Energy Board/WINB.

FIGURE 1.1
 NUCLEAR POWER PLANTS

A general review of the Western States shows that there are several significant and controversial issues that must be addressed in the site selection and development of any major new energy facilities.

Water supplies in the region are limited except for the Columbia River basin (fresh water) and Pacific coastal area (salt water). Smaller sources such as the Colorado or the Sacramento Rivers are almost completely allocated with respect to future uses. This raises the question of priorities for the allocation of this water: expanding energy resource development versus other major uses such as agriculture, municipal, and other industries.

Seismic activity may restrict nuclear facility siting along certain portions of the Pacific Coast. Seismic activity may also inhibit nuclear siting in various areas in the Rocky Mountain states and the Nevada Basin.

Another major siting problem in the west is the great variation in population densities and electric load among the states. The largest load centers in the west are along the Pacific Coast (Los Angeles, San Francisco, Seattle). If nuclear siting is limited in these areas, power plants at remote inland sites will require electric transmission over considerable distances. The remainder of the region has relatively low population and load center densities, except for a few major metropolitan areas such as Albuquerque, Denver, Las Vegas, Phoenix, Portland, and Salt Lake City. The location of all the significant load centers is shown on Figure 1.2.

1.1.2 Preliminary Studies of Nuclear Energy Centers in the West

During the last several years, several preliminary analyses have been made of the siting potential for NECs in various areas of the west. These include:

- a. A preliminary conceptual study of a nuclear energy center at Hanford, Washington;⁽⁷⁾

FIGURE 1.2
POPULATION CENTERS

- b. A coarse screening of the western United States with respect to the environmental factors appropriate to NECs with dry cooling systems;⁽⁸⁾ and
- c. Two feasibility studies of the use of brackish ground water for evaporative cooling (with some desalination for cooling and/or agricultural purposes) of NEC power plants in the Tularosa Basin of New Mexico.^(9,10)

The Hanford NEC concept is still under investigation by Battelle Pacific Northwest Laboratories, and the Tularosa Basin is being very actively studied by institutions in New Mexico.

1.2 PROJECT OBJECTIVES

The overall goal of the ERDA program is the assessment of the technical feasibility and practical desirability of siting nuclear energy centers in various parts of the United States. Such facilities are proposed as an alternative or supplement to the present practice of dispersed siting of power plants, associated fuel processing facilities, and large industrial users of process heat and electric power. A Brief on a Cooperative Study of a Regional Nuclear Energy Center which presents ERDA/DOE thoughts on this subject is attached to the Summary of the March 24, 1977 meeting in Appendix D.

This project with WINB and a somewhat similar one with the Southern Interstate Nuclear Board (SINB) have been funded by ERDA(DOE) as a preliminary phase of the overall ERDA program. The WINB study project covers the eleven contiguous western state members: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming, hereinafter referred to as the Western States. Specific project objectives include:

1. An evaluation of large land areas in the Western States as "potential site areas" for NEC development, to select the most suitable site areas for further investigation;

2. A determination of levels of interest and attitudes toward NEC development among appropriate state governmental, utility industry, and other key personnel in the Western States; and
3. Preparation of recommendations for subsequent courses of action (e.g., additional specific site evaluations, policy formulation, etc.) which may be taken by DOE and other federal agencies, electric utilities and other pertinent industries, and state and regional governmental agencies.

1.3 PROJECT LIMITATIONS

Due to time and resource limitations, the following related issues were not included in the analysis:

1. Comparison of siting problems between NECs and dispersed sites,
2. Identification and evaluation of specific site locations,
3. Site areas unsuited to NECs but possibly suited for one or two individual plants (which could arise, for example, from a limited local growth and long transmission distance to major load centers),
4. Highly localized site specific environmental and geotechnical parameters: aesthetics (visibility), ecology, wind, humidity, atmospheric stability, surface faulting, soil conditions,
5. Social and political opposition to power plant and transmission line siting,
6. Ownership, financing and other institutional constraints.

7. System reliability problems inherent in the co-location of so much generating and transmission capacity.
8. The location of unfavorable areas such as state and local parks, military training areas or missile firing ranges (which would strongly discourage, without outright prohibiting).

1.4 PROJECT HISTORY (ASSUMPTIONS & GROUNDRULES)

The following brief history contains summaries of meetings conducted by WINB, as well as the progress milestones of the Dames & Moore study team. More extensive summaries of the meetings are given in Appendix D.

As the first part of the ERDA contract under which this report was prepared, the Western Interstate Nuclear Board sponsored a meeting on Thursday, March 24, 1977 at the Airport Marina Hotel in Los Angeles for the purpose of informing state, utility, industrial and public interest representatives of the Western States as to the project objectives and plans, and to solicit their interest and cooperation during this preliminary phase. A Brief on a Cooperative Study of a Regional Nuclear Energy Center which had been prepared by ERDA to provide information on the overall NEC program was made available to meeting attendees. This brief is attached to the meeting summary contained in Appendix D. In addition to a description and discussion of this project, a review of the current status of nuclear energy center studies was presented at the meeting with particular emphasis on those studies relating to the Western States. The speakers at this meeting included ERDA and WINB representatives, representatives of the major studies presently ongoing, representative state governmental agencies most concerned with energy development, and representatives of certain electric generating utilities.

A meeting of the WINB Project Steering Committee was held the following day, March 25, 1977, in which a formal project plan prepared by Dames & Moore's project staff was presented and discussed. Following modification, the plan was approved by the WINB Project Steering Committee. At this time the alternative NEC concepts (to serve as the basis for evaluating the site

areas) were selected. These served as guidelines for the Dames & Moore project staff and the WINB Executive Director, who provided the overall project management. It was also agreed that the Western Systems Coordinating Council (WSCC) would solicit the nomination of individual site areas from member bulk electricity generators; in addition, WINB would solicit nominations from individual state members. The nominated sites would be subjected to a more detailed analysis by the Dames & Moore project team, to the extent that time and resources would permit. The replies to this solicitation nominated eight different sites; these are identified in Section 2, Results and Conclusions. The summary of all the replies is given in Appendix E.

The Dames & Moore project staff initiated the analysis by gathering data and defining issues of major importance. The impacts of these issues were evaluated in a manner parameterized for application under the range of site conditions found in the Western States. These impact evaluations were summarized on a partly quantitative scale, with written descriptions and explanations, for the participants of a Delphi assessment. This group consisted of the WINB Project Steering Committee plus a number of individuals representing interests outside the electric power industry. The Delphi group met June 23 and 24 in San Diego. After three rounds of evaluation and discussion, the group had narrowed the range of individual preferences so that a coherent set of importance ratios was developed for weighting all significant issues in an index determining overall site preferability. A brief WINB Project Steering Committee meeting was held immediately following the Delphi session. Guidelines were developed for the conduct of the remainder of the study (by D&M), and the items to include in the final report.

To process the site-related data, the study region was divided with a grid structure into 15,000 10 mile x 10 mile site areas, each of which was evaluated with respect to the individual issues and the overall suitability index, reflecting the combination of individual issues. In this manner maps were generated, depicting the relative rankings of the individual site areas with respect to the individual issues and overall composite suitability. These results were analyzed (with particular attention to the sites nominated by WSCC members) and summarized in the draft report, issued August 16, 1977.

The draft report was reviewed by the WINB members and a number of the members of the Western Systems Coordinating Council (WSCC). The resulting comments and suggestions were reviewed by the WINB Project Steering Committee and the Dames & Moore project staff at a meeting in Las Vegas, September 8 and 9. Appropriate changes for the final report were agreed upon. In addition, the scope of work and due date were extended to include sensitivity studies relating changes in importance weight of individual issues to resulting changes in suitability ranking of various site areas.

The final report was sent by WIEB to the cognizant agencies of each state to identify further interest in the investigation of sites within their jurisdiction. Positive replies were received from Arizona, New Mexico and Utah.

1.5 SUMMARY OF CONCEPTS

As a result of the WINB Project Steering Committee guidelines and the Dames & Moore project team investigations and analysis, the following four nuclear energy center concepts were selected to serve as the basis for the identification of potential site areas:

1. Nuclear energy center producing electric power only with a total generating capacity of 6 GWe,
2. Nuclear energy center producing power only with a total capacity of 12 GWe,
3. Nuclear energy center producing power only with a total capacity of 18 GWe,
4. Nuclear energy center producing electric power plus steam for a co-located desalination plant, with a total power output equivalent to 12 GWe.

The rationale for the specific concepts chosen for study is given in Section 3.

1.6 REPORT CONTENTS

The summary results and conclusions of this report are presented in Section 2. These consist of a listing of the nominated sites together with their evaluation plus a selection of the highest suitability site zones (groups of 10 mile x 10 mile grid cells) from within the Western States. A summary of the results of the WINB survey of state interest is also given. Section 2 also presents recommendations for future, more detailed investigations of specific site areas.

Section 3 describes the method of investigation, including the data gathering methodology, the data management program, and the Delphi process for determining the importance weights of individual siting issues. Further details of the evaluation methodology and the Delphi process are given in Appendices B and C, respectively.

Section 4 presents a description of each of the individual issues and the methodology for evaluating their impact. Also included are maps of the relative rankings of all of the site areas with respect to each of the ten issues. Details of the methodology for estimating cooling system cost are given in Appendix A.

Section 5 presents the composite suitability and cost maps. These lead directly to the identification of the highest suitability zones and the evaluation of the nominated sites.

Section 6 presents an examination of the relative rankings of preferable site areas to determine their sensitivity to changes in importance weights of the individual issues and to changes in the assumed electric power demand growth rate. Sensitivity is also discussed in terms of individual issue contribution to the composite suitability map itself.

As an aid to the reader, a glossary of brief definitions of the professional terms used in this report is given in Appendix G. All references noted in the text are listed in Appendix H.

2 SUMMARY OF RESULTS AND CONCLUSIONS

2.1 INTRODUCTION

The results of this study reflect extensive analysis of composite suitability maps (reflecting the weighted sum of nine component siting issues) and cost maps (representing the sum of dollar per Kw for the seismic, transmission, and cooling issues). The analysis suggests three sizes of promising areas for further investigation:

1. Selected site areas, which are 10 mile x 10 mile grid cells ranking in the top 10 percentile of suitability for all three power only concepts (6, 12, and 18 GWe),
2. Selected zones, which are groups of contiguous selected site areas,
3. Selected regions, which are groups of contiguous highly suitable cells satisfying a less restrictive criterion than the selected site areas.

The analysis also provides an evaluation of the nominated sites.

These results represent a significant advance over previous NEC site evaluations in the Western States. Not only is the evaluation more comprehensive by including all possible site areas, but the consideration of seismic, transmission, and cooling issues is made on a more quantitative basis than has been done for most of the previous individual site evaluations. The development of this quantitative analysis could also be useful as a starting point for the selection of individual dispersed sites.

Details of the analysis, and the results, are given in Chapter 5 of this report. The sensitivity of these results to changes in assumptions and relative importance of issues is summarized in Chapter 6.

2.2 EVALUATION OF NOMINATED SITES

The locations of the eight sites nominated by WSCC member utilities are indicated in Figure 2.1. The evaluation summary for these eight sites is presented in Table 2.1, in terms of percentile ranking for each of the three power only concepts (6, 12, and 18 GWe) plus the industrial application concept in which the desalination suitability issue is added to the nominal 12 GWe power only suitability. Nominated sites ranking above the 90 percentile of suitability for all three power only concepts are Hanford, Boardman, Green River and the Tularosa Basin. The latter two sites rank somewhat below the first two for the three power only concepts, but they improve markedly with the industrial application concept because of the extensive associated saline ground water reservoirs.

The Galt site ranks lower for 6 and 12 GWe but does rank above 90 percentile (10 percent most suitable site areas) for the 18 GWe power only concept. This results from the relative proximity to the Southern California load center, which is the only one capable of absorbing the entire output of an 18 GWe center.

Of the remaining three nominated sites, Glasgow, Montana ranks lowest because of its great distance from any significant load centers. Desert Valley and Owyhee Plateau in Nevada have no particular distinction.

SITE	NAME
N1	HANFORD
N2	BOARDMAN
N3	GLASGOW
N4	DESERT VALLEY
N5	OWYHEE
N6	GREEN RIVER
N7	GALT
N8	TULAROSA BASIN

WESTERN INTERSTATE ENERGY BOARD/WIEB <small>(FORM 540-7272/1)</small>	PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS	MAP NAME <hr/>		
		SOURCE <hr/>		
		<hr/>		

FIGURE 2.1
NOMINATED SITES

<u>NOMINATED SITES</u>		<u>Power 06</u>	<u>Power 12</u>	<u>Power 18</u>	<u>Industrial</u>
N 1	Hanford	98	97	95	95
N 2	Boardman	99	98	98	97
N 3	Glasgow	10	10	6	14
N 4	Desert Valley	69	72	69	59
N 5	Owyhee	20	25	31	18
N 6	Green River	96	95	96	99
N 7	Galt	70	86	91	77
N 8	Tularosa Basin	94	90	91	97

TABLE 2.1
EVALUATION OF NOMINATED SITES
(Suitability Percentiles)

2.3 SELECTION OF SITE ZONES

The results of the general analyses suggest the zones shown in Figure 2.2. These are the most significant sized areas ranking in the top 10 percent of suitability for each of the three power only concepts (6, 12, and 18 GWe), with the exception of the dashed outline areas in eastern New Mexico and southern Wyoming (which rank in the top 10 percentile only for the 6 GWe concept) and the dotted outline area in northwest Montana (which doesn't rank in the top 10 percentile for any concept). The site zone in eastern New Mexico is included to illustrate a somewhat marginal site zone which would be greatly improved under certain particular circumstances: in this case, the possibility of serving the large industrial load in western Texas (which is presently supported by oil and gas). The 6 GWe zone in southern Wyoming illustrates the best area available in that state. The 6 GWe zone in northwest Montana is the only one shown on the figure which fails to qualify in the top 10 percentile for any of the concepts. It does have a rather low cost, but the overall suitability is significantly degraded because of the mountainous terrain. If enough gently sloping area could be found to fit 6 GWe, this marginal siting area might be worth further investigation.

To provide a more detailed analysis of the suitable site zones outlined in Figure 2.2, 27 typical site areas (individual grid cells) have been selected. The locations and characteristics of these site areas are given in Section 5.3 after a discussion of the detailed supporting analysis. It should be noted that the four nominated sites which rank in the top 10 percentile for all three power only concepts also fall within the selected zones shown in Figure 2.2.

2.4 RECOMMENDATIONS FOR SUBSEQUENT DETAILED SITE STUDIES

Of the four highly suitable nominated sites, Hanford has already been subjected to detailed site investigations, particularly since nuclear power plants are already being built there. The Boardman site has been studied in detail for both fossil and nuclear power plants. The Tularosa (New Mexico) and Green River (Utah) sites are also under some study, but these sites are in

FIGURE 2.2
SELECTED ZONES

generally unexplored areas so a significant amount of site specific information should be gathered and analyzed to identify and evaluate the actual potential for NEC development in these areas.

In the Tularosa Basin, temperature distributions (both dry and wet bulb) should be determined and applied to develop more precise estimates of the cost of alternative cooling systems (salt water evaporative, wet/dry with salt water evaporated, wet/dry with desalted water evaporated). The opportunities for replacing aging oil and gas generating capacity electricity with nuclear-generated electricity in the industrial areas near Midland/Odessa in west Texas during the decade 1990-2000 should be critically examined. These areas were not included as load centers (although El Paso was) so, if the Tularosa generating capacity could be fit into these large demand requirements, the site would look even more promising.

A major contribution to the high Green River suitability is its proximity to the Denver load center. Economically feasible transmission line routes through, or around, the Rocky Mountains should be found; otherwise the suitability of the site would have to be decreased somewhat.

Of the selected zones not containing nominated sites, central California, northwestern Oregon, and western Idaho look most promising. The San Joaquin Valley of California is already represented by nuclear power plant projects in various stages of planning (San Joaquin at the southern end and Stanislaus at the northern end). Additional sites could be identified and evaluated for the central part of the Valley. The large new generating capacity requirements forecast for California in the decade 1990-2000 would probably utilize many additional qualified sites. The areas indicated as selected zones in northeast California might be disqualified as NEC sites because of the high volcanism and associated potential for geothermal development.

The selected zones in northwestern Oregon and southwestern Idaho rank high because of their proximity to large freshwater sources (the Columbia and Snake Rivers, respectively). The range of actual water requirements should be determined (based on the appropriate mixture of wet/dry cooling); the problems

of securing a commitment for such a water supply should then be determined. The Boardman site has the additional question of the nearby U.S. Navy Weapons System Training Facility. This facility would have to be moved before the immediate vicinity of Boardman could be developed as an NEC.

2.5 GENERAL ISSUES FOR FURTHER STUDY

The following issues apply to nuclear power developments generally, but their importance increases with generating capacity size. Many of them are highly sensitive to political change and might best be performed just before the final site selection.

Methods for working with existing regional, state and local planning and/or regulatory agencies must be developed to formulate the requisite set of criteria as required in current statutes for the evaluation of specific "sites" within the selected "site areas." Such criteria must include social and political factors that determine "public acceptability" and not just technical siting factors. One example of such factors would be the ability of the local area to absorb the growth required for the construction and operation of such a facility. The development of both the specific technical and the socio-political factors should be done in a regionally coordinated, open-planning process. The analysis of the political factors should be updated frequently in response to changing public opinion and electoral judgements.

A stronger basis for the general analytical framework should be developed; plant design relationships represented by several of the utility functions used in assessment of suitability should be more thoroughly investigated. If it develops that detailed comparisons are to be made between a few specific sites, it would be desirable to determine the appropriate level of accuracy for the utility functions, perhaps through a more extensive sensitivity analysis made over a wider range of values to determine the amount of change in a given variable which will influence site area suitability.

As a part of the broad sensitivity analyses and refinement of input data, an investigation should be made to determine if different values should be used for different states to more nearly reflect their laws and regulations and socio-political factors. For example, an investigation of the sensitivity to the seismic issue in areas of low seismicity might show that the issue could be dispensed with entirely.

2.6 INDIVIDUAL STATE INTEREST IN FURTHER INVESTIGATIONS

The states of Arizona, New Mexico and Utah have all expressed interest in further investigation of nuclear energy center candidate site areas within their borders. These were all identified as selected zones in Figure 2.2.

Arizona is most interested in the area near Yuma (southwestern part of the state); New Mexico is most interested in the Tularosa basin (central part of the state); and Utah is interested in the Green River area (east-central part of the state). Copies of the individual state responses are given in Appendix E.

3 METHOD OF INVESTIGATION

The goal of this part of the study is to identify site areas which may be suitable for development of nuclear energy centers. To identify such areas, a systematic investigation of the Western States for several different nuclear energy center concepts was undertaken. In addition, site areas were nominated by members of the WINB Project Steering Committee and the Western Systems Coordinating Council. Both identified site areas and nominated sites were evaluated using the same selection criteria.

The investigation was conducted with the aid of a computer-based information management system (Dames & Moore's GIMS program), which provided the investigators with the capability to: (1) examine the entire study region at the same level of detail; (2) evaluate several energy center concepts simultaneously; and (3) quickly and easily conduct analyses and display their results. The information management system stores, analyzes and displays all data in a grid cell format where each cell was defined to be 10 mile x 10 mile for the purposes of this study.

3.1 INTRODUCTION

To investigate both the geographic and concept-dependent aspects of NEC siting, the following three-phased investigation strategy was used.

Phase 1: Definition of Nuclear Energy Concepts

Many alternative energy center concepts were examined, and those concepts that could not be feasibly developed within present trends in technology development and/or energy demand forecasts during the next 50 years were eliminated. The remaining concepts were reviewed and final study concepts were selected which would best illustrate the real differences among siting concepts in terms of their feasibility for siting, as illustrated by the number and geographic distribution of feasible energy center site areas.

Phase 2: Data Management Program

A data management program was undertaken to identify and define the data requirements and salient siting issues that should be considered to evaluate site area feasibility. These siting issues and their requisite data requirements were structured into a chart (the Data Structure Diagram) that illustrates the flow of information through the site suitability analysis.

Phase 3: Site Area Suitability Assessment

A site area identification model that measures the suitability of all potential site areas was defined. This suitability model, which is based on decision theory, provided for the evaluation and comparison of all potential site areas within the Western States to determine those site areas that exhibited greater suitability, and which are, therefore, assumed to be potential locations for a particular energy center concept.

3.2 DEFINITION OF NUCLEAR ENERGY CENTER CONCEPTS

To fully explore the question of siting feasibility for nuclear energy centers, a set of alternative energy center concepts was defined and an investigation was conducted for each concept. In this way, the basic issue of siting of nuclear energy centers could be examined, and the differences among siting concepts explored at the same time.

3.2.1 General NEC Alternatives

Three categories of NECs were initially considered in the study. They are as follows:

1. Nuclear Power Centers - Centers involving a minimum of six nuclear power reactors of a nominal 1,000 megawatt electric (MWe), or 1 GWe, generating capacity for each unit, or a combined generating capacity of approximately 6,000 MWe. The maximum center size initially considered was 40 GWe.
2. Combined Power Fuel Centers - Co-location of nuclear power generation stations with elements of the nuclear fuel processing cycle.
3. Multipurpose Energy System Complexes - Co-location of various types of resource processing and/or energy consuming industries, together with a nuclear energy center at the same site. Among possibilities that were considered for co-location are: industrial, agricultural, and desalination operations.

Concepts falling in each of the three categories were examined to determine which characteristics of a specific concept could be expressed as physical site requirements. These site requirements for different NEC concepts were then used to discriminate among all potential site areas to determine which site areas would be more or less suitable for a specific type of concept. After examination of many concepts, the only concept that didn't show strong siting implications was the fuel cycle based concept. This problem is discussed in detail in Section 3.2.2.

In addition to different alternatives for nuclear energy centers, the nominal size of the center based on the number of units to be operated was found to be highly related to the physical site requirements. The two prime aspects of plant location and operation that are size-dependent are: water

availability, which determines cooling system alternatives; and the distance from the site area to the load centers, which determines electric power transmission requirements.

3.2.2 Study Concepts

After review of the general concept alternatives and the cooling and transmission system implications of center size, a set of five concepts was defined. For the three power only concepts, all parameters of plant development and operation are the same except for the total generating capacity (or number of reactors) which was taken to be 6 GWe, 12 GWe, and 18 GWe, respectively.

The fourth and fifth concepts took a nominal 12GWe power generating capacity in combination with industrial applications (which would require additional energy) and co-siting with fuel cycle processing facilities.

These concepts are summarized in the following table:

TABLE 3.1

<u>CONCEPT NO.</u>	<u>ELECTRIC GENERATING CAPACITY (GWe)</u>	<u>OPTION</u>
1	6	Power only
2	12	Power only
3	18	Power only
4	12	Power and fuel
5	12	Power and indus- trial application

Of the five nuclear energy center concepts defined, most of the site-related investigation was concentrated on the three "power only" concepts. The range of sizes (6 GWe, 12 GWe, and 18 GWe) was chosen because the smallest is only slightly larger than the four-unit "quads" presently being developed entirely independent of any nuclear energy center policy, and the largest,

18 GWe, represented the largest-sized center which seemed reasonable in today's environment of limited energy growth. The 18 GWe center is similar to the 24 GWe center, which was found by the NECSS-75 to be the smallest center that could achieve maximum per unit cost reduction through the use of production techniques such as bridge cranes and on-site fabrication facilities.

The concept of a 12 GWe power generation facility, accompanied by a large-scale desalination facility, was considered as an example of a combined energy industrial system. The nuclear desalination studies cited and summarized in Section 4.10 indicate that the desalination operation could efficiently consume between 50 percent and 100 percent of the useful output of a nominal 1 GWe power plant, and produce between .5 and 1 billion gallons of fresh water per day. Thus, a nominal 18 GWe center could produce 18 billion gallons per day (consuming the entire power output of the center) which could irrigate approximately 5,000 to 10,000 square miles. Unfortunately, the cost of desalinated water would probably be considerably greater than present irrigation water sources in the western United States. Because of the flexibility in fraction of nuclear energy consumed for desalination and uncertain costs, no size has been specified for the desalination facility to accompany the nuclear energy center. Fortunately, the siting criteria for this type of combined facility are not particularly sensitive to the amount of salt water needed. Supplies from existing surface salt water sources are virtually unlimited and ground water reservoirs such as under the Tularosa Basin can provide a supply that is larger than any presently conceived need. The rights to ground water beneath land not dedicated to the energy center would not be expected to be difficult to obtain, since no one else would want water with such high salt content. However, the potential subsidence from withdrawal of ground water could cause some problem.

The project plan for this study originally included the concept of a power-producing nuclear energy center with a co-located fuel processing facility. This would have included the facilities considered by the NECSS-75 and other recent studies:^(11,12,13) spent fuel processing, plutonium fuel element fabrication, and waste management (possibly including underground disposal). However, before work was actually begun, the scope of the fuel

cycle facility was greatly reduced to correspond to the near-term federal policy of retrievable surface storage of spent fuel elements (with no re-processing). The optimum method and location for such spent fuel storage is presently being investigated by several groups; the policy eventually selected may provide for storage centers, or simply to keep the spent fuel in permanent storage facilities at the power plant site. The potential importance of such combined facilities (particularly from the standpoint of plutonium safeguards) is evidenced by a number of other recent studies on the engineering, economic, and siting aspects, including consideration of plutonium-burning light water reactors.^(11,12,13)

It is evident that a nuclear energy center would offer considerable flexibility in the location of a spent fuel storage facility, if for no other reason than the large amount of land available under carefully controlled access. However, there are no additional siting implications for such a facility that would not already be included for any power only nuclear energy center. Of course, the spent fuel storage facility will have a specific cooling requirement, but it will be small by comparison with the nearby power plants. Similarly, whatever land requirements are finally specified will be much less than the unused land within the energy center boundaries.

Due to the lack of any additional siting requirements for the mixed fuel cycle (storage only) and energy center concept, this alternative was not specifically investigated to determine siting areas for such a concept. This does not imply rejection of this concept, only that it does not present any new siting implications beyond those already considered for the three basic power production center concepts (6 GWe, 12 GWe, and 18 GWe).

3.3 DATA MANAGEMENT PROGRAM

Subsequent to the definition of the energy center concepts, a data management program was undertaken to structure the investigation of these concepts. This included two steps:

1. Specific siting issues were defined. Each issue was evaluated for the entire study area and these evaluations combined

using the suitability model to form a composite analysis from which site areas are identified.

2. A data structure diagram was developed that shows the sequence of input data maps (source maps), additional derived maps and finally a composite map for each concept.

3.3.1 Define Siting Issues

A set of general siting issues was defined and used to identify and discriminate more suitable energy center site areas from less suitable ones. These issues cover a diverse set of siting factors including guidelines promulgated by the Nuclear Regulatory Commission⁽¹⁴⁾, cost considerations normally related to the location of nuclear power generation facilities, and finally, issues of broad public interest that have historically been included in the siting process. The siting issues or criteria considered in this study for siting of the nuclear energy center concepts are as follows:

1. Protected and Restricted Lands - Those areas in which the development of a nuclear power plant of any sort is restricted.
2. Population Density - A relative measure of population density expressed as an index of cumulative population within an area defined by a radius of 30 miles.
3. Air Transportation Corridor and Airport Locations - An index reflecting safety risk within commercial air traffic corridors would decrease the suitability for NEC siting and airports which would exclude siting of NECs altogether.
4. Seismic Design - The additional cost or difficulty of compliance with seismic design criteria; assumed to be measured by the maximum expected (50 YR) horizontal ground acceleration expressed in fractions of g.

5. Transmission Cost - A relative cost index that reflects the distance, and allocation, from the power supply generated at a NEC to the major load centers in the Western States.
6. Cooling System Cost - An index reflecting the relative cost of the wet-dry cooling system most appropriate to local climate and water availability.
7. Landform - A relative measure of the ruggedness of localized topography expressed as an index which indicates the percentage of land with access and construction difficulty.
8. Major Transportation Access - A generalized index of the distance to the nearest major transportation route for transport of construction materials and reactor components to the site.
9. Coal Development - An index reflecting the location of those areas where surface or deep coal deposits would be feasibly mined and where meteorology conditions would permit coal combustion.
10. Thermal Applications - An index showing areas where specific types of industrial applications (primarily salt water supplies for desalinization) would be feasible for co-location with a nuclear energy center.

A more complete discussion of each of the siting issues is included in Section 4 of this report. Several issues that are typically considered in the detailed evaluation of nuclear sites (namely ecology and some meteorological parameters), were not considered for this study. For a specific site evaluation these neglected issues may be more important than some of the issues considered here, but they are not as meaningful for regional level consideration, as discussed in Section 4.

For each issue, a variety of sources of information are available throughout the Western States. Further, this information exists in different levels of classification and areal coverage. These various sources of data were investigated, and those that provided uniform coverage of data over the geographic region, and/or were classified with an appropriate data taxonomy, were collected and input to the computer-based data management system.

3.3.2 Data Structure Diagram

The flow of data and information used in the analysis is illustrated in the Data Structure Diagram (Figure 3.1), which includes separate maps that are either input to the computer and exist in the computer's data base, or were generated by computer using the various analytic operations available as part of the computer-based information management system.

In addition to the map elements shown on the Data Structure Diagram, three specific analysis models are shown. These models (shown as circles) are additions to the standard analytic operations available in the computer-based data management system. Two of the three models were programmed to develop information related to transmission line costs and cooling system costs. These two models are discussed in general terms in Sections 4.5 and 4.6. A more detailed discussion of the cooling system model is included in Appendix A. The third model, which is the site area suitability model, is discussed in detail in Appendix B.

Data maps shown in the Data Structure Diagram are classed in four separate categories, which include:

1. Source Data Maps - Data maps that are collected from published sources and encoded into the computerized data base.
2. Derived Data Maps - Maps that are derived using the computer-based data management system to combine or evaluate one or more of the source data maps.

Fig. 3.1 DATA STRUCTURE DIAGRAM

3. Issue Maps - Maps that represent specific siting criteria or issues. Each map represents the inclusive evaluation of all the input data relevant to a single siting issue.
4. Suitability Maps - Maps that show the overall composite suitability for each of the siting concepts. Also included in this general category are maps that show cost for each of the three power only concepts, based upon the three issues having the largest site related cost: seismic design, cooling system, and transmission line.

In addition to the Data Structure Diagram, which is shown in Figure 3.1, a table has been included briefly describing each of the maps included in the Data Structure Diagram. More specific information on each of the issue maps is contained in Section 4, where a discussion of the contents, method of derivation, and general importance of each of the issues is included.

TABLE 3.2
DATA MAP DESCRIPTIONS

<u>ISSUE</u>	<u>CONTENTS</u>	<u>METHOD OF DERIVATION</u>
Air Corridors	Air traffic corridors	Taken from published maps
Airports	Civil and/or military airports	Taken from published maps
Available Water	Available water supply in CFS	Computer combination of surface water, ground water & irrigated lands
Coal Development	Known coal fields and suitable fossil fuel plant sites	Taken from published maps
Concepts Maps	Power 6GW, Power 12GW, Power 18GW, and industrial suitability	Computer overlay performed with weighted values
Cooling System Maps	Cooling system costs in \$/kw	Optimum wet/dry system for fixed water consumption
Cost Maps	Units of cost per GWe	Computer overlay of cooling and transmission cost maps
Distance/Center Maps	Sixteen separate maps showing distance to each of the sixteen centers	Computer-generated distances
Ground Water	Area where ground water exists	Taken from published sources
Irrigated Lands	Area where ground is irrigated	Taken from published sources
Load Centers	Sixteen major load centers	Taken from published sources
Landform	General ruggedness of terrain	Taken directly from published maps
Major Highways	Interstate, defense and federal-aid highways	Data taken from published maps
Major Railroads	Primary railroads	Data taken from published maps

TABLE 3.2 (continued)

<u>ISSUE</u>	<u>CONTENTS</u>	<u>METHOD OF DERIVATION</u>
Major Transportation	Distance to major highways and railroads	Computer generated
Population Density	Zones of site population factors	Published sources used as base and then translated to 2020
Protected Lands	National parks, forests, monuments and wilderness areas	Taken from published maps
Salt Water Sources	Combined salt water sources	Computer combination of salt water sources
Seismic Design	Zones of probable acceleration	Taken directly from literature
Surface Salt Water	Pacific Coast, Salton Sea and Great Salt Lake	Taken from published maps
Surface Water	River flow in CFS of major rivers	Taken from published sources
Temperature	Wet and dry bulb temperatures	Taken from engineering weather data
Transmission Maps	Units of GW-miles summed from each cell to load centers	Computer-generated from allocation model

3.4 SITE AREA SUITABILITY

To identify potential siting areas for nuclear energy centers, a suitability analysis was conducted for each energy center concept and the results displayed on a map. These maps were reviewed and compared to determine the areas that scored highest, which defined selected site areas. Specific site areas were then checked to validate the suitability of each and compared to form an overall rank ordering of site areas.

The suitability analysis proceeds as follows: an evaluation of each issue map is made independently (by defining a utility function) to determine those areas that are more or less suitable for plant location, the issue maps are then overlaid and a composite map formed that shows areas that are more or less suitable considering all issues simultaneously. When all of the issue maps are overlaid they each contribute to a different extent in the formulation of the composite suitability assessment. This difference in contribution or importance is defined by the issue's importance value. The evaluation of each issue (definition of utility functions) and assignment of importance weights is described further in the following sections. For a complete discussion of the suitability model see Appendix B.

In addition to the identification of site areas using the suitability analysis procedure, eight specific site areas were nominated by WINB member states and WSCC member utilities. Nominations were made for the purpose of gaining additional information about these site areas and not to indicate any commitment to the development of a specific site. The nominated site areas were evaluated using the issues and data that were included in the suitability analysis. The results of this evaluation were integrated with selected site areas into an overall summary of selected and nominated site areas.

3.4.1 Individual Siting Issue Assessments (Utility Functions)

To evaluate the suitability of each potential site area each of the siting issues is first evaluated independently. This evaluation is accomplished by defining a utility function for each issue such that the

characteristics of a specific site area can be translated into a value on a defined suitability scale. This is a numeric scale ranging from 1 to 9 where 1 is the lowest level of suitability and 9 is the highest. Under special circumstances a restricted value can be applied. However, the restriction is absolute; a site with only one restriction is eliminated from further consideration even if it is highly acceptable for other issues.

3.4.2 Siting Issue Importance Weighting

Using the utility functions, each issue map is translated into a partial suitability map where each potential site area is represented by a utility value as determined by the issue's utility function. These are partial suitability maps because each includes only one siting issue. They are combined into a composite suitability map by first weighting each issue map with an importance value, then adding the individual maps together to form the composite map.

The issue importance weights determine the contribution or "level of importance" of each siting issue. They are established by a multidisciplinary and multi-interest group of siting experts using a modified version of the Delphi technique. Through this group decision process, an iterative, structured discussion takes place which continues until the group opinion for each issue's importance value has stabilized (as measured statistically). A complete summary of the Delphi assessment is included in Appendix C.

The importance values assigned to each of the issues as a result of the Delphi group assessment are summarized in Table 3.3. These values were compared to similar weightings from a study by Oak Ridge National Laboratory for siting energy facilities. In their study, comparable values were derived for most siting issues with two significant exceptions; transmission and cooling system. In the Oak Ridge study, Transmission was rated much lower than in this study while Access to Water was considered to be much more important than the analogous cooling issue used here. Shorter transmission distances and a denser transmission grid could account for the lesser concern with transmission access. The implicit assumption of once through or purely

evaporative cooling (as compared with the more water conserving wet/dry cooling considered here) would account for the greater concern with Access to Water.

TABLE 3.3
SUMMARY OF ISSUE IMPORTANCE VALUES (WEIGHTS)

Population Density	2.15
Air Corridor (used as a sensitivity test case only)	1.40***
Seismic Design	2.70
Transmission**	
18 GWe	2.85
12 GWe	2.01
6 GWe	1.36
Cooling System**	
18 GWe	2.51
12 GWe	1.79
6 GWe	1.28
Landform	0.67
Transportation	0.91
Coal Development	0.59
Industrial	0.57*
Thermal Application	0.43*

*Used only for the industrial application concept.

**Only one weight is used for each concept.

***Defined by the consultant subsequent to the Delphi.

3.4.3. Suitability and Cost Analysis

Using the importance values and utility functions developed for each of the siting issues, a composite suitability value was computed for each potential siting area within the nonexcluded portion of the study area. The

composite suitability values are expected to occur within a range of 10 to 90, with those cells that are excluded having a value less than zero. A separate site area suitability map was computed for each of the four evaluated concepts, and displayed. The suitability maps for each concept were reviewed, and those areas scoring highest (most suitable) were further examined and identified as potential nuclear energy center siting areas.

In addition to the composite suitability maps, a set of maps giving site related cost for each of the size variant concepts was computed and displayed. Cost in each area was computed by summing the costs for the three major issues: seismic design, transmission, and cooling.

The suitability and cost maps were finally compared to the source data maps and issue maps to determine the characteristics that compose the suitability of each of the various areas. These component characteristics for each siting area are summarized and discussed in Section 5 of the report.

NUCLEAR ENERGY CENTER
4 SITE AREA SELECTION CRITERIA

The identification and selection of nuclear energy center site areas must consider both the impacts that such a facility could have, and the physical requirements necessary for construction and operation of such a facility. These considerations are termed "site selection issues" and must be evaluated systematically to determine which sites are most suitable for location of an NEC.

The issues selected for the analysis of site area suitability each reflect either particular short and long-term environmental/societal impacts or specific engineering considerations related to the construction and operation of nuclear reactors for generation of electricity. Further, to contribute meaningfully to the analysis, each of the issues considered for site area selection must exhibit the following characteristics:

1. Variety - Each issue can be shown to express different characteristics in different sections of the study area. If an issue is important but does not vary over the study area, it cannot be used to discriminate among possible site locations.
2. General Importance - Each issue is of the same general level of importance. While specific importance values were assigned to

each of the issues, all were considered to be important to the selection of site areas at the regional level. If a single issue were considered to be an order of magnitude more important than the others, it would virtually override the influence of all the other issues in the assessment of suitability. Therefore, these less significant issues could be eliminated from consideration. The opposite would also be true of issues of major importance.

3. Regional Scale Resolution - Many potential site selection issues are related to physical features that are not geographically extensive, or consider factors that are important in the site planning process (which includes the precise location of the reactor and other plant facilities within the site). While these factors are important for specific site identification, they are generally not considered at the site area selection level. This is primarily due to the high resolution of the data required to address these issues and the ability to relocate the site within the site area such that these specific problems are minimized or mitigated altogether.

Using the three criteria just described, the site area selection issues were identified and included in the analysis of site area suitability for the different nuclear energy center concepts.

Of special note are several issues which have not been considered for this regional investigation. The issue of ecology has not been considered because it fails to satisfy the third criterion; the important variations are site-specific and do not show up on a regional scale. The issue of meteorology is represented by wet and dry bulb temperatures, major determinants of cooling system size and performance. Other meteorological parameters, such as wind and atmospheric stability, require considerable analysis for each individual site; they are not appropriate to the regional screening of this study. Furthermore, they are not particularly critical to nuclear power

plant site selection, although they are an important consideration in the safety analysis. In contrast to NECs, these dispersion related parameters would be very important in the siting of a fossil energy center.

The ten issues selected for evaluation can be grouped into four categories according to the nature of each issue and the importance ratios assigned by the Delphi procedure:

1. Exclusionary or Quasi-Exclusionary - Protected and restricted lands, population density, and air transportation areas (nearby airports and air corridors).
2. Large Impact Issues - Seismic, electric power transmission, and cooling requirements.
3. Lesser Impact Issues - Landform (terrain ruggedness), access from existing transportation routes, and potential for alternative energy development uses (particularly coal extraction).
4. Special supplementary uses - Heat recovery from thermal discharge, industrial application for processed steam.

The major impact issues (seismic, transmission, and cooling) include economic effects which can be quantified (to some degree of approximation). Accordingly, the evaluations of these issues are concerned with estimation of these economic impacts (or costs), and it is assumed that the non-economic impacts will be proportional to the incremental site-related cost, or economic impacts. In the development of the transmission and cooling issues, it is actually the total costs which are estimated; however, the utility function which transforms the cost into impact operates only on the incremental cost (which is the difference between each site area and the least cost site area). The individual issues are described fully, and displayed graphically, in the following sections. The 10 mile x 10 mile grid cells used for data storage and display correspond approximately to 1 1/2 printed graphic elements vertically and 2 1/2 printed graphic elements horizontally.

4.1 PROTECTED AND RESTRICTED LANDS

The Energy Reorganization Act (Section 207) of 1974 states that national forests, national parks, national historic monuments and national wilderness areas should be excluded from consideration as potential Nuclear Energy Center sites. These designations together include approximately 280,000 square miles or about 22 percent of the study area.

Those areas listed for restriction were identified on a USGS base map⁽¹⁶⁾. The restricted zones are indicated by the white areas on the graphic map, Figure 4.1; the remaining, non-excluded, areas are shown in black. The fact that there are only two types of areas implies a very simple two value utility function: The restricted value is assigned to the restricted areas, and the value of one is assigned to all other areas.

It should be noted that restricted land is not really an issue in the sense that is evaluated similar to the other issues. Because the restriction designation is absolute in the suitability analysis, there was no need to assign an importance ratio as part of the Delphi session. (Any importance ratios will have the same effect so a small value was used.) Removing these lands from further consideration is simply a conformance with stated national policy. Nevertheless, there are two possible exceptions to these seemingly absolute requirements. Firstly, additional lands could be added to the restricted list sometime in the future. Prime candidates for such inclusion are state parks and Indian reservations. Both permit some development at present, but the approval process is becoming increasingly difficult and costly.

The other potential exception is that some of the wilderness areas might be opened for limited energy development of a non-impact producing type. The Bureau of Land Management has been considering the possibility of limited mining in some of the wilderness areas; if nuclear power plants are recognized as environmentally benign, they might, conceivably, be permitted also.

WESTERN INTERSTATE
ENERGY BOARD/WIEB
(PROM/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

RESTRICTED LANDS

SOURCE

U.S.G.S. MAP 3A 1985

FIGURE 4.1

4.2 POPULATION DENSITY

4.2.1 Introduction

The radiation hazard to population from a postulated serious accident can be minimized by locating nuclear reactors in areas where population densities are lower. The NRC criteria treating population in relation to radiation hazard, which are discussed in 10 CFR 100,⁽¹⁴⁾ describe three general limitations: (1) an exclusion zone surrounding the facility, (2) a low population zone surrounding the exclusion zone, and (3) a minimum distance from the low population zone to the nearest population center. Specifically, 10 CFR 100 requires the following:

- An "exclusion area" surrounding the reactor in which the reactor licensee has the authority to determine all activities, including exclusion or removal of personnel and property;
- A "low population zone" (LPZ) which immediately surrounds the exclusion area in which the population number and distribution is such that "there is a reasonable probability that appropriate measures could be taken in their behalf in the event of a serious accident;"
- At any point on the exclusion area boundary and on the outer boundary of the LPZ, the exposure of individuals to a postulated release of fission products (as a consequence of an accident) be less than certain prescribed values;
- That the "population center distance," defined as the distance from the nuclear reactor to the nearest boundary of a densely populated center having more than 25,000 residents, be at least one and one-third the distance from the reactor to the outer boundary of the LPZ.

Appendix A.3 of NRC Regulatory Guide 4.7⁽¹⁷⁾ reports that a minimum exclusion distance of 0.4 miles (radius) and 3 miles to the outer boundary of the LPZ are typical in recent siting experience. Using 3 miles to the boundary of the LPZ, the minimum distance to the nearest population center is 4 miles (1.33×3). These limitations are distances that are specific to site level analysis. The evaluation of site area suitability as assumed for this study is at a regional scale; therefore, the collection and analysis of population data in response to such specific criteria is not practicable.

4.2.2 Site Population Factor

To treat the issue of radiation hazard to population at a regional scale or more generalized measure, the Site Population Factor (SPF) has been developed.⁽¹⁸⁾ $SPF_{(x)}$ is expressed as an index of equivalent population density within a radius (x). The base of the index scale is 1, which is equated to a population density of 1000 people per square mile. Therefore, $SPF_{(30)} = 1.0$ is equal to an average population density of 1000 persons per square mile within a 30-mile radius. (Correspondingly, $SPF_{(30)} = 0.5$ is equal to 500 people per square mile.)

Population density restrictions specified by the NRC guidelines⁽¹⁷⁾ for a specific site suggest the following SPF limitations for regional analysis:

- 1) $SPF_{(30)} \leq 0.5$ at the time of initial operation of the facility,
- 2) $SPF_{(30)} \leq 1.0$ over the lifetime of the facility.

To evaluate population density as a function of SPF, regional maps showing SPF iso-contours were obtained from the U.S. Atomic Energy Commission (NRC).⁽¹⁸⁾ These maps show SPF iso-value contours of 0.2, 0.4, 0.5, 0.7 and 1.0 for a 30-mile radius and are based on population data from the 1970 U.S. Census.

To evaluate the Western States for levels of suitability using the $SPF_{(30)}$ index, the 1970-based contours had to be modified to reflect population growth. For the analysis, 1985 was taken as the reference year since it would be the time of licensing in order to have initial operation by 1990. The last year considered was 2020 since some decommissioning would be underway by that time. While this is a somewhat optimistic time frame, it is balanced by two factors: (1) population projections for such time frames must be considered with a certain degree of skepticism (projections for shorter time frames are obviously more accurate), and (2) because only urban areas are considered, the total land area affected by any projection error is not large. In any case, given that the objective of the study is to screen potential site areas, by using an optimistic time frame, population values will likely be lower and therefore, sites will not be unfavorably ranked or prematurely eliminated from consideration because of population.

To modify the $SPF_{(30)}$ map, the OBERS⁽¹⁹⁾ projections of economic activity and population growth on a subregional basis were used. This projection includes all of the Western States and uses a consistent set of growth parameters (i.e., migration, birth-rate, mortality, etc.). (OBERS is not necessarily the most reliable forecast for every region, but it is the only one treating all parts of the study area on a common basis, and it is generally accepted.) Using OBERS, a growth rate (percent increase over 1970) was calculated for 1985 and 2020 for each Standard Metropolitan Statistical Area (SMSA) shown on the original $SPF_{(30)}$ map. These values are shown in Table 4.1, which includes all those population centers with sufficiently high density to appear on the contour map. Using the calculated growth rates, the specific contours surrounding each SMSA were increased proportionately creating new contour values for 1985 and 2020.

4.2.3 Utility Function and Issue Map

To translate the modified SPF values into a measure of utility for the suitability analysis, the linear utility function shown in Figure 4.2 was used. It was assumed that the level of suitability should be directly proportional to the number of people exposed to the NEC and its potential

impacts. Such a linear relationship would only apply, however, if exposure were equal for all individuals. The potential impact on an individual is directly related to the distance of that individual to the reactor. Thus, if distance is considered, impacts are not equal for all individuals. However, the effect of distance is incorporated into the calculation of SPF which normalizes the population distribution with respect to distance. Therefore, a linear relationship as shown in Figure 4.2 can be used for utility with respect to SPF.

Both the 1985 and 2020 projections were translated into utility values. If an area exceeded either 0.5 for 1985 or 1.0 for 2020, it was restricted from further consideration. The remaining areas were assigned utility values from the utility function according to their projected 2020 SPF value. The 2020 projection was used because this results in a more conservative evaluation.

The results of the translation of SPF into a measure of utility are shown in Figure 4.3. The white areas within the study area boundary are restricted, having an SPF₍₃₀₎ of greater than 0.5 for 1985 or 1.0 for 2020. These areas include the major metropolitan regions of Seattle-Tacoma in Washington; Portland, Oregon; the San Francisco-Sacramento and Los Angeles regions in California; Phoenix, Arizona; Salt Lake City, Utah; and the Denver metropolitan area in Colorado.

TABLE 4.1. PERCENT INCREASE IN POPULATION BY STANDARD METROPOLITAN STATISTICAL AREA (SMSA)

SMSA	STATE	1985 (%)	2020 (%)
Phoenix	Arizona	47.8	139.6
Tucson		30.4	86.5
Bakersfield	California	7.7	20.5
Fresno		5.5	15.2
Los Angeles		15.0	46.6
Oxnard-Ventura		25.7	64.8
Riverside-San Bernardino		22.2	58.3
Sacramento		18.1	56.4
Salinas-Monterey		10.3	45.1
San Diego		20.9	75.1
San Francisco-Oakland		16.9	52.2
San Jose		42.7	126.7
Santa Barbara		23.9	72.4
Santa Cruz		17.4	41.9
Santa Rosa		13.1	31.8
Stockton		8.5	15.3
Vallejo-Napa		18.1	61.2
Colorado Springs	Colorado	7.5	42.8
Denver		34.5	88.1
Las Vegas	Nevada	37.6	116.4
Albuquerque	New Mexico	24.8	63.1
Eugene-Springfield	Oregon	18.9	33.1
Portland		19.9	54.5
Salem		21.1	53.1
Ogden	Utah	19.6	52.0
Salt Lake City		18.1	65.9
Seattle-Everett	Washington	12.7	44.3
Spokane		9.1	17.5
Tacoma		-3.4	10.4

UTILITY VALUES

1	2	3	4	5	6	7	8	9
.....								
.....								
.....								
.....								

WESTERN INTERSTATE
ENERGY BOARD/WINEB
(ORNL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

POPULATION DENSITIES

SOURCE

U.S. ATOMIC ENERGY COMMISSION 1974
POPULATION CONSIDERATIONS
IN SITE COMPARISONS

FIGURE 4.3

Other urban areas with lower levels of population are shown in gray tones indicating higher levels of suitability.

In addition to those urban areas shown on the issue map, urban areas in the states of Idaho, Montana and Wyoming were also considered. However, these cities did not appear on the SPF source map due to their relatively small populations (which did not qualify some of them as SMSAs) or their small size in land area. Of these cities (including Boise, Helena, Butte, Great Falls and Cheyenne) none produced a significantly sized SPF over a major part of a grid cell. Even though these small cities are not included in the regional analysis of population distribution, they would of necessity be considered in the specific location of an NEC which would be required to adhere to 10 CFR 100 criteria.

4.3 AIRPORTS AND AIR TRANSPORTATION CORRIDORS (ADDITIONAL RESTRICTION APPLIED FOR A SENSITIVITY TEST, ONLY)

As part of the general increase in public concern with safety-related factors in nuclear reactor operations, aircraft hazards have become a significant issue for siting nuclear power plants. The Safety Analysis Report for a power plant must contain an estimate of the probability of an aircraft penetration of any safety-related structure on the plant site. If the expected frequency is greater than one event in 10 million years, further analysis or hardening must be done to prove that the consequences of such an accident could not result in impairment of operation sufficiently serious to produce a significant radioactive emission from the plant.

NRC guidelines⁽²⁰⁾ suggest that it is desirable to site nuclear power plants more than five miles from an airport and several miles from any busy air corridor⁽²⁰⁾. A nuclear energy center should adhere to these guidelines since any probability of impact and damage is multiplied by the number of power plants present. In other words, a radius of five miles surrounding an airport could be considered an exclusion zone for NEC siting.

The five mile radius surrounding an airport would take up most of a 10 mile x 10 mile grid cell if the airport were located near the center of the cell. If the airport were located near the edge of a cell, the five mile exclusion radius would overlap into an adjacent cell. It, therefore, seems appropriate to consider the cell in which the airport is located as an excluded zone (although the actual area excluded might fall equally in an adjacent cell).

Air corridors present a problem to determine an importance ratio or the individual utility function since there is little recent experience in the evaluation of this issue as a major nuclear power plant siting issue. Given no guideline, a mid-range compromise of an importance ratio of 1.4 (between the major and the minor issues) has been used. The utility function was chosen to give a value of 5 for cells which have an air corridor passing through and a value of 9 for all other cells. With this utility function for air corridors and the exclusion of airports, the issue map is as shown in Figure 4.4. The corridors are nominally one cell wide (10 miles), but paths along a diagonal direction will appear to fluctuate in width because of the use of rectangular grid cells to represent the corridor.

Although proximity to air transportation facilities is an important issue, it has not yet become a major siting criterion with those decision makers most responsible for site selection. In fact, several sites lying beneath air corridors or closer than five miles to an airport have been approved by NRC, after suitable demonstration of safety. Therefore, it does not seem appropriate to apply these restrictive criteria at the coarse screening level of the present study. Accordingly, the airport exclusion and air corridor restriction are applied to only the 12 GWe concept, and only to test overall sensitivity to the inclusion of this issue.

The locations of airports and routes of air corridors were determined from the air navigation maps published by the Federal Aviation Administration.⁽²¹⁾

UTILITY VALUES

1	2	3	4	5	6	7	8	9
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.....								
.....								

WESTERN INTERSTATE
ENERGY BOARD/WINB
(ORNL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

AIR CORRIDORS

SOURCE

U.S. FLIGHT INFORMATION SERVICE 1972

IFR WALL PLANNING CHART

0 25 50 75 100 125 150 175 200 MILES
0 25 50 75 100 125 150 175 200 KILOMETERS

PLANNING
AT CENTER

FIGURE 4.4

This discussion of aircraft risk has omitted mention of missile hazards. There are two major missile firing ranges in the study area (White Sands and Vandenberg). The definition of any exclusion zone in connection with these ranges would require a statistical analysis of the historical activity and accidents, which is beyond the scope of this general study. Furthermore, missile firing is a relatively recent phenomenon so there is little basis for predicting the lifetime of such facilities. There are already several instances of abandoned military bases actually being offered as logical sites for NECs.

For these reasons no military test facilities or bases have been excluded or restricted in the present analysis, and neither has the nuclear weapons test site in Nevada.

4.4 SEISMIC DESIGN

4.4.1 Introduction

There are generally three major factors to be considered in the seismic evaluation of a nuclear power plant site:

1. Fault Rupture Hazard - primarily a siting problem
2. Dynamic Soil Stability (liquefaction) - both a siting and a design problem
3. Strong Ground Motion (vibratory) - both a siting and a design issue

A detailed site qualification study would require the careful consideration of all three factors. The siting requirements are specified by the NRC⁽¹⁴⁾, and the evaluation of the site (for design purposes) is based upon the additional cost imposed by these site-related conditions. The evaluation of all these factors generally requires effort far beyond the scope of

this study. However, after careful consideration of their overall impact, a methodology has been developed, for a coarse screening process, which generally reflects the overall impact of these factors.

4.4.2 Evaluation Factors

The fault rupture siting criterion is generally manifested by a minimum distance from the nearest capable fault which is typically five miles. A detailed site evaluation should exclude areas in the immediate vicinity of such a fault, but the 10-mile x 10-mile grid cell size used for the present screening is too large for this purpose. A single fault running through a cell would most likely leave a portion of the cell outside of the locally excluded zone, and consequently available for nuclear power plant siting. Another difficulty with the fault rupture criterion is the inhomogeneity of available data over the entire Western States area. For example, detailed fault investigations have been conducted in most areas of California, but much of the large, sparsely populated regions of the remaining Western States have only been investigated in a reconnaissance fashion.

Fault densities greater than one per cell would seriously restrict the cell availability; fortunately, the regions known to have high fault densities are also areas of high seismicity (such as the San Andreas Fault area of California) and will be negatively ranked on that basis, as described below.

Dynamic soil stability at a given location will be determined by the susceptibility to strong ground motion, soil density, and depth of the water table. As with the fault rupture issue, the data necessary to evaluate this potential problem is not uniformly available throughout the Western States. Furthermore, many areas in the Western States could be expected to show quite significant variations of these parameters over any typical 10-mile grid cell. For these reasons, seismic design will be evaluated solely on the basis of vibratory ground motion.

4.4.3 Seismic Design Evaluation in Terms of Vibratory Ground Motion

Strong ground motion criteria are determined by the postulated Safe Shutdown Earthquake (SSE) which is the largest possible event on the controlling seismogenic feature, which could be a capable fault (not necessarily the closest one) or a tectonic province. The SSE is determined on the basis of historical earthquake data (seismicity) and detailed investigation of the length and capability of nearby faults, according to procedures specified by the NRC.⁽²²⁾ The plant must be able to survive such an earthquake in a manner which will not result in the release of radioactivity in excess of stated limits. An additional design requirement is imposed by the Operating Basis Earthquake (OBE) which is commonly defined as having a peak acceleration equal to one-half that of the SSE. The plant must be designed so that it can continue to operate during and after an OBE; alternatively, none of the structural or mechanical components may be stressed beyond their elastic limit by the OBE. While the detailed investigations required for the determination of SSE in each 10-mile x 10-mile grid cell are clearly beyond the scope of this study, it is possible, using available data, to probabilistically evaluate the relative severity of the strong ground motion hazard in the study area. This can be accomplished using probabilistic studies of seismic risk prepared by the U.S. Geological Survey⁽²³⁾ or the Applied Technology Council.⁽²⁴⁾

Although the SSE is specified by a deterministic process, it is nominally agreed that, viewed as random events, the typical SSE and OBE will have associated recurrence intervals (the recurrence interval is the average time between occurrences of the specified earthquake in the source zone of strongest influence on the site) of 10,000 and 100 years, respectively. The differences between these typical recurrence intervals and those that would be calculated from the deterministically specified earthquakes at each cell are within the degree of approximation of the overall seismic risk procedure. Once these design earthquakes have been associated with recurrence intervals, they can be approximately related to probabilistic estimates of vibratory ground motion for the Western States generally.

The seismic history (vibratory ground motion due to historical earthquakes) of the continental United States has been summarized by contour maps giving the peak horizontal accelerations expected over a 50-year time interval. The most recent of these is a map of Effective Peak Acceleration (EPA) prepared by the Applied Technology Council (ATC).⁽²⁴⁾ The ATC map contains four contour levels (.05g, .1g, .2g, and .4g). This work represents an adaptation of a comprehensive analysis by Algermissen and Perkins⁽²³⁾ for accelerations in bedrock; the modification reflected propagation of seismic disturbances from the rock through soil characteristics of the general area, but did not reflect site specific local soil conditions. The contours of the ATC map represent acceleration levels which have a probability between .8 and .95 of not being exceeded in a 50-year time interval. Assuming random events, the 50-year probability range of .8 to .95 translates into a return period ranging from 224 to 975 years. (The return period is the average time between peak accelerations of a certain level at the site.) The 100-year recurrence interval normally attributed to the OBE refers to the occurrence of such events in the earthquake source region. Since not all such events will produce the maximum peak acceleration (which is what is calculated by ATC), the return period of the maximum peak acceleration corresponding to the OBE is commonly assumed to be 3 to 10 times longer than the recurrence interval for the OBE itself in the source region.⁽²³⁾ Hence the maximum peak acceleration produced by the OBE would have a return period of 300 to 1,000 years, which corresponds quite closely to the ATC range.

Further evidence of the approximation between ATC acceleration and OBE is provided by the examples of seismic design in the Western States. The SSE figures range from .2g for Palo Verde to .67g for San Onofre and .7g for Diablo Canyon. The Palo Verde site is in a region characterized by .05g on the ATC map, while San Onofre and Diablo Canyon are in the region characterized by .4g. Recalling that the OBE is nominally one-half the SSE, the correspondence here seems to be fairly good, except for the Palo Verde site which appears to have an SSE twice as large as it needs to be (four times larger than the ATC acceleration). This apparent conservatism for lower accelerations is explained further in the cost discussion of the following section.

For this study, the ATC map data were adapted by interpolating between the four contour levels to develop a more continuous distribution of seismic risk (horizontal acceleration). The continuous distribution was desirable from a siting standpoint, so that sites falling on opposite sides of a dividing contour (somewhat by accident) would not appear to have greatly differing seismic requirements. (The contours of the ATC map do not generally have any geological significance which would warrant such sharp distinctions.) It is still recognized that the absolute resolution of the ATC acceleration map is probably no more precise than the contour intervals given; however, the relative ranking of nearby sites is probably representable to the finer resolution implied by the interpolation used in this study.

The ATC map was further adapted by extrapolation to accelerations higher than the maximum (.4g) in the vicinity of major faults or fault networks (the maximum value being .53g in the vicinity of the San Andreas Fault). The ATC report implied that accelerations significantly above .4g were warranted by the analysis of the basic data; indeed, the Algermissen and Perkins map,⁽²³⁾ from which it was derived, gave larger accelerations (for bedrock).

4.4.4 Estimated Impact and Cost of Seismic Design Requirements

The general impact of seismic design requirements is assumed to be proportional to the specific cost of the additional design and construction features required to satisfy the seismic design requirements. Unfortunately, a determination of this excess cost is generally considered to be a complex process involving the detailed design of the plant itself. The only recent generic seismic design cost study is a paper by John D. Stevenson, "Economic Effect of Increased Seismic Loading."⁽²⁵⁾ Stevenson estimated a cost increase proportional to the peak acceleration of the OBE. The excess cost ranged from zero at a .1g OBE to \$22 per kilowatt for an OBE as large as .3g. The cost curve given by Stevenson increases somewhat faster than linearly and suggests a mathematical function between a straight line and a parabola (concave upwards). One seismic design expert⁽²⁶⁾ has suggested that

Stevenson's cost curve be scaled upward by a factor of 2.5 and modified to the form shown in Figure 4.5a. The shading up to .35g represents the range of recent experience. There have been no designs beyond .35g, but it should be possible to withstand the resulting accelerations by spreading the plant layout so that the cost increase can continue upward in an approximately linear manner until .5g.

The entire range up to .5g can then be approximated by the piecewise linear function which is zero up to .1g and a straight line up to \$100/KWe at .5g. This cost function translates into the piecewise linear utility function shown in Figure 4.5b (based on the assumption that relative impact, or unsuitability, is proportional to cost). The horizontal portion of the utility function (up to .1g) can also be understood in terms of the following two reasons. First of all, the basic structural safety factors imply a certain minimum resistance to seismic stress that must be built into any nuclear power plant, however small the OBE may calculate to be. Secondly, there are other structural stress hazards (such as tornados) which would impose certain minimum stress resistant requirements, even in the absence of earthquake considerations. It should be noted that this piecewise linear form of utility function implies that a .1g OBE (or .2g SSE) is consistent with an ATC acceleration anywhere between zero and .1g. Thus, the Palo Verde ATC acceleration of .05 is consistent with a .1g OBE (or .2g SSE).

4.5a SEISMIC COST

4.5b SEISMIC UTILITY FUNCTION

In considering the overall suitability of sites with respect to seismic criteria there are many intangible negative factors such as: additional time and effort required to show that minor local faults are incapable, considerations of system reliability for non-safety related plant structures which are not designed to strict seismic standards, or political problems arising from increased public concern in seismically active areas. Insofar as these are at all measurable (for purposes of this study), a proportional relationship to the economic cost of meeting the seismic requirements will be assumed.

The graphic display of seismic siting utility value, based upon projected peak acceleration, is given in Figure 4.6. The general areas of lowest seismic utility are the California coast (the zone of influence of the San Andreas Fault system), the part of the Nevada Great Basin closest to the Sierra Nevada Mountains, and the Wasatch seismotectonic trend along the Wyoming-Idaho border. The remaining areas constitute most of the Western States and are shown in the darker shades on Figure 4.6, indicating higher utility values.

It should be noted that many seismic design experts regard the situation as so unsettled that they are reluctant to commit to any specific cost function at all. There has, however, been some comment generated by the draft of this report. One authority has suggested that cost might actually increase sharply beyond .35g because of the very high acceleration design requirement on the reactor vessel itself, resulting from an assumed amplification of the ground motion by a factor of 20. A utility function modified according to this prescription would strongly downgrade areas having higher than .3g horizontal ground acceleration. Since, however, no such accelerations show up in the selected areas, the general conclusions of this report would not be changed.

UTILITY VALUES

[illegible]

**WESTERN INTERSTATE
ENERGY BOARD/WINB**
(ORNL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

SEISMIC CRITERIA

SOURCE

APPLIED TECHNOLOGY COUNCIL S.E.A. 1977.

A scale bar showing distances in miles and kilometers. The top scale is in miles, with markings at 25, 0, 25, 50, 75, 100, 125, 150, 175, and 200. The bottom scale is in kilometers, with markings at 25, 0, 25, 50, 75, 100, 125, 150, 175, and 200.

25 0 25 50 75 100 125 150 175 200 KILOMETERS

AT CENTER

FIGURE 4.6

4.5 ELECTRIC POWER TRANSMISSION REQUIREMENTS AND COST

4.5.1 Introduction

Transmission line cost is a major decision factor in evaluating generation sites which are remote from the load centers. A line carrying 1 GW typically costs \$235,000 per mile (plus the purchase of land), and up to 35 percent should be added for rugged terrain which may be necessitated by bottlenecks in mountain passes or geopolitical obstructions.⁽²⁷⁾ In addition, considerable time and effort may be expended securing the right-of-way (even for relatively undesirable terrain) because of local opposition.

4.5.2 General Methodology

The transmission line requirements to carry the power from the NEC to the load centers are measured in GWe-miles. They are estimated by first defining the load centers and forecasting the generating capacity increment required to support the expected load growth for the decade 1990-2000. Then the specific requirements for each site area are determined by the following steps which are conducted for each of the grid cells in succession:

1. Rank the load centers according to their distance from the cell.
2. Allocate the NEC generating capacity (for the 6 GWe, 12 GWe, and 18 GWe cases) taking the capacity increment for each load center in sequence, according to the ranking by distance (step #1 above), and assigning a portion of the generating capacity until all of the center's capacity has been used up.
3. Multiply the distance to each load center by the generating capacity allocated to that load center and sum over all load centers (which have been allocated power) to get the total GWe-miles.

This methodology assumes that the NEC generating capacity will be absorbed over the ten-year interval 1990-2000 (which is equivalent to a 10-year buildout period for each center concept, regardless of size). Under this assumption there is no concern with the generating capacity increments coming on line before 1990 or with the specific load centers which they will serve. It is assumed that any generating capacity coming on line before 1990 will be allocated efficiently according to the needs at that time, without prejudice to the future required capacity increments for the decade 1990-2000.

4.5.3 Load Center Definition and Required Capacity Increments

The load centers were defined by the major population concentrations in the Western States. Populations were determined by aggregating the Bureau of Economic Analysis (BEA) districts, accounting for the entire Western States population, into 16 load centers, which are listed in Table 4.2, together with population forecasts for 1990 and 2000. These population forecasts have been derived from the 1972 OBERS economic and demographic projections by BEA districts.⁽¹⁹⁾ While the OBERS projections were based on the series C population growth rates, more current national aggregate forecasts use the lower series E population growth rates. For this reason the OBERS projections for each BEA district were adjusted downward by a multiplicative factor (constant for all BEA districts) reflecting the ratio of national total series E forecast to OBERS forecast (with separate ratios for 1990 and for 2000).

Development of capacity requirement forecasts can be undertaken from two perspectives. National per capita averages (for a sequence of years) can be assumed; this discounts regional differences in per capita peak power consumption or historical supply costs. On the other hand, these differences can be acknowledged in a disaggregated set of regional assumptions. Due to significant regional differences within the Western States, both forecasting assumptions were used. The national average is defined in the following discussion as scenario A while a regional based assumption is stated as scenario B.

For purposes of this study, capacity requirement is defined as peak load plus 15% reserve. Capacity requirements for each load center were allocated by population from the national totals forecast by ERDA of 900 GWe and 1200 GWe for 1990 and 2000, respectively⁽²⁸⁾. These figures represent a significant reduction from the previous official forecast of the former Atomic Energy Commission⁽²⁹⁾. The assumption of a fixed 15% reserve implies that generating capacity requirement will be proportional to peak consumption throughout the period of interest.

Using the series E national population forecast, these total figures translate into per capita generating capacity requirements of 3.64KWe and 4.55KWe for 1990 and 2000, respectively. These per capita capacity requirement forecasts represent a 2.6% growth rate compounded from 1975 to 1990 and a growth rate of 2.3% compounded from 1990 to 2000. Such growth rates are quite conservative by comparison with the average of over 6% for the 20 years prior to 1975. Multiplication of the forecasted per capita generating capacity requirements by the forecasted population for each load center, and subtracting 1990 from 2000 gives the increments for the nominal scenario A forecast shown in Table 4.2. El Paso, Texas has been included in this list because of its proximity to Southern New Mexico; power is routinely transferred across this border. The Western Texas industrial region between Amarillo and Lubbock also represents a potentially large increment of capacity requirements because its present source of power, natural gas and oil, will be running out in the decade 1990-2000. However, since the population of this area is relatively small, it does not fit into the demographically based projection, so it has not been used.

The forecasting task is further complicated by the fact that the present per capita generating requirement is not homogeneous over the Western States, although the average figure for the Western States is approximately the same as the national per capita generating requirement. California, Colorado, New Mexico, and Utah all have present capacity requirements that are less than 70% of the national average. Washington, Oregon, and Idaho, by contrast, all have present generating capacity requirements more than 50% greater than the national average. If these tendencies were to continue to the year 2000, a

TABLE 4.2

FORECAST OF CAPACITY REQUIREMENT
1990 - 2000 INCREMENT

<u>State & Urban Center</u>	<u>BEA Districts</u>	<u>Pop(10⁶) 1990</u>	<u>Pop(10⁶) 2000</u>	<u>Nominal New Capacity Requirement (GWE) (Scenario A)</u>	<u>Alternative (Scenario B)</u>
<u>ARIZONA</u>					
Phoenix	162,163	2.4	2.6	3.1	3.1
<u>CALIFORNIA</u>					
Fresno	166	1.1	1.2	1.35	.95
Los Angeles	165	14.3	16.0	20.7	14.5
San Diego	164	1.7	1.9	2.25	1.58
San Francisco	167,168,171	9.1	10.1	12.6	8.81
<u>COLORADO</u>					
Denver	147,148,150	2.8	3.1	3.63	2.54
<u>IDAHO</u>					
Boise	152(1/2), 156(1/3),159	.57	.59	.60	.60
<u>MONTANA</u>					
Silver Bow	94,95,153	.6	.7	.64	.64
<u>NEVADA</u>					
Las Vegas	161	.55	.67	1.04	1.04
<u>NEW MEXICO</u>					
Albuquerque	146,149(1/2)	.78	.81	.83	.58
El Paso	145	.73	.75	.75	.53
<u>OREGON</u>					
Medford	158,160,169,170	1.26	1.35	1.57	1.57
Portland	157	2.1	2.2	2.63	2.63
<u>UTAH</u>					
Salt Lake City	149,151,152(1/2)	1.57	1.65	1.82	1.27
<u>WASHINGTON</u>					
Seattle	155,156(2/3)	3.28	3.54	4.15	4.15
Spokane	154	.72	.73	.73	.73

distribution of capacity requirement vastly different from scenario A would result. The historical reasons for these sharp differences do not, however, support such a projection.

The large present per capita generating capacity requirement in the Pacific Northwest is a manifestation of the high per capita electricity peak consumption which, in turn, is the result of historically cheap hydropower from the Columbia and Snake Rivers. This tendency cannot continue because the number of economically feasible hydropower sites on these rivers is nearly used up, and even the existing hydroelectric stations cannot sustain their output in dry years (such as 1977). The Pacific Northwest power companies recognize this limitation by planning most of their new units to be coal and nuclear. It is, therefore, assumed that per capita generating requirements in the Pacific Northwest will increase at a slower rate so that by 1990 they will be no larger than the national average.

The low per capita electric generating capacity (and consumption) of California and Colorado is probably the result of two factors: the historical widespread availability of oil and gas, and the lack of energy intensive primary industry. In California oil and gas production rates are rapidly declining and they may soon follow suit in Colorado. New sources such as offshore oil in California or shale oil in Colorado could reverse this declining trend, but there will also be increasing pressure to share these scarce energy resources with other states. The California electric utilities are forecasting a 3% per year increase in per capita generating requirement⁽³⁰⁾ compared to a 2.6% increase for the nation as a whole implied by the ERDA capacity forecast for 1990, perhaps in the expectation of a shifting away from the direct consumption of oil and gas. If a 3% per year increase in the per capita capacity requirement were sustained through the year 2000, California would still have a figure lower than the forecast national average, but the requirement increment in the decade 1990-2000 would be only 5% smaller than the scenario A figure given in Table 4.2.

The only alternative scenario which results in a significantly lower capacity requirement for California consists of the per capita generating

capacity requirement always maintaining a position at 70% of the national average. In view of the uncertain and conflicting possibilities identified in the previous paragraph, it seems reasonable to generate an alternative scenario B with California, Colorado, New Mexico, and Utah all having an increment of generating capacity requirement equal to 70% of the corresponding figure for scenario A. This conservative forecast for these four states represents continued contrast in per capita capacity requirement which might still be maintained in the Western States by 1990.

Two additional factors must be included in estimating the requirements for NEC capacity: the new capacity construction required to retire existing capacity and the fraction of new construction which will be nuclear. A reasonable estimate of replacement capacity is the capacity which went on line in the decade 1960-1970, which will become 30 years old during the 1990-2000 decade. Allocating the national average to the Western States on a population basis gives 30 GWe for the decade. (Many utilities do not follow such a strict replacement policy; instead, they carry some fully depreciated plants as reserve. This would result in a much lower estimate of replacement requirement, but would, unrealistically, ignore the fact that most of the retiring capacity would be oil and gas fired and could not be counted on for reserve if the fuel supply became unavailable.)

The most recent ERDA forecast⁽²⁸⁾ has the nuclear capacity of 195 GWe for 1990 and 380 GWe for 2000. The implication is that 62% of the generating capacity increase of 300 GWe during the 1990-2000 decade will be nuclear. This fraction is taken as the nominal estimate for this study.

The nominal generating capacity requirement for each load center is then obtained by multiplying the figure given in Table 4.2 by a factor to adjust for the additional replacement requirements and the fraction to be satisfied by nuclear: .94 and 1.03 for scenarios A and B, respectively.

The total generating capacity increments for the Western States specified by scenarios A and B are 58.4 GWe and 45.2 GWe, respectively. These represent a conservative approach by comparison with an extrapolation of the WSCC

published⁽³¹⁾ projection for 1990 (173,000) to 1996 (218,000) which, after adjusting to 2000 and allocating only the U.S. portion, gives an increment of 81 GWe.

4.5.4 Transmission Line Cost

Transmission line costs can be estimated at $\$0.235 \times 10^6/\text{GW-mile}$ in current dollars, or $\$0.41 \times 10^6/\text{GW-mile}$ escalated to 1985 at 8 percent per year. These figures are based upon recent experience of the Bonneville Power Administration.⁽²⁷⁾ They are 17% higher than a recent study of transmission requirements for the Intermountain Power Project (IPP) and for the Kaiparowits project.⁽³²⁾ Both involved transmission of coal-generated electricity from Utah to Southern California. Other recent studies quoted in NECSS-75, for transmission lines over 100 miles in length, agree with the IPP-Kaiparowits estimate. Nevertheless, the Bonneville results appear to be based on more practical experience, so a compromise value of 7% below the Bonneville estimate will be assumed.

These estimated costs are for construction and right-of-way (except in urban areas) and, within the approximations used here, can be considered equal for both 500- and 765-kV lines (on a per-GW carried basis). The latter have the advantage of carrying 2-3GW/line (compared with approximately 1 GW for the 500-kV line), and generally require less land and construction cost per GW carried than the 500-kV line. However, the extra reactive compensation and terminal equipment required at the higher voltage can make the costs fairly equal over the typical 500-mile distances considered here. The apparent cost advantages of the 765-kV and higher transmission line could be further diminished by extra right-of-way which could be required to allay the fears of environmental activists concerning some of the possible adverse effects.

4.5.5 Miscellaneous Considerations

Transmission losses of electricity are an important consideration, but few experts are willing to agree to standard loss coefficients. For any given transmission line, the losses will be determined by a cost tradeoff between the price of electricity and the cost of transmission line construction

(heavier cable, supports, etc.) or the ancillary costs associated with increased voltage. Nevertheless, NECSS-75 has given an estimate of 0.17 MW/mile for a 765-kV line nominally carrying just under 2 GWe. For the typical distance of 500 miles, this translates into a 4 percent transmission loss. Others have suggested that a nominal 765-kV line could carry 3.2 GWe, with a transmission loss of only 2% over a 500 mile segment.⁽²⁷⁾ In any case the value is small by comparison with uncertainties in construction cost for various types of terrain, so it was not explicitly included in the cost estimate. On the other hand, since transmission loss is a linear function of distance, it is implicitly incorporated into both the transmission requirement (GWe-miles) and cost.

This study originally planned to estimate excess transmission costs due to rerouting lines away from certain mountain passes which have already become transmission line bottlenecks. The importance of this problem is indicated by the fact that one-third of the NECSS-75 transmission system cost for the Galt, Nevada surrogate site was allocated for underground transmission for 17 miles near Henderson, Nevada (out of an average of more than 250 miles for the entire model). After some investigation, other principal bottlenecks were identified. All happen to be in Southern California or the Cascade Mountains east of the Seattle-Tacoma area.

The judgments of individuals responsible for transmission line planning and development indicated that they are not facing imminent physical limitations. However, all the bottlenecks in Southern California are showing increasing political resistance to transmission line development, so the physical limitations may never be reached. In fact, Southern California utilities are already routing over rugged terrain rather than battle political opposition in some of these areas. The Henderson, Nevada area has the physical capacity for more than 20 GW in unoccupied land, but the local governing body still refuses to permit any additional aboveground transmission at all.

In the face of such potential routing inhibition, a straight line distance from source to load has been assumed, suitably weighted up to 25 percent for any rugged terrain passed over. This procedure is not completely conservative; there are significant amounts of national forest acreage lying under

these direct routes, and some forest managers have been quite effective in preventing encroachment on their scenic territory. Nevertheless, if, and when, a policy of implementing nuclear energy centers is developed, there will have to be considerable federal support. With the more organized approach that this implies, it should be possible to devise land exchanges or other compensating arrangements to gain approval of transmission lines in otherwise unoccupied areas.

Another factor tending to encourage routing of transmission lines around settled areas is the cost of land, which could be as high as \$100,000/mile. Since such high values could only arise in suburban areas, they have not been explicitly included in the present study. They are, however, implicit in the assumption that the transmission line routing planners will not hesitate to avoid the suburban areas if they present any political obstacles.

4.5.6 Utility Functions and Issue Maps

Since the number of GWe-miles increases with NEC size, three utility functions are defined to maintain a consistent utility value range from 1 to 9 for all three concepts. The utility functions for the 6, 12, and 18 GWe concepts are shown in Figure 4.7 (a, b, c, respectively).

Comparison of the three utility functions shows an approximate doubling of the worst case GWe-miles with each jump in NEC size. This implies that the transmission requirement, or cost per unit generating capacity (obtained by dividing GWe-miles by NEC size), is approximately the same for the 6 GWe and 12 GWe centers but increases sharply for the 18 GWe center. This is due to disproportionately larger distances which must be covered to use up the very large 18 GWe capacity.

The transmission issue maps, shown in Figures 4.8, 4.9, and 4.10, for the 6, 12, and 18 GWe concepts can be viewed as representing relative costs. The higher utility values indicated by the darker shadings are the areas of lowest GWe-miles which translates into the lowest cost.

4.7 TRANSMISSION UTILITY FUNCTIONS

WESTERN INTERSTATE
ENERGY BOARD/WINB
(DRL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

TRANSMISSION 6

SOURCE

BASED ON FORECAST INCREMENT OF GENERATING

CAPACITY REQUIRED 1990 -2000

UTILITY VALUES

WESTERN INTERSTATE
ENERGY BOARD/WINEB
(BOMB/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

TRANSMISSION 12

SOURCE

BASED ON FORECAST INCREMENT OF GENERATING

CAPACITY REQUIRED 1990-2000

25 0 25 50 75 100 125 150 175 200 MILES

25 0 25 50 75 100 125 150 175 200 KILOMETERS

JAMES S. MOORE

AT CENTER

FIGURE 4.9

FIGURE 4.10

All three maps show these darkest areas on the Pacific Coast where most of the population and load is presently concentrated, and where the largest future growth is forecast to occur. The 6 GWe map (Figure 4.8) shows the most dispersion of the lower cost (dark) areas. The areas surrounding Denver and Seattle disappear for the larger NEC sizes because of the diminishing fraction of the NEC capacity which these cities can utilize.

The transmission costs are highest for site areas in Montana and Wyoming because of their distance from major load centers.

4.6 COOLING SYSTEM

4.6.1 Introduction

Cooling system cost has become a major component of total power plant cost. Increased environmental resistance to the thermal impact of once-through cooling has almost eliminated this relatively inexpensive mode. Evaporative cooling (wet) is being used for most power plants under construction today. Increasing conflicting demands for dwindling water supplies in the west has lead to the considerations of wet/dry and all dry cooling systems. Because of these factors, it was assumed for this study that wet/dry cooling would be used for all sites and concepts. This is consistent with present limitations on once-through cooling. The California Coastal Zone Management Commission has effectively excluded once-through ocean cooling from most of its coast. Most of the Oregon and Washington coast is too rugged for close siting. (These northern areas all have ample fresh water supplies and a cool climate so they are ranked quite favorably on the cooling issue, even without being permitted to utilize the nearby ocean water.)

4.6.2 General Methodology

The relative portions of wet (evaporative) and dry cooling, in a wet/dry system, are determined for each site, by minimizing the total cooling cost (capital plus operating) within a fixed water budget. The resulting cost consists of three general components: (a) the cost of the wet system itself, including the cost of water (from surface or ground sources), the cost of

operating the system, and the cost of power for auxiliary pumping functions, (b) capital and operating costs of the water transportation and storage system (over and above the nominal water cost considered in Item (a)), and (c) dry system capital and operating cost. The wet/dry system is optimized according to the following policy: during the hottest months, the major portion of the heat rejection load is carried by the wet system. The dry system is sized to carry the entire heat rejection load at the cooler temperatures after the water has been used up. Even if ample water for wet cooling appears to be available, total consumption will be limited so that the overall system uses no more than 48 percent of the total water that would be consumed by a completely evaporative cooling system. In other words, the system is at least 50 percent dry. Within the constraints of limited water availability, the size (and cost) for both wet and dry cooling systems are determined by the local peak wet bulb temperature and the distribution of dry bulb temperatures. The specific algorithms for the wet/dry optimization are described in Appendix A. The cost and performance figures developed there are based upon a recent, and comprehensive ERDA funded study of wet/dry cooling system design, performed by United Engineers & Constructors.⁽³³⁾

4.6.3 Water Availability

The availability of surface water for evaporative cooling at the sites throughout the United States has been described generally by NECSS-75, and by a more specific ERDA-sponsored study to indicate the areas where dry cooling would be required due to lack of available water.⁽³⁴⁾ A still more detailed study has assessed both surface and ground water availability for power plant cooling in Utah and Nevada.⁽³⁵⁾

Either surface or ground water (or both) is used where available. Available surface water is taken as 3 percent of the annual average flow from the nearest major river as determined by the nearest gauging station. This is slightly less conservative than the figure of 5 percent of the 20-year low flow usually assumed (NECSS-75), but it may be justified by additional storage capacity or the utilization of partly treated wastewater. Surface water flows were taken from U.S. Geological Survey (USGS) Water-Supply papers for 1961 to

1965 (which also reflects many years of historical data). In no case, however, was the plant allowed more than 50 percent evaporative cooling. This artificial ceiling was reached near the larger rivers. It may be objected that this limitation prevented such sites from getting full credit for the potential for lower cooling system costs near large fresh water sources. There are, however, two additional considerations which strongly suggest a need for a limitation on cooling water consumption, even near the large rivers. There are few portions of any river which would still permit unlimited withdrawal; there is a strong desire to eliminate the vapor-plume effects associated with wet cooling during the colder months.

Surface water is transported from the source by pipe which is sized according to the cheapest of two policies:

- a. Pipe sized to handle the maximum flow rate required during the hottest summer months, or
- b. Pipe sized to handle the total flow averaged over the entire year, with additional cost for the storage reservoir required at the site (assuming there will be no freezing during winter months).

The cost curves used for these evaluations are given in Appendix A.

If the site is over a known ground water reservoir which is not already appropriated for agricultural purposes, the available ground water is taken at 1.5 million gallons per day per square mile (which is based on approximately five wells per square mile, flowing at 200 gallons per minute). Ground water data were taken from USGS Water-Supply Paper 1800.

The following arguments present the rationale for these water allocations. The surface water estimates are consistent with present practice. Three percent of the average flow is of the same magnitude as 5 percent of the 20-year low flow, which is the figure frequently used for available water for these purposes (in particular by NECSS-75). The annual average may eventually

become a more appropriate base figure than the 20-year low flow, since so much storage capability has been, and is continuing to be, developed.

It may be objected that all the water outside the Pacific Northwest is already overcommitted. Nevertheless, evaporative cooling is not completely precluded. Agricultural irrigation water can be collected by drainage tiles in the aquifer under the irrigated fields; this water is generally too mineralized to be reused for agricultural purposes, but typical salinities of 1000 parts per million would be permissible in evaporative cooling systems (although some extra cost for treatment might be necessary, particularly if higher concentrations ranging up to 3000 ppm are encountered). Indeed, two large nuclear projects in California (Sundesert and San Joaquin) are planning to use such agricultural wastewater for evaporative cooling systems.

Unfortunately, the agricultural wastewater cannot yet be had "free of strings." In both of these cases, the utilities already have the rights to an equal amount of fresh water which must be given up to maintain the flow volume of the source (the Colorado River and California Aqueduct, respectively) from which the water was originally obtained by the irrigator. The rationale in the case of Sundesert is that the wastewater is presently collected and returned to the Colorado River (although in a much saltier state). Eventually, the quality of river water (particularly the lower Colorado) will be upgradable by partial desalination of agricultural discharge. Under such circumstances, the 1 or 2 percent of the total flow (represented by the requirements of a wet/dry cooling system) will not be so crucial, and half the water used for irrigation may ultimately be available for reuse for other purposes, including power plants (the other 50 percent of irrigation water being lost through evaporation).

The Sundesert and San Joaquin projects are mentioned for illustrative purposes only. Many other sources of reusable wastewater have been suggested (including municipal wastewater for power plants in Arizona, a practice already adopted on a smaller scale for the city of Burbank). A detailed evaluation of such opportunities is unnecessary for the general coarse screening provided by this study. The question is whether the water is available in

the first place. The question of where the power plant stands in the line of reusers will only provide a relatively minor change in the cost.

An additional question may be raised concerning the eventual depletion of certain ground water reservoirs, such as the Tularosa Basin (which also has problems of salinity in some areas). It is generally assumed that even those ground water reservoirs being recharged very slowly will have sufficient water to last at least 50 years' feeding evaporative cooling systems for nuclear power plants at the density of 1,000 megawatts per square mile. Of course, the resulting drawdown of the water table could cause hardship to existing nearby users. For this reason, no ground water use is assumed where there are prior agricultural uses. The remaining, presently untapped sources must, however, still be approached with caution because of long-range political problems of depleting withdrawals and the ever present possibility of subsidence causing damage to surface structures (including the plant itself).

4.6.4 Temperature Distribution

The cooling system cost estimation methodology utilizes the maximum wet bulb temperature and the distribution of dry bulb temperatures (the temperature duration curve which is a plot of temperature versus cumulative hours at that temperature or higher). Temperature distributions for 165 geographically distinct points were determined in this manner. (The data source used⁽³⁶⁾ actually had over 250 points in the Western States, but many of them were so closely overlapping as to be redundant, and others did not have sufficient temperature distribution data.) Temperatures at all cells could have been estimated by interpolating between these 165 known locations, but it was more efficient to simply calculate the cooling system cost at the 165 points and assign overall cost for surrounding cells creating a proximal map.

4.6.5 Calculations and Results

The optimum wet/dry cooling system was specified by a computer program based upon a parametrization of the wet/dry cooling system costs and performance characteristics developed in the UE&C study.⁽³³⁾ The UE&C study

actually developed wet/dry cooling system designs and costs for three sites representing completely different climatological conditions. It was originally suggested that these designs be used as reference points for simple interpolation based on peak or average temperature. Unfortunately, many of the areas in the Western States have higher temperatures than the hottest site considered by the UE&C study. Furthermore, the cooling system cost and water requirement is a function of the entire temperature distribution, not just the highest point. Since resources did not permit, and the nature of the broad scale evaluation process did not require, a rigorous design-type cost estimation was not produced for the weather station points. Instead, the more general methodology described in Appendix A was developed.

The output of the program is total cooling system cost (including present value of operating cost) in 1985 dollars per kilowatt of generating capacity, assuming a 75 percent capacity factor for a base loaded unit.

The resulting costs range from \$130 to over \$400 per kilowatt. The larger figure reflects very low water availability and high temperatures. For suitability evaluations, the cost range is divided into nine categories ranging from zero to \$500 per kilowatt.

Cost estimates were made for the three sizes of nuclear energy center: 6 GWe, 12 GWe, and 18 GWe. Since most of the sites are water-limited, the larger center sizes generally require greater reliance on dry cooling, and result in a higher cost per unit power (but this is sometimes more than counterbalanced by the lower unit cost of the larger volumes of water transportation for the wet system).

4.6.6 Comparison with Previous Studies

The technology of evaporative cooling towers is well developed with many operating examples in the United States. There are no analogous examples of large dry or wet/dry cooling systems in this country. This is not because the technology is inherently more difficult, but simply because, until now, the availability of water has made evaporative cooling the much cheaper

alternative. The inevitability of the impending water shortage in the southwestern United States has encouraged a number of studies of dry cooling systems. The cost estimates of studies completed in the early 1970's^(37,38) are now quite out of date (probably low by a factor of 3). A fairly extensive study of wet/dry systems optimized for minimum cost (without a fixed-water constraint) also presents cost estimates which are now obsolete.⁽³⁹⁾

A more recent study⁽⁴⁰⁾ of conventional and advanced wet/dry cooling systems has been performed by Battelle, PNWL under the climatic and meteorological conditions of Farmington, New Mexico (one of the three sites considered in the UE&C study⁽³³⁾) for a 500-MWe coal plant (which is actually being built). After adjustment for the 2.88 times greater heat rejection load of the UE&C study,⁽³³⁾ the Battelle study gives the same capital cost for the example considered (which happens to be a 60 percent dry system).

4.6.7 Environmental Impacts

The major environmental impacts of cooling towers are the atmospheric heat load, the water consumption, and the vapor plume effects (visibility, fogging, and sometimes even snow). The plume vapor effects occur mainly at lower temperatures where the wet portion of the wet/dry system will not be operating. (In fact, much of the impetus behind the development of wet/dry systems stems from the desire to eliminate vapor plume effects.)

The environmental impact of water consumption depends quite strongly on the alternative use to which the water would be put (if it were not evaporated in the cooling tower). The impact of the atmospheric heat loading has not been sufficiently studied (experimentally or theoretically) to support any precise prediction of specific phenomena such as thunderstorms or heat island effects. In view of these uncertainties, the total impact could be assumed to be simply proportional to the cost of the cooling system. This cost generally increases as water becomes unavailable (necessitating larger dry fractions of the system) and as the temperature increases. Although less water is used, the impact will be greater because of its scarcity (higher value in the

drought-prone regions). The direct atmospheric heat loading impact of a dry cooling system is, obviously, proportional to the system size, and thereby proportional to the cost.

4.6.8 Utility Functions and Issue Maps

The utility functions for the three NEC sizes are shown in Figure 4.11. Comparison of the three graphs shows that the highest cost/Kw computed for each NEC concept actually declines slightly with increasing center size. The implication of this trend is that the highest cooling cost sites for the larger center sizes are most efficiently served by large water sources with the benefits of lowered water transportation unit costs for increased volumes transported. If transportation distance had been artificially limited (as it might become through strong "local consumption" policies), the unit cooling cost would have increased sharply with increasing center size as the local sources were used up.

The issue maps are given in Figures 4.12, 4.13, and 4.14. The darkest shades, representing the lowest cooling system costs, are largely concentrated in the Pacific Northwest, which has moderate summer temperatures and a potentially ample supply of river water. Other areas which appear to be attractive are the California coast and some moderate temperature inland sites with ample supplies of ground water.

Some of the special situation low cooling cost areas may be shown larger than the actual climatological conditions warrant. For example, the California coastal area inland from Santa Barbara seems to have a low cooling cost because the temperature data from Santa Barbara (being the closest station for which complete annual data are published) have been used for inland areas which may be 20°F hotter in the summer. Similarly, the Tularosa Basin area low cooling cost reflects a nearby weather station at a higher altitude, which is probably significantly cooler. A finer geographical resolution of these data will be required for the detailed investigation of the more promising, selected sites.

UTILITY VALUES

1	2	3	4	5	6	7	8	9
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WESTERN INTERSTATE
ENERGY BOARD/WINB
(DORL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

COOLING 12

SOURCE

ENGINEERING WEATHER DATA 1967

47 CENTER

FIGURE 4.13

4.7 LANDFORM

A nuclear energy center will require a land area of 5 to 20 square miles (not including the exclusion zone) depending on the number of plants (or GWe). Within this land area, an increase in slope or ruggedness of terrain translates directly into increased cost for construction. This includes difficulty that may be encountered in excavation for foundations, construction of access roads where low grades are required (due to the extreme weight of components such as the turbine or pressure vessel), and finally measures that must be taken to mitigate environmental disturbances such as control of runoff and erosion from cut slopes.

To evaluate the impact of landform (terrain) considerations over a large regional area, a general index that indicates both the steepness of slopes and the areal extent of such slopes is needed. Such data which was found to be available from the U.S. Geological Survey⁽⁴¹⁾ characterizes each local area (6 square miles) by the percentage of that area which is classified with a topographical gradient less than 8 percent (gently sloping). The 8 percent slope is not strictly a critical threshold value for land utilization. It does, however, indicate a value beyond which movement of vehicles becomes impeded, and in general, construction and operation becomes more difficult.

Based on the USGS map⁽⁴¹⁾, the categories of percent gentle slope shown on Table 4.3 are used for evaluation of landform with respect to NEC siting. Associated with each of the landform categories is a corresponding utility value.

TABLE 4.3
LANDFORM UTILITY VALUES

<u>Percent Gentle Slope</u>	<u>Utility Value</u>
Over 80%	8
50 to 80%	5
20 to 50%	2
Less than 20%	1

Using the 10 mile x 10 mile grid cell for the suitability analysis, it is possible for a cell to have the lowest preferability ranking and still have 20 square miles gentle sloping. If this level area which theoretically could exist in several portions of land happened to be contiguous it would be possible to fit in an NEC without having to bear the rugged terrain construction cost penalty. However, at the regional level of analysis these special conditions are not practically observed; therefore, the analysis is based solely on the general indication of ruggedness as defined by the data.

As the landform map which is shown in Figure 4.15 shows, the least suitable areas coincide with the major western mountain ranges including the Cascades in Washington and Oregon, the Sierras in California, and the Rockies which occur in northern Idaho, eastern Montana, and central Colorado. Southwestern New Mexico also is included in this category. Most of Montana and the northeastern portion of Oregon are somewhat better. The highly suitable areas are found only in the California central valley, northwestern Utah, and southeastern New Mexico.

The overall results presented in Section 5 of this report show suitable site areas in the coastal mountains of southwestern Washington and northwestern Oregon. Closer investigation could identify isolated level areas which would look even better. It is known that Washington Public Power Supply System has found enough level land for two nuclear plants in southwestern Washington at Satsop.

4.8 Major Transportation Access

Construction of a nuclear energy center will involve the transport of unusually large pieces of equipment. In addition, large quantities of materials such as structural steel, concrete aggregate, mechanical system components, etc. must be transported to the site from diverse locations. If the site is not directly adjacent to a major transportation access system such as a railroad or major highway, a connection to such a system in the form of a

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WESTERN INTERSTATE
ENERGY BOARD/WINB
(DOEL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

LAND FORM

SOURCE

U.S.G.S. 1970

NATIONAL ATLAS

DAMES & MOORE

47 CENTER

FIGURE 4.15

rail spur line or access highway must be built. The cost of initial construction of such an access and its maintenance over the period of power plant construction is directly related to the length of such access.

To consider transportation access as a siting issue at the regional level, the access distance to the nearest major highway or rail line for all potential site areas was determined. This distance measured in miles was assumed to provide an index of a specific site area's suitability based on the cost of providing access. U.S. Dept. of Commerce⁽⁴²⁾ and U.S. Dept. of Defense⁽⁴³⁾ sources were used to determine the location of major highways and railroads. A computer program was used to determine the distance from all site areas (cells) to the nearest highway or railroad, assuming no preference in the mode of transportation.

The transportation utility function is defined by Table 4.4. The resulting utility value map is shown in Figure 4.16.

TABLE 4.4
TRANSPORTATION UTILITY VALUES

<u>Distance (Miles)</u>	<u>Utility Value</u>
0 - 10	9
10 - 20	8
20 - 40	7
40 - 60	6
60 - 80	4
80 - 100	2
100 - 999	1

Major transportation access is greater in the major urban regions such as the Seattle-Tacoma-Portland region, San Francisco-Los Angeles region, than it is in the sparsely populated areas around Denver, Phoenix, and Salt Lake City.

A. FORTA

FIGURE 4.16

In these areas transportation systems are most extensively developed and offer a high degree of access. Major interstate routes connect these regions thus forming a network of transportation links which leaves very few isolated regions within the study area.

It should be noted that limited navigable water transportation routes are available, particularly along certain portions of the Columbia and Sacramento Rivers and along the Pacific Coast, close to harbors. Navigable waterways were not included, but their general areas of service rank fairly high anyhow because they are covered by rail and/or highway, as can be seen from the figure.

4.9 COAL DEVELOPMENT

There is a high probability that the coal reserves of this country will be increasingly utilized in the generation of electricity and as a general energy source. Coal reserves also represent a land resource that covers significant geographic area within the Western States and therefore, must be considered in the evaluation of siting areas.

Due to the foundation stability requirements of a nuclear power plant, it is unlikely that deep mining of coal could be conducted beneath, or in close proximity to, a nuclear energy center. This suggests that such coal bearing areas be assigned low utility values for NECs, which would indicate a higher priority for these areas as coal development centers. On the other hand, coal deposit locations that have been strip mined could be good power plant sites provided that the stripping excavation is not too deep and no valuable additional coal seams lay beneath. Fortuitous circumstances might leave excavations for foundations partially complete and little additional ecological damage would result.

Consideration also might be given to downrating the utility value for areas having oil shale deposits, particularly the rich ones bearing more than 25 gallons/ton. However, there is still no commercially demonstrated technology for shale oil extraction, and the richer areas have not been completely delineated, so no particular utility value was assigned for this study.

For the coal area utility value it was assumed that wherever conflicts between coal extraction and the development of a nuclear energy center existed, that the area would be preserved for coal development.

To be able to consider the site development conflicts between coal and nuclear energy, the location of major coal reserves and sites selected as suitable for coal power plants were identified. The data were taken from two different sources. The locations of coal reserves were taken from a U.S. Geological Survey map.⁽⁴⁴⁾ The more restricted set of sites suitable for

coal-fired power plants (particularly with respect to meteorological dispersion) were taken from a report published in 1976 by the Energy and Environmental Systems Division of Argonne National Laboratory.⁽⁴⁵⁾ The classification of these data and the assigned utility values are listed in Table 4.5.

TABLE 4.5
COAL DEVELOPMENT UTILITY VALUES

<u>Category</u>	<u>Utility Value</u>
Coal plant sites (mine mouth)	2
Coal field areas	5
All other areas	7

The results are shown in Figure 4.17. The areas of high utility correspond to the absence of any significant coal deposits. The areas of low utility lie in Utah, Wyoming, Colorado, and Montana and correspond to areas which also have meteorological conditions which can tolerate coal combustion emissions; these areas would be the logical locations for fossil energy centers.

UTILITY VALUES

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WESTERN INTERSTATE
ENERGY BOARD/WINB
(DROUL/Sab-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

COAL DEVELOPMENT

75 0 75 50 75 100 125 150 175 200 MILES
75 0 75 50 75 100 125 150 175 200 KILOMETERS

SOURCE

U.S. GEOLOGICAL SURVEY 1960

COAL FIELDS OF THE U.S.

DAMES & MOORE

MAP 111
AT CENTER

FIGURE 4.17

4.10 THERMAL APPLICATION

4.10.1 Introduction

There have been many studies of dual-purpose nuclear power plants which would be able to provide process heat as well as electric power. The most important industrial applications utilize high temperature process heat for coal gasification,⁽⁴⁶⁾ or steelmaking.⁽⁴⁷⁾ Unfortunately, these applications require temperatures of over 900° Fahrenheit which cannot be obtained from the reactors commercially available at the present time.

Three industrial applications for the lower temperature steam available from light water reactors have been considered extensively in the literature: paper pulp, petroleum refining and miscellaneous chemical manufacturing processes.^(48,49) The first two probably lend themselves more naturally to co-generation since some of the relatively unused parts of their own material from the process stream can be used for fuel. In this situation, the user can more easily generate his own electricity and export the excess than import a supply of steam from a nuclear power plant. More emphasis can be expected on such efficiency improving arrangements in the future. Co-generation was actually more common 50 years ago, but the practice waned because of the relative inconvenience to both utility and user. Energy conservation economics could reverse this trend within the next few years.

Chemical manufacturing and desalination are applications of low temperature process steam which are ideally suited for co-location with a dual-purpose central power station (one providing process steam as well as electricity). The Dow Chemical plant at Midland, Michigan has made arrangements with Consumers Power Company for the supply of process steam and electricity from a two-unit nuclear plant being built in proximity to the Dow Chemical plant (described briefly in Reference 48). The steam supply will be used by Dow to replace that currently being supplied by their own fossil boilers which are now reaching the end of life and are not able to meet current emission regulations. The Dow plant has a mixture of products including aspirin, agricultural chemicals and chlorine. The reagents will be equally general: brine

and salt from nearby sources plus typical oil-based feedstocks. There appear to be no particular siting requirements for this type of facility. The reagents are readily available throughout the country, and customers are also widely distributed. For this reason, the chemical processing application is not reflected in any of the issue maps.

4.10.2 Desalination

Desalination is an application which does have strong siting implications. A number of studies over the past 10 years have examined site-specific concepts of dual-purpose power desalinating plants.^(51,52,53,54,55,56) Transportation costs, and the large volumes of water, dictate that promising areas for nuclear desalination be within approximately 10 miles of an unlimited supply of salt water. Additionally, there must be a local demand for the desalinated water and competitive fresh water supplies should be at least 200 miles away.

An evaporation desalination plant has two advantages when considered in conjunction with nuclear power. By utilizing more of the low grade energy (low temperature steam), the desalination plant reduces the need for cooling towers, and it also increases the efficiency of the remaining electric generating process by approximately 10 percent (from 32 percent to over 35 percent), after taking credit for the heat used for desalination.

Areas favorable to nuclear powered desalination plants are those with a large available supply of salt water. In the 11 Western States, the only surface salt water supplies are the Pacific Ocean, the Salton Sea, and the Great Salt Lake. (The latter has the potential additional advantage for mineral recovery; the recoverable values in these minerals do not provide a major reduction in desalination cost, but they do provide a secondary benefit of an incentive for co-location of processing facilities for these recovered minerals.) Cells bordering on these bodies of water have been designated as high utility. Saline ground water resources (1,000 to 35,000 ppm) were identified from the USGS map⁽⁵⁰⁾ and designated as medium utility; the water is available in large quantities but it will be more difficult to get.

Lower salt concentration sources, such as irrigation wastewater and the Colorado River near the Mexico border, are more efficiently desalinated by a membrane process (reverse osmosis or electrodialysis) which uses mechanical or electrical energy. Since they do not utilize low temperature steam, such sources have no influence in NEC siting.

The utility values for sources of salt water for desalination are given in Table 4.6

TABLE 4.6
THERMAL APPLICATION (DESALINATION) UTILITY VALUES

<u>Category</u>	<u>Utility</u>
Unlimited surface salt water	6
Large salt ground water reservoir	4
All other lands	1

The resulting issue map for the desalination application is shown in Figure 4.18. The high suitability zones lie along the Pacific Coast and adjacent to the Salton Sea and the Great Salt Lake. (There was no special consideration to exclude either of these large inland water bodies, or any other large inland lakes. Any highly suitable sites found directly over water would have to be rejected.) The areas of medium suitability lie above recognized ground water reservoirs (some of which are fairly saline).

4.10.3 Warm Water Utilization (Reject Heat)

An extensive review of the literature was conducted on the potential uses of warm water from a nuclear power plant cooling system. These include the following:

- a. Space heating^(57,58)
- b. Aquaculture^(57,59)

FIGURE 4.18

- c. Outdoor soil warming to accelerate crop growth^(57,59,60,61,62,63)
- d. Spray irrigation for both warming and cooling (evaporative)^(60,61,62,64)
- e. Greenhouse climate modification^(57,59,61,65,66)

Such applications have very special siting requirements, some of which are summarized in an analysis of five sites (all in undeveloped countries).⁽⁶⁷⁾ Of all these possible applications, only the greenhouse heating appears to have any economic potential in the near future. If a greenhouse must be heated in the winter, nuclear waste heat is an energy conserving way of providing the required heating. Unfortunately, the combination does not save capital. The primary greenhouse heating requirement is in the winter, but the cooling system for the power plant must be sized to carry the peak summer load (when there is no requirement for greenhouse heating to use up some of the power plant heat rejection requirement).

The most recent and comprehensive study of the economics of this process was for an application in Canada⁽⁶⁶⁾ (to utilize waste heat from the CANDU reactor, which has thermal characteristics similar to the LWR reactor used in the United States). The Canadian study found that if there was a winter market for fresh cucumbers and tomatoes (which are presently imported during these winter months) it could be profitable to base a greenhouse industry on waste heat from nuclear power plants. If natural gas costs more than \$2 per thousand cubic feet, the reactor-heated water will be the cheaper heat source. Despite the high capital cost for the system, it is still better to find some useful purpose for the interchange, rather than dump the heat directly into the atmosphere.

Since the economics of this issue were not compelling, and since the Delphi session assigned the general issue of thermal applications the lowest importance ratio, no issue map for agricultural use was constructed. Even if

the issue had appeared of great importance, it is not clear that a nuclear energy center would be the most appropriate vehicle for implementation. Waste heat would be quickly dissipated during the winter cold, so it is extremely important that the greenhouse be located as close as possible to the power plant. The Canadian study had the greenhouses located at the very edge of the nuclear power plant exclusion zone. Dispersed nuclear power plants would be accessible from all sides for this sort of application, but plants in a nuclear energy center would only be accessible along the circumference of the center. Locating the greenhouses within the center boundary could be considered (but still outside the exclusion zone of the individual power plants). However, it is unlikely that the economic benefits would be sufficient to compensate the enormous increase in the difficulty of the nuclear energy center security and management problems.

Similar considerations also apply to the possibility of using reject heat for space heating. The concept has been given some attention; a site in Sweden was studied with the objective of underground siting a nuclear power plant in an urban area to permit the use of some low temperature steam (not quite reject heat) for district heating. ORNL and Northern States Power Company are currently studying the potential for district heating with central power station steam (coal or nuclear). However, both these situations (reject heat or process steam) would require a proximity which would be inconsistent with current siting criteria.

5 SITE AREA ANALYSIS AND EVALUATION

5.1 SUITABILITY RESULTS AND ANALYSIS

Graphic display maps showing composite suitability for the 6, 12 and 18 GWe concepts are shown in Figures 5.1 through 5.3, respectively. For each cell the total suitability has been computed as the sum of the products of the utility values for each issue multiplied by the corresponding importance weight. For the three basic concepts presented in these figures, seven issues have been used: population density, seismic design, transmission, cooling system, landform, transportation, and coal development. Before producing the final maps, excluded areas, defined by the protected lands map, are removed, leaving the blank spaces which cover nearly half the study area.

The different graphic characters (shades of gray) have been assigned to percentage intervals to indicate the relative ranking of the site areas (10 mile by 10 mile grid cells). A more concrete evaluation of the site areas is provided by the cost maps described later.

In the 6 GWe power only concept, Figure 5.1, the top two and a half percentile (solid black graphic elements) includes site areas in Arizona, California, Colorado, Idaho, Oregon, Washington, and Wyoming. The next two and a half percentage points add site areas in New Mexico and Utah to complete the top five percentile.

WESTERN INTERSTATE
ENERGY BOARD/WINB
(WIEB, Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME
POWER 6 SUITABILITY

SOURCE

0 25 50 75 100 125 150 175 200 MILES
0 25 50 75 100 125 150 175 200 KILOMETERS

AT CENTER

FIGURE 5.1

LABEL	PERCENTILE	VALUE
1	97.5-100	78-82
2	95-97.5	77-78
3	90-95	76-77
4	80-90	75-76
5	60-80	73-75
6	40-60	71-73
7	0-40	58-71

[illegible]

WESTERN INTERSTATE
ENERGY BOARD/WINB
(ORNL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

POWER 18 SUITABILITY

SOURCE

25 0 25 50 75 100 125 150 175 200 miles

75 0 25 50 75 100 125 150 175 200 KILOMETERS

PLAY CENTER

Nevada has no significant representation until the top 20 percentile is included, although there are two cells at the Utah border occurring in the top 10 percentile. Montana has no significant representation until the top 40 percentile is included, although it has one cell included in the top 20 percentile.

For the 12 GWe concept, Figure 5.2, the top two and a half percentile includes site areas in Arizona, California, Idaho, Oregon, and Washington. The top five percentile also contains site areas in Colorado, Nevada, and Utah. New Mexico does not show up until the top 10 percentile, and Wyoming and Montana do not show up until the top 20 percentile is included. The reason for Wyoming slipping from the top two and a half percent in the 6 GWe concept to only the top 20 percent in the 12 GWe concept is primarily the greatly increased cost of transmission for the additional 6 GWe. The favorable parts of Wyoming in the 6 GWe concept were close to Denver, Colorado which could take over half the 6 GWe load. This is not so significant a factor for center concepts of 12 GWe and larger.

In the 18 GWe concept, Figure 5.3, the top two and half percentile includes sites in Arizona, California, Idaho, Nevada, Oregon, and Washington. Considering the top five percentile includes areas in Utah. The top 10 percentile brings in Colorado and New Mexico, while Wyoming and Montana are not included until the top 20 percentile. The most significant trend from the 6 GWe concept to the 18 GWe concept is the marked increase in the ranking of site areas in Nevada. For the larger center sizes, proximity to load centers in California increases the relative rankings of these sites.

The fourth concept considered was the industrial application of desalination. To evaluate this concept the desalination issue map, Figure 4.18, was multiplied by the appropriate importance weight (.57), and the result for each cell was added to the corresponding cell for the 12 GWe overlay (Figure 5.2). The result is given in Figure 5.4. Some areas which ranked fairly high on the 12 GWe power only concept are seen to be significantly improved because of the

WESTERN INTERSTATE
ENERGY BOARD/WINB
(ORNL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME
INDUSTRIAL SUITABILITY

SOURCE

0 25 50 75 100 125 150 175 200 MILES
0 25 50 75 100 125 150 175 200 KILOMETERS

PRINTED
AT CENTER

FIGURE 5.4

opportunity to exploit the saline ground water (above and beyond simply using it for cooling). The following are examples:

1. Southeastern Imperial County in California (near the Mexico and Arizona border) shows an enhanced ranking based upon the potential for desalination of the saline ground water. The area would look even better if the saline water in the Salton Sea were available. Unfortunately, the separation of 35 miles probably makes the pumping of billions of gallons of highly saline water a day commercially unfeasible.
2. A few cells southwest of the Great Salt Lake managed to rank in the top five percentile because of the potential for exploitation of ground water. Additional cells in the top five percentile appear to be entirely or largely situated over the lake itself and would, consequently, be rejected.
3. The Green River area of Utah, which ranked in the top five percentile for each of the three power only concepts, moves up to the top two and a half percentile and expands in area. As with the other areas, this is due to the potential for exploitation of saline ground water.
4. The Tularosa Basin and a few cells in northwestern New Mexico move from the top 10 percentile to the top 5 percentile on the basis of the potential for ground water exploitation.

The consequences of greater concern with aircraft hazards are illustrated in Figure 5.5., which was generated by weighting the air corridor issue map (Figure 4.4) by the importance value (1.4) and adding it to the nominal power only 12 GWe map (with an adjustment to all other importance values, so that they still sum to 10). On the resulting graphic display map the corridors can be seen as criss crossing patterns of lightened shading (by comparison with Figure 5.2) which indicates lower levels of suitability. Since the airports

WESTERN INTERSTATE
ENERGY BOARD/WINB
(ORNL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME
**POWER 12 WITH AIR CORRIDOR
SUITABILITY**

SOURCE

NORTH
AT CENTER

FIGURE 5.5

themselves are excluded, there are also additional restricted cells indicated by the small white areas. Although many promising sites appear to be disqualified by these additional restrictions, most of the highly suitable areas remain.

5.2 COST ANALYSIS

In order to evaluate the strictly economic site specific impacts of nuclear energy centers, the capital costs associated with seismic design, power transmission, and cooling system requirements were added together, in units of dollars per kilowatt. The results for 6, 12, and 18 GWe are represented in Figures 5.6 through 5.8, respectively. It should be noted that the graphic symbols correspond to the same cost ranges on all three of these maps, so that they can be compared to assess the relative costs for the three concepts at any given site area.

For the 6 GWe concept the lowest cost areas are found in California, Oregon, and Washington, in the range of \$200 to \$250 per Kw. The next lowest range of \$250 to \$300 per Kw contains additional areas from Arizona, Colorado, Idaho, Montana, New Mexico, and Wyoming. No sites in Nevada are included until the range of \$300 to \$350 per Kw is reached. It should be noted that Montana is not in the worst category (as was the case with the suitability maps); the relatively low cost areas in Montana are in the northwest part of the state which would be significantly reduced in ranking if the landform issue were included (which could have an effect on construction costs).

In the 12 GWe concept only California site areas fall in the lowest cost category, (\$200 to \$250 per Kw). Idaho, Oregon and Washington have their best site areas falling in the \$250 to \$300 per Kw category. The remaining states are not represented until the \$300 to \$350 per Kw category.

In the 18 GWe concept California is again the only state having site areas in the \$200 to \$250 Kw category. In addition, Oregon is the only additional state represented in the \$250 to \$300 per Kw category. Site areas

LABEL \$ COST X10/kw

1.	60-65
2.	55-60
3.	50-55
4.	45-50
5.	40-45
6.	35-40
7.	30-35
8.	25-30
9.	20-25

LABELS

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

WESTERN INTERSTATE
ENERGY BOARD/WINB
(ORNL/Sub-7272/1)

**PRELIMINARY ASSESSMENT
OF
NUCLEAR ENERGY CENTERS**

MAP NAME **COST MAP 6**

SOURCE

75 0 25 50 75 100 125 150 175 200 MILES
75 0 25 50 75 100 125 150 175 200 KILOMETERS

NORTH
AT CENTER

FIGURE 5.6

WESTERN INTERSTATE
ENERGY BOARD/WINB
(ORNL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME

COST MAP 12

SOURCE

0 25 50 75 100 125 150 175 200 MILES
0 25 50 75 100 125 150 175 200 KILOMETERS

FIGURE 6.7

LABEL	\$COST X10/kw
1	60-65
2	55-60
3	50-55
4	45-50
5	40-45
6	35-40
7	30-35
8	25-30
9	20-25

LABELS	1	2	3	4	5	6	7	8	9
									
									
									
									
									
									
									
									
									

WESTERN INTERSTATE
ENERGY BOARD/WIB
(DRL/Sub-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME
COST MAP 18

SOURCE

AT CENTER

FIGURE 5.8

in Arizona, Idaho, Nevada, Utah, and Washington first appear in the \$300 to \$350 per Kw category. The least cost site areas in the remaining states are not found until the \$350 to \$400 per Kw category.

As would be expected, the best sites in all the states, except California, appear to increase in cost with increasing center size. This reflects the influence of transmission cost. Only California has enough domestic load so that transmission distances need not increase significantly with center size. Transmission is not, however, the largest factor in the total cost. The areas of Arizona and Nevada which do well on transmission (because of their proximity to Southern California) still rank in the higher cost categories because of their high cooling costs. Since dollar costs are simply added, with no importance weighting factors, the fact that cooling costs are significantly higher than transmission costs in Arizona and Nevada makes cooling a more important issue, as far as economic impacts are concerned.

5.3 SITE AREA SELECTION

The three power only concepts can be compared to identify areas most suitable to two or three of the concepts simultaneously. One such comparison is shown in Figure 5.9. The top 10 percentile of suitability for each of the three concepts is represented. Those areas included in the top 10 percentile of all three concepts are shown with the black symbol; areas covered by only one or two of the concepts are indicated by the numerical characters 1 through 6 according to the table given on the figure. The larger, and the most distinct, black areas are designated as selected zones (or selected site zones). All but the smallest of these were outlined in Figure 2.2.

In order to further characterize the highly suitable areas, 27 typical cells were selected from within the black areas of Figure 5.9. These selected sites are identified on Figure 5.10; all but the smallest black areas of Figure 5.9 are represented, and the larger black zones in California and Oregon are represented by more than one selected site area. The characteristics of the selected site areas are summarized in Table 5.1. Suitability

SELECTED SITES	State	PERCENTILE						\$ /KW		
		Suit.* 06	Suit. 12	Suit. 18	Cost 06	Cost 12	Cost 18	Cost 06	Cost 12	Cost 18
S 1 NE Coconino	Ariz	94	92	93	28	29	21	290	330	350
S 2 NW Yavapai	Ariz	97	97	98	14	45	8	270	330	320
S 3 Apache	Ariz	96	94	92	21	23	28	280	330	360
S 4 NW Lassen	Cal	94	97	98	26	10	5	290	300	310
S 5 NE Lassen	Cal	91	97	98	21	11	6	290	300	310
S 6 S Tehama	Cal	99	99	99	11	2	3	270	270	290
S 7 Sutter	Cal	98	99	99	5	0	0	250	250	280
S 8 Sac/Stanislaus	Cal	98	99	99	7	1	2	260	260	290
S 9 W Madera	Cal	98	98	95	29	18	22	290	320	350
S 10 W Mesa	Colo	97	95	95	32	17	21	270	320	350
S 11 Nez Perce	Idaho	98	98	97	8	8	13	260	290	330
S 12 W Ada	Idaho	96	95	94	20	15	21	280	310	350
S 13 S Elmore	Idaho	95	93	92	23	24	28	290	330	360
S 14 N Gillian	Ore	99	98	98	2	4	9	230	280	320
S 15 NW Umatilla	Ore	97	97	95	12	11	18	270	300	340
S 16 Wasco	Ore	99	99	99	2	3	6	220	270	310

* Suit. = Suitability

TABLE 5.1
SUITABILITY (PERCENTILE) AND COST (PERCENTILE
AND \$/KW) FOR SELECTED SITE AREAS

SELECTED SITES	State	PERCENTILE						\$ /KW		
		Suit.* 06	Suit. 12	Suit. 18	Cost 06	Cost 12	Cost 18	Cost 06	Cost 12	Cost 18
S 17 SW Linn	Ore	98	98	98	5	8	9	250	290	320
S 18 SW Crook	Ore	93	96	97	6	5	3	250	280	300
S 19 Lake	Ore	93	96	98	5	4	2	250	280	290
S 20 S Klamath	Ore	91	96	97	39	17	10	310	320	320
S 21 E Emory	Utah	95	95	96	32	16	16	280	320	340
S 22 S Pacific	Wash	97	94	93	0	1	5	190	260	310
S 23 Franklin	Wash	97	97	94	10	11	21	260	300	350
S 24 SW Lincoln	Wash	98	98	97	2	7	15	250	290	340
S 25 W White Pine	Nev	88	91	95	36	27	15	310	330	340
S 26 S Clark	Nev	89	96	98	43	16	7	320	320	210
S 27 N San Juan	N Mex	93	94	90	31	24	34	300	330	370

* Suit. = Suitability

TABLE 5.1 (continued)
SUITABILITY (PERCENTILE) AND COST (PERCENTILE
AND \$/KW FOR SELECTED SITE AREAS

for each of the three power only concepts is represented by the percentile ranking. Since these site areas have all been selected to fall in the top 10 percentile for all three concepts, all of the percentile numbers are above 90. The cost characteristics of these selected site areas are represented by both percentiles and dollars per Kw. It should be noted that the better site areas are defined by lower cost values (with lower percentiles) and higher values of suitability (with high percentiles).

5.4 ANALYSIS OF NOMINATED AREAS

The suitability and cost characteristics of the eight nominated sites are summarized in Table 5.2. Suitability is represented by percentile rankings, while cost is represented by both percentile and dollars per kilowatt. The sites were evaluated in the most liberal possible manner (as befits the screening objectives of this study) by shifting location up to 20 miles to actually select the best site area in the immediate vicinity. The locations of the eight nominated sites are shown in Figure 5.11; the background for this figure is a composite suitability map for the 12 GWe power only concept. This map display differs from the 12 GWe map shown in Figure 5.2 in that only the top 25 percent of the cells are represented by the graphic display symbols to highlight these higher ranking areas. The map background provides a basis for comparison of the nominated sites with surrounding areas and for determining the geographic flexibility in the location of a site within these local areas.

It is seen, from Table 5.2, that four of the nominated sites have suitability percentiles ranking above 90 for all three power only concepts. These sites (Hanford, Boardman, Green River, and Tularosa) fall in the areas indicated by the black graphic elements in Figure 5.2.

Of the remaining four nominated sites, Galt, Nevada also shows some promise. It ranks above the 90 percentile on suitability for the 18 GWe concept and not too much below for the 12 GWe concept. The Galt site area does even better on the cost comparison, ranking ahead of Tularosa Basin for the 12 GWe concept and tied with Boardman for lowest cost in the 18 GWe concept. In fact, for the 18 GWe concept several areas of Nevada rank lower

NOMINATED SITES	PERCENTILE						\$ / KW		
	Power 06	Power 12	Power 18	Cost 06	Cost 12	Cost 18	Cost 06	Cost 12	Cost 18
N 1 Hanford	98	97	95	8	10	18	260	300	340
N 2 Boardman	99	98	98	2	4	9	230	280	320
N 3 Glasgow	20	10	6	99	99	99	520	570	620
N 4 Desert Valley	69	72	69	75	64	60	370	400	410
N 5 Owyhee	20	25	31	58	54	48	340	380	390
N 6 Green River	96	95	96	21	15	17	280	310	340
N 7 Galt	70	86	91	35	16	9	300	320	320
N 8 Tularosa Basin	94	90	91	28	33	35	290	340	370

TABLE 5.2
SUITABILITY (PERCENTILE) AND COST (PERCENTILE
AND \$/KW) FOR NOMINATED SITE AREAS

WESTERN INTERSTATE
ENERGY BOARD/WINB
(ORNL/Sub-7272/1)

**PRELIMINARY ASSESSMENT
OF
NUCLEAR ENERGY CENTERS**

MAP NAME

**POWER 12 SUITABILITY
WITH NOMINATED SITES**

SOURCE

PLATE 17
AT CENTER

FIGURE 5.11

in cost than any others outside of California or Oregon; this is due to the dominance of the transmission issue and the proximity to the large California load centers.

Although only five of the nominated sites appear to offer much promise on the basis of composite suitability or total cost, all eight sites have some issues on which they rank fairly well (which may have been responsible for their nomination in the first place). The individual issue rankings can be seen from the utility values given in Table 5.3. To facilitate comparison, the seismic, cooling, and transmission utility values are expressed in two significant figures. It can be seen that all the nominated sites rank equally well on the population, transportation (except for Owyhee), coal development, and landform issues. With the exception of population, these issues are represented by discrete utility functions which are completely accurate at only one significant figure. Population could be represented by two significant figures, but the second figure would only make a difference close to population centers. The differences on the seismic issue are small, being reflected only in the second significant figure. Most of the difference among these nominated sites appears to come from the cooling and transmission issues.

In order to better understand the contribution of the seismic, cooling, and transmission issues in the composite suitability, the chart shown in Figure 5.12 has been prepared. The numbers represent the individual sites and indicate the relative contribution to composite suitability. These relative contributions are computed; for each nominated site and for each issue, by subtracting the mean value for each issue map from the utility value for each site (and each issue) and multiplying the resulting difference by the importance weight. In this manner, Figure 5.12 shows how the nominated sites compare with the average of all sites, how they compare with each other, and how their deviations from the average contribute to the composite suitability.

One surprising feature of Figure 5.12 (and Table 5.3) is the very high ranking of the cooling issue for the Tularosa Basin. This results from two circumstances: an abundant supply of ground water and moderate summer

NOMINATED SITES		Seismic	Population	Transportation	Coal Development	Landform	Cooling 12	Transmission 12
N 1	Hanford	8.8	9	9	7	5	7.3	6.3
N 2	Boardman	8.8	9	9	7	5	7.7	6.5
N 3	Glasgow	8.9	9	9	7	5	4.0	2.9
N 4	Desert Valley	8.8	9	9	7	5	5.2	6.2
N 5	Owyhee	8.9	9	6	7	5	6.0	5.8
N 6	Green River	8.9	9	9	7	5	7.6	5.0
N 7	Galt	8.6	9	9	7	5	6.8	6.5
N 8	Tularosa	8.6	9	9	7	5	6.8	6.5

TABLE 5.3

UTILITY VALUES FOR NOMINATED SITES

FIGURE 5.12
COMPONENT ANALYSIS OF NOMINATED SITE SUITABILITY

temperatures from one of the nearest weather stations (Sacramento Peak). The utilization of ground water for evaporative cooling is a reasonable expectation, particularly for areas devoid of salt sensitive agriculture in the immediate vicinity. However, the temperature distribution of the Tularosa Basin might be more accurately reflected by the weather station at nearby Holloman Air Force Base. This would increase the cooling system cost by \$50 per kilowatt and decrease the composite suitability correspondingly. This alternative is also shown on Figure 5.12 for comparison. The result would be a rather mediocre ranking for the Tularosa Basin on both a suitability and cost basis.

This uncertainty regarding the potential of the Tularosa Basin site illustrates the problem with relying on one good cell in the midst of a rather poor general region. Further investigation will be necessary to determine whether a viable site can be found for a nuclear energy center in this vicinity. One or more of the following would probably have to be found:

1. The center could be located at a high enough altitude to assure moderate summer temperatures, without greatly increasing the cost of ground water pumping.
2. If pumping costs require that the center be located at a low altitude with higher temperatures (such as are characteristic of Holloman Air Force Base), sufficient ground water would have to be available to permit over 50 percent evaporative cooling.
3. Load centers would have to be found in the industrial areas near Amarillo and Lubbock, Texas to reduce the excessive transmission costs associated with the great distances to major load centers in the Western States; any such load would probably only be significant for the 6 GWe concept.

6 SENSITIVITY AND REGIONAL SELECTION

The NEC site areas identified and reviewed in Section 5 of this report result from a numerical evaluation of available data and information generated by computer analysis. These results cannot be viewed as immutable because of the regional nature of the data and the use of numerical values to represent subjective decisions (importance values). However, a measure of confidence can be developed for the suitability analysis results by examining the general sensitivity of the results to changes in any of the parameters that have been used (including basic assumptions, data or issue maps, utility functions or importance values). To vary each parameter incrementally would generate so many possible comparisons that a meaningful understanding of sensitivity within the context of the study could not be practically obtained. Therefore, the sensitivity analysis is based on a general assessment of sensitivity through two measures, individual issue contribution to composite suitability and the sensitivity of the ranking of specific site areas (the selected site areas). Each of these measures is discussed in detail in the following sections. As a general conclusion for the sensitivity analysis, regional areas are identified which define geographically contiguous areas within which the site area suitabilities are relatively insensitive to changes in NEC size.

6.1 INDIVIDUAL ISSUE CONTRIBUTION TO SUITABILITY VARIATION

One of the strongest characteristics of each issue map is the geographic variation of the utility values across the map. These individual utility variations combine to produce the geographic variations of suitability over the composite suitability map. The extent of the variations for each map is measured by the standard deviation or the variance (square of the standard deviation) for the parameter of that map (utility or suitability).

The sample statistics used to describe measures of sensitivity have been simplified in the following discussions. The applicable statistical theory is summarized in Appendix F. There the reader will find detailed definitions of, and relations among the specific sample statistics used.

If the geographical variations of the individual issue maps were independent of each other (that is, they have no similar geographic patterns) the variance of the suitability map would be equal to the sum of the variances of the utility values for each issue map, multiplied by the square of the importance weight for that map. When the test is applied to the specific issue maps developed in this study, it was observed that the variations of the utility values of some of the issue maps are strongly correlated with each other.

The correlation between the variations of any pair of maps is represented by the correlation coefficient, which is a number between -1 and +1. The +1 indicates that the variables always vary together. The -1 indicates that the variables vary together, but with opposite sign. A value of 0 indicates that the variations are in phase half the time and out of phase half the time in a way that approximates independent variation.

The correlation coefficients between the seven issue maps are shown in the matrix of Table 6.1 using the 12 GWe transmission and cooling issues. Note that the diagonal elements are equal to 1, representing the complete correlation of the variable with itself. The correlation coefficients of largest magnitude are the values of -.5 between seismic and transmission and +.4 between coal development and transmission. The -.5 correlation reflects

	Seismic	Transmission	Cooling	Population Density	Coal Development	Landform	Transportation	Fractional Contribution
Seismic	1.0	-.495	.104	.119	-.153	.066	-.085	.29
Transmission	-.495	1.0	-.131	-.187	.403	-.002	.035	.18
Cooling	.104	-.131	1.0	.003	-.099	-.229	.044	.23
Pop. Density	.119	-.187	.003	1.0	-.027	-.016	-.118	.06
Coal Dev.	-.153	.403	-.099	-.027	1.0	.068	.000	.04
Landform	.066	-.002	-.229	-.016	.068	1.0	.058	.04
Transport.	-.085	.035	.044	-.118	.000	.058	1.0	.16

TABLE 6.1
ISSUE MAP CORRELATION MATRIX

the fact that population (and low transmission cost) is concentrated along the seismically active Pacific Coast. The +.4 correlation reflects the fact that coal deposits (which imply a low NEC utility on this issue) tend to be away from the major load centers along the Pacific Coast. With the correlations between all possible combinations of issue maps taken two at a time, the contribution of each issue to the composite suitability variance can be calculated. This is the sum of the single variance and six covariances (product of correlation coefficient and standard deviations) for each issue, appropriately weighted by the issue importance ratios. The formulae for these calculations are given in Appendix F.

Dividing the individual issue contributions by the suitability variance (which is equal to the sum of the seven individual issue contributions) gives the individual issue contributions in fractional form. These are shown in the last column of Table 6.1. The relative rankings are similar to the importance weights except for population density which moves from second to fifth in rank order. Although the importance ratio is high, the contribution is small because the only geographical variations are found in the small areas around the population centers (which leads this issue map to have the smallest variance). In contrast, transportation has a surprisingly large contribution, in spite of its low importance ratio, because it has the highest variance of all the issue maps.

The individual issue contribution expressed in fractional form can be viewed as the sensitivity of the entire map to changes in the individual issue map. For this reason it can be referred to as entire map sensitivity.

6.2 SITE AREA SENSITIVITY

Changes in the importance weights of individual issues will generally change the relative rankings of the individual site areas. The amount by which the rankings are changed, per unit of importance weight change, is the site area sensitivity. The simplest way to measure this sensitivity is to compare area rankings under different importance weight conditions.

Figure 6.1 shows such a comparison for the transmission issue. The nominal 12 GWe concept (power only) is compared with two alternatives, one having the transmission importance weight increased by 25 percent and with the second having the transmission importance weight decreased by 35 percent. The two different sizes of deviation produce some indication of the constancy of the sensitivity. For the transmission sensitivity depicted in Figure 6.1, 8.2 percent of the cells remain in the upper 10 percentile for all three conditions; this means that 82 percent of the upper 10 percentile suitability remain unaffected by the variation in importance weight. Such a large unaffected percentage implies that the suitability is relatively insensitive to changes in transmission importance weight of up to 35 percent.

To get some measure of the change in sensitivity (or constancy) with increasing larger changes in importance weight, it can be observed that of the top 10 percentile (877 cells) of the nominal 12 GWe concept, 5.6 percent are dropped out by a 25 percent increase in transmission importance value; 13.4 percent are dropped out by the 35 percent decrease in transmission importance value. Dividing by the percentage change in importance value for each case, the 25 percent increase removes .22 percent of the cells from the most favorable 10 percent category for each percent increase in importance weight; the decrease of 35 percent produces a .38 percent decrease in the number of favorable cells for each percent decrease in the transmission importance weight. It would appear that the higher rate of removals for the larger percentage change in importance weight implies that the sensitivity becomes enhanced for larger deviations from the nominal. (It should be remembered that this particular sensitivity discussion refers only to the upper 10 percent on the nominal 12 GWe case; removals from this category are, of course, compensated by other cells which move into the upper 10 percentile for the cases with the changed importance weight for transmission.)

The above analysis is not sufficient to determine a complete measure of sensitivity, but it does indicate that changes in importance ratio of up to 35 percent will produce no significant shift of the upper 10 percentile site areas. Maps similar to Figure 6.1 have also been prepared to measure the sensitivity to similar changes in importance weight for the seismic design and

cooling issues, but the changes in the upper 10 percentile site areas have been even smaller.

The suitability percentile rankings of selected site areas are also quite insensitive to 25 percent and 35 percent changes of the importance weights, as can be seen from Table 6.2. Here the percentile rankings are given for each of the 27 selected site areas, under the six sensitivity test conditions (+25 percent or -35 percent change in importance weight for each of the three issues). The sensitivity of the rankings for the eight nominated sites is summarized by Table 6.3. Again, the highly ranked sites are almost completely insensitive to these changes in importance weight. The only exception is Tularosa Basin which shows a significant sensitivity to the transmission issue.

Two additional types of selected area sensitivity are also of interest. The discussion of transmission suitability (Section 4.5) suggested two alternative scenarios for per capita generating capacity increment; these are described as Scenarios A and B in Section 4.5.2 and detailed in Table 4.2. The sensitivity to these two assumptions is indicated in Figure 6.2. Of the most suitable 10 percent of the cells for one scenario, 93 percent remain in the top 10 percentile when the per capita alternative capacity requirement scenario is considered. Only 7 percent of the top 10 percent in each scenario are dropped out when the scenario is shifted. Hence, it is concluded that the selection of the most suitable site areas is relatively insensitive to reasonable modifications in the per capita capacity requirement forecast for the decade 1990 to 2000. Of course, scenarios which depict vastly smaller nuclear generating capacity increments would invalidate these conclusions and would appear to foreclose any nuclear energy center concepts at all.

The second type of sensitivity of interest is with respect to changes in NEC size. One example of this type of sensitivity measure has already been given in Figure 5.9 in connection with the identification of the highest

SELECTED SITES	State	Seismic		Transmission		Cooling	
		High	Low	High	Low	High	Low
S 1 NE Coconino	Ariz	92	92	91	93	92	92
S 2 NW Yavapai	Ariz	97	97	97	97	97	97
S 3 Apache	Ariz	94	93	93	70	94	93
S 4 NW Lassen	Cal	97	97	98	97	97	97
S 5 NE Lassen	Cal	97	97	97	96	96	97
S 6 S Tehama	Cal	99	99	99	99	99	99
S 7 Sutter	Cal	99	99	99	99	99	99
S 8 Sac/Stanislaus	Cal	99	99	99	99	99	99
S 9 W Madera	Cal	98	98	99	96	97	99
S 10 W Mesa	Colo	95	94	94	97	96	94
S 11 Nez Perce	Idaho	98	98	97	98	98	96
S 12 W Ada	Idaho	96	95	94	97	96	94
S 13 S Elmore	Idaho	93	92	90	96	94	91
S 14 N Gillian	Ore	99	98	98	99	99	98
S 15 NW Umatilla	Ore	97	97	97	97	97	97
S 16 Wasco	Ore	99	99	99	99	99	98

TABLE 6.2
SUITABILITY OF PERCENTILES OF SELECTED SITE AREAS

SELECTED SITES	State	Seismic		Transmission		Cooling	
		High	Low	High	Low	High	Low
S 17 SW Linn	Ore	98	98	98	98	98	98
S 18 SW Crook	Ore	96	95	95	96	96	94
S 19 Lake	Ore	97	96	96	96	97	94
S 20 S Klamath	Ore	96	95	95	96	95	96
S 21 E Emory	Utah	95	95	94	97	96	93
S 22 S Pacific	Wash	94	94	94	94	96	91
S 23 Franklin	Wash	97	97	96	97	97	96
S 24 SW Lincoln	Wash	98	98	97	99	98	97
S 25 W White Pine	Nev	91	91	89	93	91	90
S 26 S Clark	Nev	96	96	97	94	94	97
S 27 N San Juan	N.Mex.	94	93	92	95	94	93

TABLE 6.2 (continued)
SUITABILITY OF PERCENTILES OF SELECTED SITE AREAS

NOMINATED SITES		Seismic		Transmission		Cooling	
		High	Low	High	Low	High	Low
N 1	Hanford	97	97	97	98	97	97
N 2	Boardman	98	98	98	99	98	98
N 3	Glasgow	11	8	8	15	9	12
N 4	Desert Valley	73	72	73	70	68	70
N 5	Owyhee	26	22	26	23	25	24
N 6	Green River	96	95	94	97	96	94
N 7	Galt	85	85	86	83	85	85
N 8	Tularosa	91	89	86	95	92	87

TABLE 6.3

SUITABILITY OF PERCENTILES OF NOMINATED SITE AREAS

NORTH
AT CENTER

FIGURE 6.2

suitability site areas. An extension of this approach to the top 20 percentile is shown in Figure 6.3. As would be expected, the area in the top 20 percentile for all three concepts (6, 12, and 18 GWe) is more than twice as large as the area common to all three center size concepts falling in the upper 10 percentile of each concept. The 13.7 percent of all the cells which fall in the top 20 percent of all three concepts is approximately equal to the sum of the 5.7 percent which fall in the top 20 percentile of only two concepts plus the 7.6 percent of all the cells which fall in the top 20 percentile for only one of the three center size concepts. The relative sizes of these three percentages are comparable to the analogous percentages determined for the top 10 percent of Figure 5.9.

6.3 REGIONAL SELECTION

In order to define a very coarse screening, the areas in the top 20 percent of all three center size concepts (shown black in Figure 6.3) can be combined with the areas which appear in the top 10 percent of one or two of the concepts (shown by the numerical characters 1 through 6 in Figure 5.9). The resulting area defines the selected site regions and is shown in Figure 6.4.

LABEL	DESCRIPTION
0	NO COMBINATIONS
1	POWER 6
2	POWER 12
3	POWER 18
4	POWER 6 & 18
5	POWER 6 & 12
6	POWER 12 & 18
8	POWER 6 & 12 & 18

LABELS
0 1 2 3 4 5 6 9
000000 111111 222222 333333 444444 555555 666666 999999
000000 111111 222222 333333 444444 555555 666666 999999
000000 111111 222222 333333 444444 555555 666666 999999

WESTERN INTERSTATE
ENERGY BOARD/WINB
(PHEL/SUB-7272/1)

PRELIMINARY ASSESSMENT OF NUCLEAR ENERGY CENTERS

MAP NAME
POWER 6 & 12 & 18 AT 20%

SOURCE

FIGURE 6.3

APPENDIX A

A METHODOLOGY FOR ESTIMATING COOLING SYSTEM COST

A.1 INTRODUCTION

This appendix describes the methodology for determining the optimum wet/dry mix, for estimating cooling system cost, and for estimating the cost of the water delivery system. The accurate estimation of cooling system costs is usually based on a specific system design. To compare a number of sites using such extensive calculations would be prohibitively expensive. Instead, general performance descriptions were developed by parametrization of the results of a recent study of a family of wet/dry systems for three sites having widely differing temperature characteristics.⁽³³⁾ The optimum cooling systems were then determined from these performance descriptions. Finally, the cost of water transportation (for the wet part of the system) was estimated from current pipeline and reservoir costs.

A.2 PARAMETRIZATION AND PERFORMANCE DESCRIPTION

Any wet or dry cooling system consists of cells, each of which can carry a specified heat rejection load under various operating conditions. The results reported in the UE&C study⁽³³⁾ were analyzed to determine heat rejection rate per cell for dry and wet systems, with the results shown on Figures A-1 and A-2 as a function of dry and wet bulb temperatures, respectively. The

wet system performance curve of Figure A-2 is derived from the monthly peak evaporation rates given in Reference 33, a typical example of which is reproduced on Figure A-3. The uppermost curve gives the flow rate for the 100-percent wet system during the hottest 8-hour period of the month. The wet bulb temperature corresponding to this hottest 8 hours is determined from the engineering weather data.⁽³⁶⁾ The heat rejection per cell for the hottest month is obtained from summary tables from Reference 33, such as the one reproduced in Table A-1. The last column is for the 100-percent wet system, and the heat rejection per cell is obtained by dividing the maximum heat load by the number of cells. The use of the hottest months gives three points on Figure A-2 (corresponding to the three sites used by UE&C). The remaining points are obtained from the other monthly maxima from Figure A-3 (plus the corresponding figures for Boston) and assume that the heat rejection rate per cell that could actually be achieved is inversely proportioned to the flow rate under the design conditions developed by the UE&C exercise. In other words, the actual heat rejection remains the same regardless of temperature; as the wet bulb temperature is reduced, less water is evaporated to supply this heat rejection; the tower could sustain the higher evaporation rates (characteristic of the hotter months) at the lower temperatures, which would mean a higher heat rejection rate per cell at the lower temperature.

The dry system heat rejection rate (presented on Figure A-1) is also determined from the flow rate curves such as Figure A-3. The percentage figures for each curve indicate the amount of water consumption for the wet-dry system, expressed as a percentage of the water consumption for the pure evaporative system. The five different percentages of wet system are viewed individually, and for each month, the fraction of the total heat rejection carried by the wet system (wet portion of the wet-dry system) is determined by the ratio of the flow rate for the combined wet-dry system to the flow rate of the pure wet system. This wet cooling fraction is then plotted as a function of the associated dry bulb temperature, and the resulting points fall on a straight line for each cooling system combination and site. The data plotted in Figure A-4 for the 10-percent system are typical. If these straight lines are projected to zero-percent wet cooling, an effective design point temperature for the dry system is obtained.

The heat rejection per cell for the dry system is determined for each effective design point temperature (of Reference 33) by simply dividing the total heat rejection by the number of dry cells in that particular system; these data are given in Table A-1 (and similar tables for the other two sites). The justification for this procedure is that the dry system will always be sized to carry the full heat rejection load at the design point temperature.

The effective dry design point temperatures determined by the above heuristic procedure turned out to differ by, typically, 10 percent from the actual optimum dry system design temperatures developed in Reference 33. Part of this difference is due to a restriction to 5-degree-interval quantization in design point temperature selection by Reference 33; the rest of the difference may result from the approximate procedure used here (particularly attempting to fit straight line performance characteristics for relations which should not be a simple linear function of temperature). Furthermore, the slope of the empirical straight line relationship between percent wet cooling and dry bulb temperature tends to decrease with decreasing effective design point temperature, as shown on Figure A-5. This variation is specifically considered in the cooling tower synthesis described below.

A.3 SYNTHESIS OF COOLING SYSTEM DESIGN

The basic algorithm for determining the mixture of wet and dry cooling, to optimally satisfy the constraints of a given annual water consumption and a given site temperature distribution, is as follows:

1. Size the wet system to handle the entire heat rejection load at the maximum wet bulb temperature.
2. Compute the total water consumption for the wet system, starting with the hottest days, and continuing through successively cooler days until the entire water allotment has been used.

3. Take the dry bulb temperature of the hottest day for which there is no longer sufficient cooling water, and establish that as the first estimate of the effective design point for the dry system.
4. Recompute the water consumption on the hottest days to meet only those heat rejection requirements that cannot be satisfied by the dry cooling system (for the design point temperature identified in the previous step); the percentage for the cooling requirement is determined from a general straight line relationship synthesized from those shown in Figure A-4 and corresponding ones at different wet-dry mixtures, but using the slope given as a function of effective design point temperature in Figure A-5.
5. Recompute the effective dry design point temperature as the dry bulb temperature on the hottest day for which no water is left for evaporative cooling. This new estimate of effective design point temperature will be significantly lower than the first.
6. Iterate this process; the third estimate of effective dry design point will generally be higher than the second, but lower than the first. The process is repeated until a stable dry design point temperature is reached.
7. Size the wet system to carry its share of the heat rejection load at the maximum wet bulb temperature.
8. Size the dry system to carry the entire heat rejection load at its effective design point temperature.

This optimization procedure may produce a dry system which carries so much of the load that the wet system cannot use up its allotted water in the 8,760 hours of the year. Under such circumstances, the size of the dry system is

reduced (without lowering the design point temperature) so that all the water can be consumed.

The water consumption for the pure wet system was determined as a function of dry bulb temperature as an intermediate step in the sequence of deriving the wet heat rejection rate (shown on Figure A-2) from the peak flow rates given in Reference 33 (such as the one shown on Figure A-3). The results are compiled on Figure A-6; an average straight line fit to this data is taken to estimate evaporation rate as a function of dry bulb temperature. It must be admitted that this is an extreme simplification; not only is the true evaporation rate only approximately linear, but it is also a function of wet bulb temperature, rather than dry bulb temperature. Nevertheless, the approximate straight line relationship appears to hold over the region of interest. The consistent difference among the three sites shown on Figure A-6 is probably due to the different average humidities which lead to different relationships between wet and dry bulb temperatures at the three sites. Since the dispersion appears to average less than 5 percent, and will in no case be greater than 10 percent, it appears to be suitable for the overall 10 percent accuracy of this methodology. Furthermore, the simplification only introduces an error in the wet system cost, which is never more than one-third the dry system cost over the wet-dry system range considered.

The actual temperature distribution for each site is approximated by straight line segments connecting six points from Reference 36: maximum annual temperature and temperatures exceeded only 1, 2-1/2, 5, 10, and 50 percent of the time. A typical example is shown on Figure A-7. This approximation permits the use of temperatures given in Reference 36, eliminating the need to resort to the extensive analysis of the daily meteorological data. The water consumption is computed for successive segments of the temperature distribution, until the allotted water has been used. The water consumption for the k th segment is given by:

$$W_k = \int_{T_{k-1}}^{T_k} W_{er}(T) F_w(T) N_k(T) dT, \quad (A-1)$$

where the evaporation rate for the 100 percent wet tower is

$$W_{er}(T) = a + bT,$$

from the average line in Figure A-6, and the fraction of full wet cooling required is

$$F_w(T) = \beta (T - T_e),$$

where

T_e is the effective dry system design point to be determined by the iterative process, and

the number of hours per unit temperature in the k th segment is

$$N_k(T) = \frac{87.6p_k}{T_k - T_{k-1}}$$

where

p_k is the percent of total annual hours represented by the k th segment.

This equation can be integrated analytically to give, as an example for the first segment,

(A-2)

$$W_1 = 87.6\beta \left[-T_e a + 1/2(a - bT_e)(T_1 + T_m) + 1/3b(T_1^2 + T_1T_m + T_m^2) \right]$$

where $T_m = T_0$ is the maximum temperature, and $p_1 = 1$ percent since the T_1 is the temperature which is exceeded 1 percent of the hours in the year.

The cumulative water consumption after n segments is given by

$$W_{\text{tot}} = \sum_{k=1}^n W_k = -T_e \sum_{k=1}^n \gamma_k + \sum_{k=1}^n f_k \quad (\text{A-3})$$

where

$$\gamma_k = p_k (87.6)^\beta \left[a + \frac{b}{2} (T_k + T_{k-1}) \right],$$

$$f_k = 87.6\beta p_k \left[\frac{a}{2} (T_k + T_{k-1}) + \frac{b}{3} (T_k^2 + T_k T_{k-1} + T_{k-1}^2) \right]$$

to show the dependence of W_{tot} on T_e explicitly.

The calculation proceeds through successively cooler segments until more than the allotted portion of water has been used. In other words, the process stops at the first T_j for which $W_{\text{tot}} > W$, the allotted annual water consumption. At that point, the effective design point temperature is determined within the last segment by interpolation according to the equation

$$T_e = \frac{\sum_{k=1}^n f_k - W}{\sum_{k=1}^n \gamma_k} \quad (\text{A-4})$$

which is simply the solution of Equation (A-3) for T_e with W_{tot} replaced by W .

As a check for consistency in this methodology, it was applied to the temperature data for the three sites used in the UE&C report;⁽³³⁾ the effective dry design point temperatures turned out to be quite close to those determined from the data given in the UE&C report (but not necessarily close to the actual design point temperatures used by UE&C).

The total cost per section for dry and wet systems was taken as the average of the cases presented in the UE&C report. The average cost per wet cell was determined as \$2.95 million, and the average cost per dry cell as

\$1.02 million; no individual case deviated by more than 5 percent from these averages. A typical presentation of the cost data from the UE&C report is reproduced in Table A-2; the economic assumptions used to compute present value of operating expense and water costs are given in Table A-3. It might be objected that economies of scale would invalidate the assumption of constant total cost per section, but the rate for total costs presented in the UE&C study seem to be fairly uniform across a number of examples.

It is generally assumed that dry cooling systems consume excessive amounts of power (up to 10 percent of the total plant output). In actual fact, the power consumption can be reduced to the rate of the wet system by simply providing sufficiently large heat transfer surface areas. Of course, the capital investment becomes much larger. The UE&C report considered two types of dry systems, high back pressure turbine and low back pressure; typical examples of relative costs are shown in Tables A-1 and A-2. The capacity penalties for the dry and wet-dry systems are shown in the second line of Table A-2. The cost and performance figures for the wet-dry systems are based on using the low back pressure turbine for the dry portion of the wet-dry system. In this manner, the largest capacity penalty for the wet-dry system is approximately 5 percent; since the capacity penalty for the all wet system is 2 percent, the capacity penalties appear close enough to each other that the systems can be compared on a total cost basis (which does include the capacity penalty).

With these assumptions, the cost of the dry portion of the system is computed from

$$C_d = \frac{230}{E R_d} \quad (A-5)$$

where

E is the thermal efficiency expressed as a fraction, and

R_d is the dry heat rejection rate determined from Figure A-1.

This cost is expressed in millions of dollars for a 1000-MW generator having a heat rejection requirement of 1000MWt/E. With these assumptions, the cost of the wet system is computed from

$$C_w = \frac{6.65\beta (T_m - T_e)}{R_w E} \quad (A-6)$$

A.4 COST OF WATER TRANSPORT (FOR EVAPORATIVE SYSTEMS)

The principal components of water transport cost are the pipe and the pumping. The pumping costs are a critical function of the difference in elevation between water source and cooling tower. Since this is a fairly local parameter, it was not considered in the area evaluation. Pumping cost for overcoming friction is, however, included.

Two extremes of water delivery policy can be considered:

- a. Pipe sized for the peak summer water requirement with no onsite storage, and
- b. Pipe sized for the annual average flow with onsite storage to handle higher summer requirements.

The pipe costs for these two alternatives are shown in Figure A-8. These costs are expressed in cents per gallon per day. The curves are approximated by the straight line segments, as shown. As would be expected, the line working all year has a higher cost per unit of capacity. However, the peak flow rate is so much higher than the average flow rate that this effect is more than counterbalanced. The horizontal axis of this graph is given in units of W_D (the maximum daily flow rate). Note that the curve for average pumping is expressed as a function of W_{tot} , which for this policy is equal to $365 W_D$.

The lowest cost system, in all cases considered here, turned out to be the year-round constant pumping. Except for plants located within a few miles of the river, the cost for storage, given in Figure A-9 on a per unit basis, is a negligible component.

MAJOR DESIGN DATA FOR THE OPTIMIZED COOLING TOWER SYSTEMS

SITE: SAN JUAN, NEW MEXICO

BASE OUTPUT: 1094 MWe

WET/DRY TYPE: MECHANICAL SERIES (S1)

Item	Mech. Dry (H)*	Mech. Dry (L)†	Percentage Make-up Requirement Mechanical Series Wet/Dry					Mech. Wet
			1%	10%	20%	30%	40%	
Number of Tower Cells, Wet Tower/Dry Tower	0/175	0/431	9/263	15/170	18/138	21/119	25/102	32/0
Mode of Wet/Dry Tower Operation	-	-	S1	S1	S1	S1	S1	-
Maximum Operating Back Pressure P_{max} , in-HgA (mm-HgA)	13.09 (332.5)	5.03 (127.8)	5.00 (127.0)	5.00 (127.0)	4.50 (114.3)	4.00 (101.6)	4.00 (101.6)	3.30 (83.8)
Gross Plant Output at P_{max} , MWe	939.8	1047.5	1048.2	1048.4	1059.5	1069.9	1069.9	1082.2
Heat Load at P_{max} , 10^9 Btu/hr (10^{12} J/hr)	7.62 (8.04)	7.26 (7.65)	7.25 (7.65)	7.25 (7.65)	7.22 (7.61)	7.18 (7.57)	7.18 (7.57)	7.14 (7.53)
Heat Load Distribution at P_{max} , (Wet Tower/Dry Tower), %	0.0/ 100.0	0.0/ 100.0	33.4/ 66.6	57.8/ 42.2	69.6/ 30.4	78.2/ 21.8	81.7/ 18.3	100.0/ 0.0
Annual Make-up Water for Wet Towers, 10^8 gal (10^6 m ³)	0.0 (0.0)	0.0 (0.0)	0.494 (.187)	4.57 (1.73)	9.11 (3.45)	14.19 (5.37)	18.78 (7.11)	47.02 (17.80)

* H-High Back Pressure Turbine

† L-Conventional Low Back Pressure Turbine

TABLE A-I

MAJOR COST SUMMARY FOR OPTIMIZED COOLING TOWER SYSTEMS (\$10⁶)

SITE: SAN JUAN, NEW MEXICO

PRICING YEAR: 1985

WET/DRY TYPE: MECHANICAL SERIES (S1)

Item	Mech. Dry (H)*	Mech. Dry (L)†	Percentage Make-up Requirement Mechanical Series Wet/Dry					Mech. Wet
			1%	10%	20%	30%	40%	
Total Capital Cost (Direct & Indirect Capital Costs)	119.31	263.42	194.14	136.42	121.81	112.88	103.55	53.39
Total Capacity Penalty (Capacity & Auxiliary Power)	113.28	73.06	59.66	49.19	40.89	33.77	31.81	16.28
Total Operating Penalty (Replacement & Auxiliary Energies, Make-up Water & Maintenance)	84.38	53.38	44.33	41.82	41.13	38.72	38.80	21.17
Total Evaluated Cost (Sum of Capital & Penalty Costs)	316.97	389.86	298.13	227.43	203.83	185.37	174.16	90.84

* H-High Back Pressure Turbine

† L-Conventional Low Back Pressure Turbine

TABLE A-2

BASIC ECONOMIC FACTORS

Plant Start-up Date	1985
Average Plant Capacity Factor	0.75
Annual Fixed Charge Rate	18%
Plant Life	40 years
Capacity Penalty Charge Rate (Incremental Base Load Plant Cost)	\$600/kW
Fuel Cost (For Base Load Plant)	153¢/MBtu (145¢/GJ)
Operation and Maintenance Cost (For Incremental Base Load Plant)	0.724 mills/kWhr
Water Cost	27¢/1000 gal (7.13¢/m ³)

FACTORS FOR ESCALATION

Construction Period for LWR	6 years
Construction Period for Cooling System	2 years
Escalation on Overall Plant Costs	7% per year
Escalation on Cooling System Equipment and Material	6% per year
Escalation on Cooling System Labor	8% per year
Escalation for Fuel Cost Levelization	4% per year
Interest Rate	10% per year
Base Year Cost Data	1974

TABLE A-3

DRY HEAT REJECTION RATE PER SECTION
AT T_E IN 10^7 BTU/HR=2.929MW

HEAT REJECTION RATES FOR THE DRY SYSTEMS IN THE UE&C REPORT

HEAT REJECTION RATES FOR THE WET SYSTEMS OF THE UE&C REPORT

Figure F-2 Maximum Make-up Flow Rate for Each Monthly Period: Atlanta, Georgia
Mechanical Series Wet/Dry Cooling System - SI Mode

FIGURE A-3

DRY SYSTEM PERFORMANCE (OR WET SYSTEM REQUIREMENTS)

SLOPE OF DRY COOLING PERFORMANCE LINE, β

WET SYSTEM MAKEUP REQUIREMENTS

DAMES & MOORE

FIGURE A6

TEMPERATURE DISTRIBUTION FOR SAN DIEGO

DAMES & MOORE

FIGURE A7

PIPELINE AND PUMPING COSTS

SURFACE WATER STORAGE RELATIONSHIP

APPENDIX B

B SITE AREA EVALUATION METHODOLOGY

To identify potential site areas for NECs, all areas in the Western States (excluding those areas that are restricted) were evaluated for each of the selected siting issues and a measure of site area suitability assessed. The site area suitability of all areas was then displayed (on a map) and those areas scoring highest were identified as NEC siting areas. To conduct the evaluation of site area suitability, an orthogonal grid system was superimposed on the entire study area, dividing the study area into approximately 15,000 grid cells, each of which were 10 miles by 10 miles. A suitability value was computed for each grid cell (not already restricted) under the assumption that each cell was a potential NEC siting area.

To determine a specific site area suitability value, each of the siting issues must be considered independently. These independent evaluations are then combined such that a single measure of suitability is derived for each site area. This type of procedure, which is used to develop the suitability value, is called a multiple-attribute (or multi-issue) decision model. To apply the decision analysis model, a three-step procedure is used:

1. Utility functions are defined for each siting issue
2. A set of importance weights (one for each issue) are developed, using the Delphi technique, and

3. A suitability analysis is conducted where the utility functions and importance ratios are used to evaluate all potential site areas (grid cells). The resulting composite analysis is displayed in map form and site areas are identified.

Each of these steps is described in greater detail in the following sections.

B.1 UTILITY FUNCTIONS

For each major siting issue, a utility function is stated such that any given cell can be translated from its specific characteristics into a utility value that represents its level of suitability as an NEC site area, based on that major siting issue. The term "utility" is used to represent the quality or attributes of a specific site as measured on a defined numerical scale.

The utility scale for each issue is defined as a range of 1 to 9. The range of this scale is arbitrary in terms of mathematical significance, but has been selected to form a final suitability value scale that is convenient and easy to understand. For those characteristics which are exclusive or restrictive, a utility value of zero is used as an indicator that the specific cell is restricted from further consideration independent of all other considerations for that cell. (The zero utility value is used as an indicator for the convenience of the reader only; the computer program actually treats this as a logical exclusion.)

Two general types of utility functions have been used: continuous functions and discrete functions. Continuous functions are used to describe those issues that are defined by a measurement that could occur at any point along a scale. The discrete function is used for issues that are defined by mutually exclusive categories. A graphic example of both types of functions is shown in Figure B-1. As the figure shows, the distance to surface water which could be any value from 0 to 6 miles (such as 3.5) for any given cell can be translated directly into a utility value ($u = 4.8$). For other types of

B-1 GENERAL UTILITY FUNCTIONS

factors such as land use, each cell will be characterized by one discrete category and is referenced by a label number. For example, using the illustration, label number 2 might represent all heavy industrial land use which would then be discretely translated into a corresponding utility value ($u = 8.0$). In some cases the parameters of interest involve future events, such as demand for electricity, which are best specified probabilistically. Under such circumstances, it would be appropriate to determine a utility value averaged over a probability distribution of the individual possible events. However, as long as the utility function is linear, the resulting average utility value will be the same as would result from the application of the utility function to the average parameter value, without bothering to specify a probability distribution about this average. Since most of the utility functions used for this study were linear, and since the determination of probability distributions would have required the development of additional methodology beyond the scope of this study, the suitability values were all found deterministically.

A continuous or discrete utility function was defined for each issue, based on its unique characteristics. These specific functions were developed by experts who were cognizant of each of the major issues and the full range of impacts that would occur from development and operation of an NEC. The rationales for all of the utility functions are given in Section 4.

B.2 ISSUE WEIGHTING

Once the utility functions have been defined, a specific site area (grid cell) can be evaluated with respect to each issue, resulting in a set of utility values for that site. To meaningfully discriminate among all potential site areas and segregate those that are more suitable from those that are less suitable, this set of individual utility values must be aggregated into a composite utility or suitability value.

To aggregate the individual utility values together, a relationship must be established between each of the siting issues, recognizing that the individual issues contribute at different levels to the overall measurement of suitability. This relationship is stated as a numerical importance ratio which defines the ratio relationship of contribution that one issue makes over another to the composite suitability evaluation.

These importance values are expressed on a scale ranging from 1 to 10, and together sum to 10. Using this importance scale of 10, together with the issue utility scale of 1 to 9, the overall composite suitability scale ranges from 10 to 90 (10×1 , 10×9). Again, as in the case of the utility function scale, the suitability scale is established for convenience, and does not have specific physical significance.

In this study, the importance weights for each of the issues were determined by a panel of power plant siting and nuclear energy experts. The Delphi technique, which is a group-based decision technique, was used to facilitate the evaluation of the NEC siting issues by the panel. This led to a final set of importance values which were used in the site suitability assessment. The final set of importance values represent the group average opinions, which

were developed through an iterative discussion technique. The opinions of each participant concerning the importance of each issue were expressed through numerical values. For a detailed discussion of the Delphi process as it is applied to the development of importance values, see Appendix C.

Through the Delphi process, a specific importance value was developed for each of the issues. For most of the issues, these values were developed independent of a specific concept except for the warm water discharge use and the industrial applications of process heat, which were evaluated for the co-location concept. In addition, the transmission suitability and cooling suitability issues were evaluated with size dependency included. This resulted in separate importance weights for transmission and cooling cost based on the 6 GWe, 12 GWe, and 18 GWe concepts. The importance values determined by the Delphi assessment are shown in the following table.

TABLE B.1
SUMMARY OF ISSUE IMPORTANCE WEIGHTS

Population Density	2.15
Air Corridor (used as a sensitivity test case only)	1.40***
Seismic Design	2.70
Transmission**	
18 GWe	2.85
12 GWe	2.01
6 GWe	1.36
Cooling System**	
18 GWe	2.51
12 GWe	1.79
6 GWe	1.28
Landform	0.67
Transportation Access	0.91
Coal Development	0.59
Industrial	0.57*
Thermal Application	0.43*

*Used only for the industrial application concept
 **Only one weight is used for each concept
 ***Defined by the consultant subsequent to the Delphi

B.3 SITE AREA SUITABILITY ANALYSIS

Given the definition of a utility function for each issue and a set of importance weights, the site area suitability analysis can be completed, resulting in a suitability score for each potential site area (grid cell). These scores are by definition a relative measure of composite suitability and therefore, can be used to discriminate sites of greater suitability from those of lesser suitability (by rank ordering the suitability scores). The following equation is used to compute the suitability value for each grid cell or potential site area:

$$U_{(i,j)} = \sum_{k=1}^L (u_{k,i,j}) (W_k) \text{ where:}$$

$U_{(i,j)}$ is the suitability score for cell i,j (site area)

$u_{k,i,j}$ is the utility of cell i,j for issue k , and

W_k is the importance weight of issue k

The resulting suitability score occurs on a scale of 10 to 90 (which is a function of the utility scale 1-9 and the importance value scale 10). All cells that are restricted are so indicated by a negative value.

A map display of the composite suitability evaluation is prepared and reviewed. The cells are grouped for display according to the percentile distribution of their suitability scores. These groups typically are defined such that the upper percentile ranges are on the order of 2.5 to 5 percent. This allows the analyst to observe geographically the distribution of suitable site areas as defined by the top percentile groups. The optimum result in geographic location is to find several cells in the first (upper) percentile range that are centered within a zone of high scoring cells. This indicates that some flexibility exists in the precise location of the energy center (as determined by more site-specific data), yet a high degree of confidence can be

assumed about the general location of a suitable site area. If one were to observe a high score located in a region of much lower scores, this flexibility and confidence would not exist. This does not necessarily discount the relative suitability of such a site; however, it must be very carefully examined to validate the score itself and the lack of locational flexibility must still be considered as a deterring factor in such a site area's selection for site-specific studies.

After review of the initial suitability analysis, sensitivity testing of the results is conducted. Both utility functions and importance weights are varied selectively. This alternative analysis is compared to the normative analysis and changes in the percentile grouping of selected cells is observed. By changing weighting values a sensitivity range can be defined for the most important issues. Through this analysis an additional measure of confidence for the results of the composite suitability analysis can be developed.

C APPENDIX C SUMMARY OF DELPHI PROCESS

The Delphi technique, as an integral element of the site selection process, is used to establish, through the collective judgment of a group of siting and energy experts, the relative importance of each of the issues of concern (or major criteria) for nuclear energy center site selection. This importance value or weight can then be applied to the issue evaluation for each site and a composite weighted evaluation derived for each potential site area.

C.1 DELPHI PROCESS DEFINED

The Delphi technique described herein is a modified form of the traditional Delphi procedure and has been used successfully in numerous applications on site selection projects. As with all Delphi techniques, it is characterized by an iterative methodology that begins with autonomous assessments or value assignments by each participant. These value assignments are then statistically summarized providing a group-based measure to which each participant can respond. A group discussion is then conducted completing one iteration. The next iteration is initiated with the reassignment of values based on feedback gained through the discussion process.

The overall procedure is conducted in six major steps:

1. Define problem objectives
2. Select participant group
3. Define issues of concern
4. Assign individual importance weights
5. Conduct statistical analysis
6. Conduct group discussion

Steps 1 through 3 include preparatory activities. Steps 4, 5, and 6 constitute the active segment of the process, that of iteratively defining values, summarizing those values in the group context, and redefining them based on additional knowledge or feedback.

1. Define Problem Objectives

Definition of the objectives of the Delphi includes selection of the issues of concern to be evaluated. Each issue is comprehensively documented including: (1) a general statement of the issue's relationship to the siting process (such as mandated by federal regulatory definition), (2) the method for collecting or generating information used to evaluate the issue for each potential site area, and in some cases, (3) the historical background of the issue. This documentation can then be disseminated to the participant group in preparation for the Delphi assessment.

2. Select Participant Group

After the objectives of the Delphi have been established and each of the issues of concern documented, a participant group is selected. The participant group may be formed in a variety of ways. It may be a multidisciplinary group, a multi-interest group, or both. Multidisciplinary groups, including geotechnical, hydrological, engineering, demographic and ecological experts to list a few, would explore the problem, primarily from a technical viewpoint. In contrast, interested groups (such as the conservation groups, utility associations, and politicians) would evaluate the problem from a somewhat less

technical perspective. A typically balanced group might include professionals in different applied sciences, planners, managers, lawyers, and the lay public representing specific interests. The group must include participants who can speak on the issues of concern and impart their specific knowledge to other people in the group. In addition, the group should include some generalists, people who may have come from a specific area of application and have, through their experience, developed broad general knowledge within the area of power plant siting.

3. Define Issues of Concern

At a suitable meeting place, the facilitator begins the first group meeting. The principal investigators from the project team present each of the issues of concern to be considered and evaluated. Having been made aware of a general definition of each issue, the participants gain a detailed understanding of how source data are collected and developed into information, resulting in a map showing the relative suitability of potential site area locations based on that particular issue of concern. The discussion of each issue continues until the group feels that it has a common understanding of the issue. This does imply that the group accepts the issue as being a valid site determinant, or pertinent to the particular problem, but that the participants have achieved a basic understanding of the issue. This activity assures that all participants are operating from a common information base. Each participant will be able to express his or her feelings about the validity of each issue by assigning importance weights during the iterative assessment process.

4. Assign Importance Weights

Each participant assigns a value to each of the issues. This value represents the weighting or importance value of each specific issue and is a measure of its level of contribution to the composite evaluation of power plant site suitability. These values are assigned confidentially and at the conclusion of each participant's assessment, the participant's ballot is collected by the facilitator so that his values can be included as part of the group statistical summary.

5. Conduct Statistical Analysis

Once all participants have finished value assignments, the facilitator performs a statistical analysis of the results. The results of the analysis are reported to the participants, including each individual's values which are normalized to a common scale and the group averages. By comparing the group average results of each iteration, it is apparent how the group values are changing as a result of the interactive discussion process. In addition to the group average, the standard deviation for each issue is computed and reported to the group to show the group how it may be converging or diverging for any particular issue.

After the statistics have been computed and reported to the participants, each participant reviews the values that he or she assigned (which have been normalized to a common sum total for comparative purposes) and compares them with the group average values. During a short period of review, each participant determines if he or she feels the group average should be higher or lower: and then prepares arguments to present to the group hoping to convince them to change their value assignments during the next iteration.

6. Conduct Group Discussion

The group discussion is conducted in two parts. During the first part, each participant has the opportunity to speak, without interruption, to present specific views or arguments concerning each issue. Once each participant is given the opportunity to speak, an open discussion is held where additional information may be presented.

When the open discussion is concluded, the process is iterated. Each participant assigns new values based on the information or the learning that has occurred during the group discussion. If one participant is particularly convincing in his presentation, then others may change their values. At the conclusion of the next value assignments, the statistics are computed again and reported to the group. After review of the group statistics, each individual is aware of how the group value has changed and will then develop

additional arguments or restate previous arguments to persuade the group to move a value in a desired direction. The group discussion is reconvened, and the entire process is iterated.

C.2 ACHIEVING GROUP STABILITY

The first iteration of the procedure is primarily considered to be a learning iteration; that is, each individual who is usually conversant with only some of the issues will learn a great deal about the other issues.

In the second round, a greater exploration of the siting problem begins to take place. As the participants learn more about the problem, new ideas occur to them, new thoughts about the problem are presented, and a greater exploration or a more comprehensive view of the problem is achieved. After the process iterates several times, with the facilitator continually monitoring several key statistical indicators, the group average opinion tends to become stabilized.

Upon achieving a stabilized group opinion or value for each issue, the Delphi is complete, and the final group averages are considered to be the collective group judgment concerning the importance of each of the issues of concern.

C.3 SUMMARY OF DELPHI RESULTS

A Delphi using the modified form previously described was conducted under the auspices of the Western Interstate Nuclear Board in San Diego, California on June 23-24, 1977. At this meeting, a set of importance ratios was developed through three iterations of discussion and value assignment.

Individuals selected for the participant group included most of the members of the project steering committee, representatives of the Energy Research and Development Administration, representatives of each of the Western States and several consultants. Each of the 20 participants who participated have been or are actively involved in the general field of

energy development. Several have specialized expertise in the development and operation of nuclear generating facilities or other aspects of power plant site selection. Within the participant group, all major issues of concern for NEC siting were represented by some significant degree of technical expertise. A complete list of all Delphi participants is included as a supplement to this appendix.

During the course of the Delphi, discussion of the group average opinion was intense and often quite spirited. The comprehensiveness with which the assessment was undertaken is reflected in part by the significant shift in values that occurred after each iteration. The following table and chart summarize the results of each iteration of the Delphi, showing the actual values and a graphic display of the migration of values through each iteration.

The summary table, C-1, includes both the group average and standard deviations for each iteration. Generally, the standard deviations for all issues except seismic design and transmission (12-GWe concept) decreased or remained the same through each round. A decreasing or stable standard deviation indicates a trend toward relative group consensus. In the case of seismic design, the deviation from this trend was due to a change in the perceived impact of seismic considerations as they affect power plant siting. Initially, seismic design was considered from the viewpoint of cost impacts related to permitting delays and the construction of safety related structures which must be seismically hardened. In the second iteration, the impact of this issue was reviewed relative to the public perception of accidental radioactive release from seismic incidents. In the final iteration, the group viewpoint shifted back to the position held in the first round.

Review of Table C-1 shows that the standard deviation of the transmission issue for the mid-sized concept (12 GWe) increased through each iteration. In this case, however, the group average was the same from iteration 2 to 3. This indicates that the group had reached a stabilized point where the polarized opinions within the group were balanced. It should be noted that the increase in the standard deviation from iteration 2-3 was much less than

TABLE C-1. SUMMARY OF GROUP AVERAGE IMPORTANCE VALUES

ISSUE		ITERATION		
		1	2	3
POPULATION DENSITY	$\bar{x}$ s	2.16 1.19	2.44 1.04	2.15 1.00
SEISMIC DESIGN	$\bar{x}$ s	2.79 1.01	2.38 0.84	2.70 0.95
LANDFORM	$\bar{x}$ s	0.92 0.50	0.80 0.44	0.67 0.44
TRANSPORTATION	$\bar{x}$ s	1.18 0.60	0.78 0.51	0.91 0.50
COAL DEVELOPMENT	$\bar{x}$ s	1.10 0.85	0.88 0.77	0.59 0.35
INDUSTRIAL APPLICATIONS	$\bar{x}$ s	0.76 0.61	0.48 0.46	0.57 0.47
THERMAL APPLICATION	$\bar{x}$ s	0.77 0.76	0.50 0.53	0.43 0.48
COOLING SYSTEM - 6 GWe	$\bar{x}$ s	1.39 0.52	1.36 0.57	1.28 0.58
COOLING SYSTEM - 12 GWe	$\bar{x}$ s	1.67 0.50	1.85 0.53	1.79 0.48
COOLING SYSTEM - 18 GWe	$\bar{x}$ s	2.02 0.96	2.87 1.71	2.51 0.70
TRANSMISSION - 6 GWe	$\bar{x}$ s	1.40 0.51	1.31 0.53	1.36 0.51
TRANSMISSION - 12 GWe	$\bar{x}$ s	1.72 0.43	1.98 0.73	2.01 0.81
TRANSMISSION - 18 GWe	$\bar{x}$ s	2.13 0.93	7.78 1.12	2.85 1.15
TOTAL	$\Sigma \bar{x}$	20*	20	20

$\bar{x}$ - Group average importance value

s - Standard deviation

* - NOTE: The sum of all values = 20. A larger sum total was required because of the inclusion of all three cooling and transmission issues in the Delphi assessment. For the suitability analysis a selected set of issues was used for each concept and the importance values normalized to a sum of 10 in each case. This has no effect on the ratio relationship between issues.

the change from iteration 1-2. The principal point of disagreement concerning transmission was the impact of the transmission line as it relates to the siting of the NEC. One participant pointed out that because of the total land area affected, a long-distance transmission line could have environmental impacts that are of the same order of magnitude as the NEC itself. Thus, it was argued that the weight of the transmission issue should be equal to the sum of all other weights. However, this argument was not accepted by the majority of the group, causing the polarization to occur.

In addition to the specific discussion related to the seismic and transmission issues, a general point of concern was voiced relating to consideration of economic and non-economic factors. It was pointed out that most of the issues (specifically, seismic design, cooling system suitability and transmission) were either measured in cost terms or directly related to cost. By using a cost scale, these issues are already weighted (through their cost in dollars) and not only shouldn't be weighted again to determine suitability, but also should not be evaluated in relationship to the other factors. It was pointed out in argument that the expenditure of absolute dollars for transmission line construction, for example, causes a series of related impacts or effects to occur which cannot be directly measured. However, to incorporate these non-economic impacts into the analysis, it could be assumed that their magnitude was proportioned to the cost. At this point in the discussion it was agreed that those issues which had been measured in cost should be evaluated with respect to their non-economic components.

In both of these cases just described, the Delphi moderator determined that there was not a basic polarization in the group concerning the definition of the issue or its relationship to the selection of siting areas. Instead, the group simply expressed different opinions about the level of importance of the issues.

A graphic summary of the migration of group average importance values is shown in Figure C-1. This graph illustrates the relative importance ratio relationship of any two issues by comparing their heights to the graph's base-line. It also shows the hierarchical relationship of all issues for each

FIGURE C-1

GRAPHIC SUMMARY OF GROUP AVERAGE IMPORTANCE VALUES

iteration. If the trace of migration for an issue is relatively flat over several iterations, it indicates that the participant group has reached a point of relative stability concerning the issues' level of importance. Review of the graph shows this is the case for most of the issues with mid-range values and with several of the issues in the lower range. Those issues that show continual decline in importance have reached a level in the third iteration where they contribute little to the assessment of suitability.

Significantly several of the most important issues exhibit large changes in relative importance value for each iteration. However, if the first and last values for these issues are compared, the relative ratio difference is small (given their position on the scale). Thus, over 3 iterations, relative group stability can be assumed.

The importance ratio relationships expressed in the third iteration were considered to be the final group decision. The values were then used in the suitability analysis as described in Section 3 of this report.

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APPENDIX D

D SUMMARY OF CONFERENCES AND MEETINGS

Four conferences or meetings were held in connection with this study:

1. The WINB conference on nuclear energy centers in the West, March 24, 1977 in Los Angeles.
2. Meeting of the WINB Project Steering Committee, March 25, 1977 in Los Angeles.
3. The Delphi meeting, June 23-24, 1977 in San Diego.
4. The draft report review meeting, September 8-9, 1977 in Las Vegas.

This appendix presents summaries of three of these meetings; the summary of the Delphi meeting is presented in Appendix C, together with the detailed discussion of the Delphi methodology. The ERDA "Brief on a Cooperative Study of a Regional Nuclear Energy Center" is added after the summary of the March 24 meeting.

An attendance list is given at the end of each meeting summary.

SUMMARY OF THE WINB CONFERENCE
ON NUCLEAR ENERGY CENTERS IN THE WEST
MARCH 24, 1977

As the first part of the ERDA contract under which this report was prepared, the Western Interstate Nuclear Board sponsored a meeting on Thursday, March 24, 1977 at the Airport Marina Hotel in Los Angeles to review the current status of nuclear energy center studies, particularly for the Western United States. The speakers at this meeting were representatives of the major studies presently ongoing, representative state governmental agencies most concerned with energy development, and representatives of certain electric generating utilities. A list of attendees is attached at the end of this summary.

The meeting was chaired by Wyatt M. Rogers, Jr., the Executive Director of WINB, who presented a brief introduction on the WINB perspective.

The remarks of the conference speakers, which were most relevant to this nuclear energy center study, are summarized as follows:

William F. Savage - (ERDA):

Present ERDA concerns focus on the technical issues of the ongoing Hanford Study (cooling water requirements, climatological effects of evaporative cooling towers, and the socioeconomic impact of nuclear energy center construction) and the site-related issues of the SINB and WINB studies. The concern with climatological effects reflects recent weather modifications near an evaporative cooling tower serving a fossil power plant in West Virginia; in particular, up to one inch of snow has fallen at a time. Similar modifications have been reported from power plants surrounding Moscow (in the Soviet Union). NOAA university research departments and some private industries are already investigating these phenomena.

The basic objective of the SINB and WINB studies should be to apply, to specific sites, the general results of NRC, ERDA, and FEA studies on nuclear

energy center feasibility at general sites throughout the United States. Only by looking at specific sites can the practical implementation problems be identified and solutions developed. Cooperation is needed from states, and part of the objective of these studies is to determine whether there is sufficient interest. Site selection should consider regional load growth, regional and local resources (such as water or electric power transmission corridors), and minimizing the impact of construction workers and other social "front-end loading."

Water requirements for 20 GWe cooled by evaporative towers may be excessive. Some form of government guaranteed bonds may be necessary for financing.

In response to a question on the co-location of waste disposal facilities, it was answered that it would be fortuitous to find the geological conditions most favorable to a long-term, irretrievable, repository at a site which was also ideal from the energy generating point of view.

Dennis Eyre - (Western Systems Coordinating Council):

The Western Systems Coordinating Council (WSCC) is forecasting needs for the Western United States based on inputs from their member utilities (46 regular members plus 13 small affiliates representing at least 95% of the generating capacity in the Western States region). The generating capacity is aggregated into five regions and five basic types (oil, natural gas, nuclear, coal, and hydro).

The individual utility forecasts are revised periodically so as to remain current with technological and socio-political changes. For example, the utility forecasts have been significantly reduced as compared with the composite 1973 (pre-oil embargo) forecasts.

WSCC also has records of total fuel consumption in each of the five regions. Approximately 90% of the oil for electric power generation appears to be consumed in the California/Nevada area.

Kenneth R. Geiser - (Arizona Atomic Energy Commission):

Arizona is always equally concerned with water and energy. The population is projected to grow from 1.9 million in 1973 to 2.35 million in 1985. The average population growth rate is 6% but electricity consumption is growing at over 10%. The three main growth cities are Sun City, Havasu, and Mountain Hills. They still like the idea of pumping salt water from the Sea of Cortez and desalinating by nuclear power. The site of this desalination might be appropriate for a new town. In support of this concept, research is continuing on at least one new type of desalination (which would promise to be cheaper than existing distillation processes). There are problems with this area (near Yuma) such as faults and deep silt above the bedrock. Nevertheless, they hope for a string of sites favorable to nuclear power along the lower Colorado River with new towns springing up in the general vicinity. Indians (who own much of the nearby land) are interested in participation, provided they are appropriately compensated.

In response to a question concerning how water could be appropriated for nuclear power from the already over-committed Colorado River, the response was given that some of the Indians' allocation might be sold rather than going into irrigation of lands which are not yet being cultivated.

R. L. Seale - (Department of Nuclear Engineering - University of Arizona):

Environmental studies have begun for a potential reprocessing plant in the arid or semi-arid areas of the southwest; the main water requirement will be for the domestic needs of the staff but there will be a major power requirement. The Institute of Government Research is surveying public attitudes regarding nuclear power generally. They have developed a questionnaire covering the entire spectrum of energy facilities, and they may extend this concept to predict site suitability. So far they claim a 70% response rate on randomly selected registered voters using an 11 page questionnaire for Arizona, Colorado, and Utah.

W. Darrel Gertsch - (Los Alamos Scientific Lab):

New Mexico has conducted the Tularosa Basin study for the FEA. Southern New Mexico is now viewed as a source of water based on the potential for desalination. Most of the ground water supply is at 35,000 parts per million (approximately the same concentration as ocean water), but there is also a significant amount in the range of 1,000-10,000 ppm. Modelling studies are presently under way to predict the ground water table drawdown and surface subsidence. Present predictions indicate it would be possible to develop 350,000 acre feet per year (enough for evaporative cooling of between 15 and 20 GWe) since large withdrawals would result in a maximum drawdown of 300 feet and a surface subsidence of 20 feet after 25 years of such pumping. The drawdown would also result in saline encroachment on existing wells.

In response to a question on the maximum salt concentration which would still permit condenser cooling, the answer of 5,000 ppm was given. Desalination from natural ground water concentrations to this point would best be effected by reverse osmosis or electrodialysis.

Harold Harty - (Battelle PNWL):

The objectives of the ongoing Hanford NEC study are to determine the relative advantages of the NEC concept over dispersed siting, to determine future R&D issues and to explore some of these issues. The Hanford Nuclear Energy Center concept would include fuel reprocessing and LMFBRs to provide mixed oxide fuel for the entire WSCC.

Electric power transmission costs are estimated at 1 mill per kWh for the nominal NEC relative to dispersed sites. The nominal concept for cooling consists of the following units (one for each power plant of somewhat more than 1 GWe): 6 once-through, 10 natural draft evaporative, 4 mechanical draft evaporative. The meteorological problems with wet cooling (fog, rain, hail, ice, wind, and possibly snow) will be examined in further detail. In addition to these problems, however, dwindling allocations from the Columbia River may also make wet/dry cooling necessary.

Jack Stiles - (Pacific Power and Light Company):

The West Roosevelt site on the Columbia River is being investigated for up to six nuclear and five or six coal power plants. The underlying basaltic bench looks like good foundation support. Water supply could be a problem since this year's low Columbia River flow was only 6 million acre feet. Air quality considerations may limit the number of coal fired power plants. The peak demographic impact for the full concept would involve approximately 19,000 people (including worker families) during the heaviest construction period.

PANEL ON STATE AND INDUSTRIAL PERSPECTIVES ON NUCLEAR ENERGY CENTERS

The remarks of the following four panel members are collected by speaker, although they were partly developed through the discussion process.

Noel Clark - (Nevada Public Service Commission and Acting Chairman WINB):

The questions of greatest concern are the extent of the socioeconomic impact on small nearby communities, the method of financing, and the ultimate payer (customer, stockholder, government). Financing alternatives include government subsidy, tax subsidy, and government guarantee on bonds. Implementation questions include time sequence of land purchase (not all at the start of the project) and the ultimate owner of the low population zone (LPZ).

Electric power transmission corridors will be exposed to risks of sabotage when they are carrying several GWe of power. Nevada has tried to site up to five units (presumably of upwards of 1 GWe each) together but could not find sufficient water for evaporative cooling. This investigation also considered setting up a joint venture company for the project development; a combination of public and private utilities might be able to raise front-end money by issuing bonds (which could, conceivably, be tax free). The individual utilities would probably have to pledge their assets as security for bonds to the joint venture company. The issue of tax-free bonds for private utilities could be circumvented by having title in the names of the municipal utilities and swapping, rather than selling, the generated power.

Frank Hahn - (California Energy Resources Conservation and Development Commission):

The California Energy Commission has taken no position on nuclear energy centers, but several concerns have been expressed, centering around whether the proposed advantages from co-location of reprocessing, reduced costs, and reduced risk are really obtainable. The Commission remains skeptical of any concept with a long lead time which reduces flexibility. The Commission generally favors decentralization, even to the extent of smaller, co-generation units.

Any large facilities will have to use reclaimed waste water (agricultural or domestic); coastal sites (which might permit once through cooling) are probably excluded on seismic grounds.

Frank Davis - (Utah Power and Light Company):

Utah Power and Light is investigating the possibilities of a 500 MW standardized coal burning power plant. They have several serious reservations concerning nuclear energy centers. Will the costs and environmental impacts be significantly reduced compared with dispersed siting? Where will the water come from for evaporative cooling for the larger center concepts? (The people in Utah generally seem opposed to the utilization of their water to generate the power for California.) Long distance transmission would also be a severe problem.

It might be more advantageous to develop an ad hoc center, starting with a few units and building more if the concept works out.

Gene Cramer - (Southern California Edison Company):

We already have a de facto energy park along the Los Angeles coast (up to 10 GWe total capacity spread over 20 plants stretched out over 20 miles). These were developed independently by several different companies, and there

would have probably been a lot of public concern had they all been proposed and announced simultaneously.

Insofar as the NEC concept requires remote siting, there are serious concerns for system reliability. Southern California initially relied on Hoover Dam for much of its electricity; part of the impetus for developing the local steam plants was to provide a greater measure of reliability than the long-distance transmission link.

It would be most desirable to consider technology appropriate to the time frame proposed for the center; for example, the gas turbine HTGR might be available by 1990. Its high temperature offers great flexibility in the co-location of industrial applications.

Tom Cole (Oak Ridge National Laboratories):

The ultimate objective of the WINB siting study is to identify states desiring participation and candidate sites which they will nominate for that participation. The Dames & Moore role should be to evaluate the nominated candidate sites.

The implication of the previous evaporative cooling system discussions is that wet/dry cooling is a necessity, but this raises the problem of planning with an unproved technology.

A question on the appropriate extent of reprocessing capability was addressed to William Savage; the response was that the capability should be included because reprocessing will ultimately have to be done somewhere. Editor's Note: A few weeks later this directive was changed to the consideration of retrievable surface storage facilities for spent fuel only.

ATTENDANCE

NEC CONFERENCE

March 24, 1977

W. F. Savage	U. S. ERDA
J. G. Morse	Colorado Energy Research Institute
Kelly Woods	Oregon Department of Energy
K. R. Geiser	Arizona Atomic Energy Commission
Dennis Eyre	Western Systems Coordinating Council, University of Utah Research Park
Jack Westland (Federal Rep.)	WINB
Tom Ten Eyck (Former WINB Chairman)	Rio Blanco Oil Shale Project
T. E. Cole	Oak Ridge National Laboratory
Craig P. Chase	Federal Energy Administration
Roger Polzin	Energy Facility Site Evaluation Council, Washington
Richard E. Turley	University of Utah
David F. Cope	Consultant to ORNL
Philip Sherlock	Dames & Moore
John Robinson	Dames & Moore
Merrill Harkness	Arizona Public Service Company
Eugene N. Cramer	Southern California Edison Company
David D. Tillson	Washington Public Power Supply System
Keith Porter	Sierra Pacific Power Company
E. E. Hall	Pacific Gas & Electric Company
Laraine Woitke	Pacific Gas & Electric Company
Leo Craton	Dames & Moore
Tom Wagenhoffer	Bonneville Power Administration
Jack T. Stiles	Pacific Power & Light Company
Harold Harty	Battelle Northwest
S. Kent Evans	Utah Power & Light Company
John W. Arlidge	Nevada Power Company
Carl D. Haase	L. A. Water & Power
Harry Stoehr	San Diego Gas & Electric

ATTENDANCE, NEC CONFERENCE, MARCH 24, 1977 (continued)

Frank Davis	Utah Power & Light Company
Peter Gottlieb	Dames & Moore
Jane O'Brien	Energy Users Report, Bureau of National Affairs, Inc.
Noel A. Clark (Chairman, WINB)	Nevada Public Service Commission
Wyatt M. Rogers, Jr. (Exec. Dir.)	Western Interstate Nuclear Board
R. L. Seale	Department of Nuclear Engineering, University of Arizona
John A. Dettloff	Institute of Government
Frank Hahn	California Energy Commission
Richard T. Meyer	WGREPO
Blaine Dinger	Office of Industrial Siting Administra- tion, Wyoming
Ronald G. Palmer	Los Alamos Scientific Laboratory
E. J. Lauerman	Salt River Project
Paul S. Ford	Dames & Moore

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Washington, D.C. 20545

BRIEF ON A COOPERATIVE STUDY OF A
REGIONAL NUCLEAR ENERGY CENTER

November 1976

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BRIEF ON A COOPERATIVE STUDY OF A REGIONAL NUCLEAR ENERGY CENTER

PURPOSE

ERDA studies indicate that effective utilization of the country's energy resources, consistent with protection of the environment and maximum conservation of land and other natural resources, argues for attaining greater flexibility in the siting of electric power generating facilities, specifically nuclear power stations. One means for achieving such flexibility is through the use of nuclear energy centers (NECs), though the concept can be extended to other fuels and other types of energy facilities.

This document describes a plan for establishing the feasibility and practicality of NECs, thus developing this as an option for possible use in meeting the nation's future energy requirements.

1. INTRODUCTION AND SUMMARY

The United States must be prepared for a rapid expansion of nuclear electric power generation. The forecasting of electrical power demand and the role that nuclear generation should play in satisfying the demand are highly controversial subjects. Nevertheless, the best available forecasts indicate that the equivalent of at least 600 1000-MW(e) nuclear reactors will be built in the U.S. by the year 2000.

The ERDA Nuclear Energy Center (NEC) program is concerned with the siting of these reactors, specifically with the option of siting these reactors in a relatively small number of large installations, i.e., nuclear energy centers, rather than at a much larger number of dispersed sites. The potential benefits from clustering these reactors and their associated fuel-cycle facilities in large installations may be summed up as the potential for reducing the risks, the costs, and the environmental impact of nuclear power.

The NEC concept has been the subject of several comprehensive studies over the last few years, culminating in the congressional mandated study by the Nuclear Regulatory Commission, the Nuclear Energy Center Site Survey-1975

(NECSS-75). The potential problems in establishing NECs have been fairly well defined. NECs are generally considered to be technically feasible, and the important technical problems, such as heat dissipation, are considered amenable to resolution. The more difficult problems appear to be institutional, and lie in the areas of land acquisition, land use planning and the roles of the various levels of government in land use planning, taxation and equitable revenue distribution, ownership and management of centers, and the legal and regulatory aspects of transporting power across state boundaries. It is not likely that these complex problems can be resolved without strong federal leadership and financial support. Within the federal agencies concerned with energy, a program to develop energy centers lies mainly in the purview of ERDA. Recognizing this responsibility, ERDA has proposed the project discussed in this brief.

The essence of the plan is the evaluation of a potential nuclear energy center, at a specific potential site, with a potential owner or sponsoring organization. The plan consists of three phases: program definition, site selection, and the potential energy center evaluation. The three phases are expected to require about 30 months and if the results from this three-phase program should be favorable, the next step could be an NEC implementation program.

2. JUSTIFICATION OF ERDA'S INVOLVEMENT

2.1 BACKGROUND

Over the past ten years there have been a number of studies on the advantages, disadvantages, feasibility, and practicality of concentrating relatively large amounts of nuclear electric power within a single geographical area, as contrasted with locating the same amount of nuclear generating capacity on a much larger number of dispersed sites. Such concentrations of nuclear power have been variously termed "nuclear parks," or "nuclear energy centers" (NECs). In this paper the latter terminology will be used.

The most recent and comprehensive study of NECs was the aforementioned study conducted by the Nuclear Regulatory Commission -- the Nuclear Energy Center Site Survey-1975 (NECSS-75) issued in five volumes as NUREG-0001 in January 1976. This study considered three basic types of nuclear energy centers:

- Power plant centers, consisting of 10-40 nuclear electric generating units of 1200-MW(e) electrical capacity each;

- Fuel-cycle centers, consisting of fuel reprocessing plants, mixed-oxide fuel fabrication facilities, and radioactive waste management facilities; and

- Combined centers, containing both power plants and fuel-cycle facilities.

2.2 CONCLUSIONS -- NECSS-75 STUDY

The NECSS-75 study arrived at a number of conclusions, but those stated below are the ones most relevant to this report. They are usually, but not always, the exact or nearly exact quotes. In all cases, however, it has been the aim to retain the original intent of each conclusion and to avoid making any subjective interpretation of them. For a fuller explanation and interpretation, reference should be made to the NRC report.*

*Nuclear Energy Center Site Survey-1975, Summary and Conclusions, U.S. Nuclear Regulatory Commission, NUREG-0001, Part I of V, January 1976.

2.2.1 Feasibility and Practicality of Power NECs

The NECSS supports the conclusion that it can be feasible and practical, depending on location, to construct about 20 nuclear power reactors on a single site. However, it does not indicate any great or unequivocal advantage or compelling need for such centers.

Small power NECs (in the range of 10-20 reactors) could show some significant economic advantages, relatively few uncertainties with respect to both technical and practical considerations, and a number of other potential advantages. However, it is unlikely that sites can be found in the United States at which the location of more than about 20 reactors would be a practical undertaking.

2.2.2 Feasibility and Practicality of Fuel-Cycle NECs

It can be feasible and practical to locate nuclear fuel-cycle facilities on NEC sites. Although the need for fuel-cycle NECs is not compelling, such centers might offer public benefits.

2.2.3 Feasibility and Practicality of Combined Centers

Nothing was found that would preclude combining power and fuel-cycle NECs; however, important issues do exist that could affect decisions to combine these centers, particularly if the fuel-cycle facilities were sized to match the needs of the on-site reactors. Except as described elsewhere in the NECSS report, feasibility and practicality considerations would be similar to those for separate NECs.

2.2.4 Siting Potential for NECs

There are many areas that offer potential for siting power NECs based on general screening criteria involving water flow, seismicity, population

density, and load-center location. Siting flexibility is greatest for fuel-cycle facility NECs that do not require massive amounts of water for cooling and whose location does not depend on the location of electric load centers.

2.2.5 Federal/State Participation

While some smaller power centers will evolve naturally, Federal and State participation would probably be required to further the development of a substantial number of nuclear energy centers.

- a. The workshops conducted during the NECSS considered the question of government initiatives. Federal initiatives could range from temporary assistance, through mandate and subsidy, to complete ownership and management. There was unanimity that Federal initiatives with regard to ownership, management, and mandating legislation should be at an absolute minimum (emphasis added). The Federal Government could, however, facilitate initiation of such nuclear energy centers as are deemed to be in the public interest.
- b. Any Federal facilitating role would most appropriately be exercised in coordination with States and any regional grouping of States affected, so as to minimize impact on established and customary jurisdictional, ownership, and other institutional patterns and assure appropriate representation of local interests, knowledge, and viewpoints.
- c. It was the viewpoint at all the NECSS workshops that funds to finance any Federal initiatives should eventually be repaid by utilities through the rate base, since the primary beneficiary would be the rate-payer.

2.3 RATIONALE FOR FEDERAL GOVERNMENT INVOLVEMENT

The above conclusions are neither strongly encouraging nor strongly discouraging to the NEC concept, and they can be used to support a continued laissez-faire approach to the situation or to justify government intervention to the extent of carrying out a program that actively supports work leading to possible development of NECs. However, this is not surprising, considering that the Nuclear Regulatory Commission's chief and most important function is regulating nuclear energy. Hence, they must be extremely sensitive to any secondary activities that could in any way dilute or conflict with this primary role. In this context, their conclusions could be interpreted as being about as strong an endorsement of the NEC concept as could be expected under the circumstances.

There is a cogent argument for federal government intervention in the NEC issue in order to develop and retain options which future events may show are desirable choices for adoption, but which would be foreclosed unless actions are taken now to demonstrate their feasibility.

The NECSS-75 study makes comments to the effect that:

Power NECs can have potential economic gains and social benefits on a site-specific basis. Some of the potential benefits, notably those involving significant economies, would directly benefit -- and thus provide incentives for -- entrepreneurial developers of NECs. However, prospective developers who see some economic incentives in connection with a specific potential NEC site may be deterred by the perception of increased economic risks. There are also high front-end costs, long build-up times, and large capital costs, which are beyond the capabilities of most utilities or entrepreneurial groups to handle under present circumstances. These are aggravated by the current uncertainties in government policies and actions with respect to licensing, rate regulations, land and water use, taxation, and safeguarding requirements, which make the risks faced by

private enterprise almost unsurmountable. Thus, if the concept of NECs is to be developed to the stage where it can provide an option or use when and if needed in the future, it appears that it will have to be done with federal government encouragement and support.

The last of the above NRC conclusions raises the question as to what arm or agency of the federal government should undertake this role. In Chairman Ander's letter forwarding the NECSS-75 report to Congress, he recommended that if the Congress decides to explore further the subject of possible federal encouragement of NECs, such activity would be more appropriately carried out by another agency, perhaps FEA or ERDA.

2.4 ERDA'S NEC RELATED PROGRAMS

ERDA, and its predecessor the AEC, historically has been involved in the NEC program since its conception. Over the intervening years this has included being engaged in its theoretical conception, evaluation of the concept, and R&D on some of the technical aspects. ERDA has recently supported programs in the following areas:

- . Hanford Energy Center Study (Site Layout, Transmission Analyses, Heat Sink Management, Environmental Impact, Fuel-Cycle Studies Including LMFBR)

Contractor: Pacific Northwest Laboratory

- . Atmospheric Effects of Heat Released from Energy Centers

Contractors: Oak Ridge National Laboratory
 Atmospheric Turbulence and Diffusion Lab --
 NOAA
 Argonne National Laboratory
 Pacific Northwest Laboratory
 RAND
 Pennsylvania State University

- . Plutonium Burning in Boiling Water Reactors

Contractor: General Electric Company

- Plutonium Burning in Pressurized Water Reactors

Contractor: Combustion Engineering Company

- Study of Institutional Aspects of Energy Centers (Join ERDA/FEA Study)

Contractor: National Academy of Public Administration

- Utility Interest Surveys, LMFBR Considerations, General Technical Support

Contractor: Oak Ridge National Laboratory

The FY-1976 budget (including the transition quarter) amounted to about \$1 million and the FY-1977 budget is similar.

3. BENEFITS TO STATES, REGIONS, AND UTILITIES

At this time when the problems of nuclear power seem to be increasing in number and magnitude; when energy demand forecasts are raising doubts on a continuation of the past growth rate of electricity; when utilities are experiencing financial problems of unprecedented proportions, and when the need for NECs seems nebulous and remote, a critical question is why any of the utilities, or the states that they serve, would want to devote time, money, or efforts to the development of NECs that may not prove to be feasible, or if so, may never be needed. An answer to this question is to be found in the broader, less tangible issues that -- though general in nature -- are nevertheless exceedingly important to the nuclear power future.

An on-going ORNL survey solicited comments from utilities on their plans and interests for the siting of nuclear power stations, particularly as they relate to the development of NECs. The survey also included a question on how ERDA might assist the utilities in planning their nuclear future. Responses from about 50 utilities identified the following major problem areas in which ERDA or some other agency of the federal government might be of assistance:

1. The urgent need for a clear national energy policy statement.
2. The need for a reduction in the uncertainties involved in obtaining approvals for the construction and operation of nuclear power plants.
3. The need to find ways to speed-up the licensing process for nuclear power plants.
4. Elimination of the redundancies and conflicting requirements among the various Federal and State agencies.
5. Stabilization of requirements so that the utilities can plan with assurance of not having to respond to an ever-changing set of requirements.
6. Establishment of a procedure for limited approval of pre-selected sites.

Issues such as these are precisely the kind that an NEC Cooperative Study Program could address. Such a project could focus on many issues that will involve energy policy at the State and National levels and would, as a minimum, produce information and R&D data and would permit a more enlightened consideration of the policy issues in this area. Examples of the types of issues that might be involved in an NEC study project include:

A resolution of conflicts that possibly exist between the various states and between the states and the federal government on laws, regulations, and policies that may relate to the generation of power in one state but transmitting, distributing, and consuming most of it within other states.

The structuring of transmission systems to serve the needs brought about by NECs but eventually needed in any event.

Changes in tax policies needed to adjust to NECs and their impact on the tax base of affected states.

The policies of the federal and state governments regarding the use of electricity demand growth projections that justify the construction of NECs.

Policies and methods of financing NECs.

The roles and the relationships of the various federal agencies, the several state and local governments, and the utilities in selecting and holding suitable NEC sites.

Reviewing and approving sites with sufficient assurance of acceptability to justify the large front-end capital investment and the long pay-out time by the utilities, and conducting the licensing reviews to avoid excessive time on the front-end and yet be acceptable for the full lifetime of the NEC.

An important factor in the utilities planning is how to provide generating capacity to meet projected power demands without overbuilding or having to meet unexpected needs with plants that can be constructed quickly but produce more costly power. NECs once approved provide a flexibility for responding to such unexpected needs without imposing an extra financial burden upon the utility since additional capacity can be added to the site without going through the process of obtaining approval on a different site.

A cooperatively conducted NEC study project would provide a vehicle for working on a full array of problems that are encountered in planning to meet future energy needs with optimal use of the nation's remaining resources, particularly the wise use of land, water, and air. Such a project would provide a practical setting in which the utilities, the states, and the federal government could initiate joint, cooperative efforts on these problems in a realistic technical, economic, social, and political environment. Utilities, in planning, constructing, and operating electricity generating and transmission systems, must deal with many levels of government, i.e., national, regional, state, and local. The coordination of the various actions and contacts are time-consuming, confusing, and costly, which constitutes a major problem for many utilities. An obstacle to obtaining adequate corrective measures is the difficulty that each group has in visualizing and appreciating the other groups' problems in the framework of their own responsibilities. Many attempts have been made in the past to grapple with the problem, but the efforts have been nonproductive, primarily because of a lack of motivation and urgency. A cooperative NEC project will partially meet both of these objectives by providing a common objective and a vehicle to carry the issues. Each institutional participant (utility, local government, state, regional, and national) would have the opportunity of being intimately involved in the solution of not only his problems but also problems of the other institutional participants, thus leading to a solution that is in the best common interest. These solutions in many cases would apply equally well to dispersed sites.

There are also areas in which R&D needs to be performed to guide sound decisions for making the best use of our land, water, and air resources in meeting electrical energy demands. A cooperative R&D program would deal primarily with NEC issues, but the results frequently would be applicable to sites in general. Other R&D problems will be specific to the site and to the project; hence, they cannot be easily defined until a site has been selected and the project itself has been defined. Such R&D problems can best be

identified and undertaken as a cooperative effort after the project organization has been established. Some rather broad areas in which it might be desirable to conduct R&D are: the environmental impacts from cooling towers in comparison with alternative options for cooling; the effect of close spacing of cooling towers within a given area; alternative approaches for more effective utilization of ocean cooling water; a better understanding of seismic disturbances on large concentrations of power facilities; a better understanding of soil liquefaction triggered by seismic disturbances; improvements in transmission capabilities and more effective utilization of the nationwide grid; and possible uses of low-grade heat from large power centers as a means of attaining more efficient utilization and lower costs. An NEC study project, or its equivalent, seems almost essential for dealing the R&D problems of this scope and complexity because they do not emerge as "go" or "no go" issues in dispersed sites where the utilities have broader options.

Finally, utilities are faced with great difficulties and strong opposition from many quarters in getting approval for the construction of either coal or nuclear electricity generating stations. The source of this opposition stems from different points of view on how much energy the country really needs, the environmental impact of the energy generation, and what fuel mix should be used to produce this energy. These issues are not confined to a single utility system or a single state, but are nationwide in their scope and character. This active public opposition is largely focused on nuclear power; however, a fundamental question emerges as to whether the utilities are the ones who should have to justify and defend projections of the amount of energy needed. The utilities must be involved, but the social and political nature of the controversy argues for strong roles by both the state and federal governments in determining what the public wants and defending the actions necessary to satisfy these wants. Consequently, the utilities should welcome the help of the federal and state governments in determining what courses of action are in the best interests of the public and in becoming co-defenders on these issues. At present, the issues are local in the sense that the opposition is to a particular plant proposed for a specific site. Thus, the issues

are dispersed site-oriented. Since these sites are dispersed in both space and time they present a number of targets, each of which provides an opportunity for the opponents. NECs are well-suited to focusing on the issues and presenting them to the public in the context of the alternative courses of action.

In summary, there are valid reasons why the utilities and the states should welcome the opportunity to become full-fledged participants in a project that can be fashioned into a powerful tool for attacking many of the common problems associated with the approval and siting of nuclear power plants, to help meet the nation's future energy needs, and provide informed insight in how to best plan for the future.

4. GENERAL APPROACH TO THE PROGRAM

The following is an outline of a possible plan of approach to the program. As indicated earlier, the program is generally conceived as being conducted in a series of phases with the undertakings for any phase being subject to the results and understandings obtained from the preceding phases. At the end of each phase there would be a set of findings and conclusions that would provide the bases for evaluations and recommendations on what should be attempted during the succeeding phase. This permits flexibility in adjusting the program to the realities of the situation as it develops. Thus, the program as presented in this document should be viewed as a conceptual framework, which will be filled-in as better information is developed and the advantages and potential difficulties of NECs are seen in a better perspective.

It is anticipated at this time that the program will be pursued in three phases: program definition, site selection, and evaluation. Each of these will be outlined and described in a later section following a general discussion on the goal of the program, the major issues bearing upon the feasibility and practicality of achieving this goal, and the critical elements to the program's success.

4.1 PROGRAM GOAL

The central goal of the program logically would be to develop a plan of action that if successful, could lead to the development of NECs up to some range of sizes, if and when needed. This does not imply that a decision would be made now on whether to develop NECs either naturally or through mandate. It does contemplate, however, that NECs might be highly desirable or even necessary in the future scheme of energy developments, and in anticipation of this possibility, lays out a program leading to the prospect of exercising this option.

4.2 FEASIBILITY AND PRACTICALITY COMPONENTS

Some of the components of a program aimed at demonstrating the feasibility and practicality of NECs were identified by the NECSS study. In analyzing the differences between dispersed siting versus nuclear energy centers for nuclear power stations, the study evaluated the feasibility and practicality of the NEC concept. NRC viewed feasibility primarily as technical issues, and practicality as people-oriented issues. They found the major technical feasibility issues to be dissipation of waste heat from the energy centers, transmission systems design, reliability and economics, economies of energy center construction, and radiological and environmental impacts. The major practical issues identified by their study included: jurisdictional and institutional restraints; social, sociopolitical, and socioeconomic factors; financing; questions related to accident risk, natural disasters, and national security; and safeguarding of strategic special nuclear materials from theft and nuclear power plants from sabotage.

Resolution of these issues, with any new ones that may be identified now or later, could become the set of individual program goals leading to the central goal described above. The specifics as to how such a program would be executed would be worked out in coordination with other parties to the NEC project.

4.3 CRITICAL PROGRAM ELEMENTS

Ideally, to demonstrate the technical feasibility and practicality of NECs, one would like to have a site capable of accommodating an NEC, within a load-growth region that would justify the amount of electric power to be generated by an NEC, and having the attributes and capability of being able to test each of the program components described in the previous section. It is possible that some of the issues, such as heat dissipation, may be determinable only through phasing the growth of the NEC so that the data obtained

from experience with an earlier phase can be used to project the conditions that might be encountered in a later phase -- a sort of "learning curve" approach. But on the supposition that all of the limiting issues will be resolved satisfactorily over some reasonable period of time, it could be assumed that an NEC can and eventually will be developed on the site. Thus, the site would need to be selected not only on the basis of being able to accommodate an NEC, but also all preparatory work (such as studies of land acquisition, water availability, licensing, and regulatory actions) would be based on the expectation that an NEC eventually would be built on the site. In essence, the site would become the focal point for researching and resolving all the issues -- technical, institutional, or otherwise -- that could be inhibiting or limiting to putting an NEC on that particular site, and at the same time, providing information and keys to the solution of generic problems relating to NEC sites in any region of the country. The selected site, the program participants, and the general public of the region become, in essence, an integrated field laboratory in which problems of all types will be researched and resolved either favorably or unfavorably. Thus, the site becomes one of three critical elements in the NEC program.

The second critical element to the program is the people involved. There necessarily will be many institutions and many people involved, each with varying and different degrees of interest in the program and its outcome. However, the leading participants (aside from ERDA and its contractors) will be the utilities, the state, the region, and the contractor (if other than any of the above), in that order. Needless to say, lack of cooperation or interest by either the utilities or the states will reduce the chances of the program's success. The region is not quite as crucial to the R&D aspects of the program, but as a practical matter cooperation from the region would be essential to any future implementation of an NEC on the site.

The third crucial element to the success of the program is adequate funding. Costs will need to be borne cooperatively; the specific arrangements necessarily will be a matter of negotiation. The method for developing the estimated costs for the project will be discussed later.

In summary, a general approach to the implementation of a program aimed toward developing NECs is to bring together a suitable site, interested and qualified people and institutions, and adequate financial support for the program. The site and people are not mutually exclusive and a reiterative process may be needed to find a suitable site in a utility area, state, and region where the people are qualified and interested in participating.

The following sections generally describe an approach that could be followed in the several phases of the program.

4.4 PROGRAM OUTLINE

4.4.1 Phase I -- Program Definition

This phase of the program involves the preparation of a project descriptive brief and a detailed step-by-step project plan. The preceding sections broadly describe the project, present a justification for proceeding with it, and give a rationale for the roles of the various participants. After a working agreement has been developed and as the project unfolds, this part of the brief can and should be developed in greater detail. The step-by-step development of the project plan must be done in an evolutionary manner, but an initial preliminary working plan might be somewhat as indicated in the following subsections.

4.4.1.1 The National Governors' Conference

Contact the National Governors' Conference with the view of having discussions with them on the concept as described in this brief. The purpose of discussions with the National Governors' Conference (NGC) would be:

To advise on ERDA's plans and intentions.

To seek comments, suggestions, and advice on these plans and intentions.

To solicit expressions of interest in participation by the NGC.

To solicit specific suggestions of states, groups, or several states or organized regional bodies (i.e., SINB, WINB, etc.) who might be interested in exploring the prospects of cooperative ventures.

To obtain contacts within individual states with whom discussions could be initiated to determine the interest of their state in possible coop ventures.

4.4.1.2 SINB, WINB, and/or Other Appropriate Regional Groups

Contact the SINB, WINB, and/or other appropriate regional groups to seek indications of interest in cooperating and perhaps submitting a proposal for a cooperative venture involving the appropriate states and a utility or utilities serving these states. The utility or utilities should be interested in a cooperative venture and be willing to work with ERDA and the Regional Group of States to identify a suitable site that could serve as the focus of an R&D program aimed specifically at moving toward the development of NECs.

In conjunction with the SINB, WINB (and other identified groups), and the National Governors' Conference if they desire, have discussions as appropriate with the states involved to obtain their views, comments, and expressions of interest in becoming involved in the prospective cooperative program.

In collaboration with the NGC, SINB (WINB), and individual states as appropriate, have discussions with a utility or utilities (including government-owned regional utilities such as TVA) to obtain their views and expressions of interest in becoming involved in the proposed coop program.

4.4.1.3 Continued Contacts

In parallel with the above actions, continue the contacts presently being made with utilities, on their nuclear power station siting plans and interests, particularly as related to potential NECs.

4.4.2 Phase II -- Site Selection

This phase of the program aims at selecting the best possible site having the potential for being developed into an NEC. There are many factors involved in selecting and evaluating such a site, and ERDA considers it essential to involve the utilities and the concerned administrative and political entities in this selection process as early and as completely as possible. With respect to good site selection, some regions of the country have more favorable physical characteristics than do others, but there probably is no region that does not have one or more potentially acceptable NEC sites. In some instances, utilities already have access to sites that have a potential NEC capability, and if appropriate, these will be given serious consideration. If it appears desirable, potential sites in any interested region can be subjected to a preliminary screening to identify areas that may have an NEC capability based on the most critical physical parameters.

Following the development of plans for a specific cooperative program as described in Phase I, a tentative plan for a cooperative program leading to the selection of an acceptable site might include the following steps:

1. Selection or organization of at least one sponsor for a potential NEC.
2. Selection of at least one potential NEC site for detailed study.
3. Preliminary evaluation and field study to determine adequacy and desirability of the site for an NEC.
4. Findings and recommendations on the next actions to be taken.

4.4.3 Phase III -- Potential Energy Center Evaluation

This phase will be more involved and extensive than either of the preceding ones; it will seek to specifically evaluate the feasibility and practicality of an NEC at the chosen location utilizing the established cooperative organizational arrangements.

This phase of the program will require the cooperative involvement of many parties including, but not necessarily limited to, the following: ERDA and other directly participating organizations; national laboratories under contract to ERDA; other federal agencies such as the Nuclear Regulatory Commission, the Environmental Protection Agency, the Department of the Interior (i.e., U.S. Geological Survey, Bureau of Land Management, etc.), the Federal Energy Administration, and the Federal Power Commission; National Electric Reliability Council and appropriate regional councils; the National Governors' Conference and regional and local entities as appropriate; utilities; private firms who have been involved or can contribute to the evaluation; and other organizations identified as the study progresses.

The following specific actions should be taken during this phase of the project.

1. Development and implementation of a soundly conceived and well-planned program to inform the public on all aspects of the proposed project so as to have their understanding and support as the project progresses.
2. Conduction of safety and environmental impact studies intended to provide the basic information needed for later preparation of a preliminary safety analysis and environmental report on an NEC designed for the selected site.
3. Definition and implementation of R&D programs designed to resolve the site-related technical issues.
4. Definition and implementation of programs designed to identify and make recommendations on the actions necessary to resolve the site-related, non-technical issues, such as those related to necessary legislation, regulatory, and administrative actions needed to permit ultimate construction and operation of a full-sized NEC.
5. Evaluation of a potential NEC at this site with conclusions and recommendations based on the results of the evaluation.

5. ROLE OF THE REGIONS, STATES, AND UTILITIES

The success of an undertaking of such magnitude and complexity depends critically upon the full commitment of all affected parties. The possible role for ERDA presumes their assuming a leadership role. However, this need not be the case if one of the other participants wishes to accept this responsibility. In any event, ERDA envisions the other participants as being co-equals in all respects and hopes and expects that the project will have the full benefit of their advice, assistance, and support on policy matters.

The coordination and inputs from the other participants will be determined through negotiations; however, ERDA has developed a general plan defining very broadly what may reasonably be expected from the other parties. These expectations will be modified and their tenor developed through the negotiations, but some of the projected contributions that might provide a basis for these discussions are listed below.

5.1 STATE AND REGION INPUTS

1. Provision of top-level political and administrative support to the project.
2. Taking the lead in determining the requirements for state legislation or administrative rulings needed for NECs.
3. Provision of administrative support in matters that relate to the state's or region's interests in the NEC project.
4. Provision of, at their expense, an agreed-upon complement to the full-time staff assigned to the NEC project.
5. Provision of financial assistance to the project as mutually agreed upon.
6. Assistance in the overall resource (land, water, transportation, etc.) planning to the development of an NEC.
7. Assistance in conducting a public education program.

8. Development of electricity demand projections for the state or region.
9. Assistance in developing laws, rules, and/or procedures related to the transmission and distribution of the electric power generated within the NEC.
10. Taking the lead in reviewing and making recommendations for changes in tax laws or practices as they relate to the various states and/or region involved.
11. Taking the lead in determining the needed adjustments of the state's (or states') regulatory policies and requirements as related to the NEC needs to eliminate unnecessary redundancies, restrictions, and contradictions with similar requirements of other participating governmental agencies.
12. Identification of potential sites.
13. Assistance in obtaining allocations of water to meet NEC needs.
14. Assistance in developing the site analysis to include the EIS if and when developed.
15. Making available all information that state or regional agencies might have, or can obtain, that pertains to an NEC project.

5.2 UTILITY INPUTS

1. Provision of top-management support and assistance.
2. Management and operation of specified phases of the project under mutually agreeable arrangements.
3. Assistance, as appropriate, in developing plans for the NEC project program.
4. Provision of, at their expense, an agreed-upon complement to the full-time staff assigned to the NEC R&D project.
5. Provision of financial assistance as mutually agreed upon.
6. Identification of potential sites.
7. Assistance in developing electricity demand projections for the region.
8. Taking the lead in developing a distribution plan for the electric power generated within the NEC, including transmission, power pooling arrangements, balancing of system and regional loads, etc.

9. Taking the lead in developing the site analysis to include the environmental report when and if developed.
10. Making available all information that they might have that pertains to the proposed NEC project.
11. Assistance in conducting a public education program.

6. DEVELOPMENT OF DETAILED PROGRAM PLANS

Detailed program plans must take into account the technical feasibility and practicality issues described earlier and additional specific issues to be identified during later phases of the project. These specific issues are strongly dependent upon the location and characteristics of the site, the characteristics of the utility system, the role of the states, and the size and type of regional organization involved. Thus, complete plans can be developed only as a cooperative effort after a working agreement has been entered into, one or more potential sites identified and tentatively agreed upon, and a project organization developed.

None of the participants, including ERDA, will be in a position to commit themselves to an open-ended project. However, it is impossible to fully define the project until the unknowns have been better identified and some basic information developed. This argues for a limited commitment sufficient to support an initial planning phase during which a conceptual NEC project and a general plan of its development will be defined. This will provide a basis for rough estimates on the schedule and the resources (particularly financial) needed to successfully achieve various milestones. These milestones in turn would be the end-points of a series of small evolutionary steps, and the major phases of the project as defined in Section 4.4 would be composed of a series of these small steps.

As noted previously, contacts will be made with potential participants in order to acquaint them with the magnitude and order of effort involved in the program as now seen by ERDA. Thus, all participants will have an understanding of their possible scope of involvement, although all specific tasks cannot be defined at this time.

MINUTESMEETING OF PROJECT STEERING COMMITTEE
WINB REGIONAL STUDY ON NUCLEAR ENERGY CENTERS

Los Angeles, California

March 25, 1977

ATTENDEES:

Noel Clark, Frank Davis, Dennis Eyre, Gene Cramer, Frank Hahn, Kelly Woods, Wyatt Rogers, Jack Westland, T. E. Cole (ex-officio), Roger Polzin (alternate for Larry Bradley); Dames & Moore personnel - Leo Craton, Peter Gottlieb, and John Robinson; and Dr. David Cope (observer and consultant to ORNL).

EXECUTIVE SUMMARY

The Committee reviewed and approved, with several amendments, the proposed Project Work Plan for the WINB Nuclear Energy Centers Study. Cooperative arrangements were agreed to in which the Western Systems Coordinating Council (WSCC) will assist WINB in determining interests in various sites and energy centers concepts. Also WINB would contact the states to determine their degree of interest. The committee also agreed that at least three (3) review meetings would be required during the seven (7) month study project.

MINUTES

Acting Committee Chairman Noel Clark asked Wyatt Rogers to give a brief history of the events leading to initiation of the project. Rogers mentioned that WINB had been approached by W. F. (Bill) Savage of ERDA in November, 1976 concerning ERDA's national siting assessment program for nuclear energy centers and requested WINB participation in a preliminary study of potential sites in the West. (WINB is doing a similar study of a particular site in the South under ERDA funding.) Rogers said that the WINB Power Plant Siting Committee agreed that WINB should pursue the project, and subsequently screened

candidate contractors, developed a proposal to ERDA and ORNL for funding. WINB was granted a contract via ORNL of \$76,993 on March 1, 1977 for a 6-7 month effort.

Jack Westland, Federal Representative to WINB, briefed the Committee on ERDA's radwaste program, WINB-ERDA cooperation on radwaste issues, and the relationship of the radwaste program to the nuclear energy centers project. Tom Cole of ORNL provided background information on the ERDA-ORNL "nuclear parks" program and the role of the WINB project. He said that the overall objective of the ERDA program is to identify one or more sites for "NECs" in the nation and to work toward cooperative planning and development of such sites with interested states and industries. He added that the WINB objective is to assess the Western Region to identify such sites prior to the necessary site-specific study/development phases.

Dames & Moore presented the proposed project plan. The nominal center size would be 20 GWe with LWR technology. Alternative concepts included LMFBR's (to fit with co-located fuel reprocessing facilities) and HTGR's (to provide high temperature process heat). John Robinson described the planned Delphi meeting which would decide the importance weights of the various siting issues.

Noel Clark stressed the need to orient the budgeting for any state-level involvement in NECs to the 2-year legislative budget cycles of several Western States. He suggested that manpower (donated services) might be used in lieu of cash in many cases. Frank Davis commented that any state-level activity should involve a variety of state agencies and utilities.

Concerning the various energy center concepts to be evaluated, Kelly Woods suggested a case for "mixed centers" in which six (6) light water reactors would be co-located with one (1) spent fuel reprocessing plant and other fuel cycle operations.

Frank Hahn stated that California state law inhibits his agency (California Energy Resources Conservation and Development Commission) from being an advocate for specific projects and sites. He suggested that other states may have similar constraints.

Gene Cramer suggested that a de facto NEC is already developing along the lower Colorado River. Others noted a similar situation around the Hanford, Washington complex. Tom Cole noted that South Carolina has expressed interest in a NEC as a result of the SINB project.

Dennis Eyre indicated that the states will need to be involved in the coordinated planning process for NECs. Tom Cole mentioned that the National Academy of Public Administration has recommended in a recent study (ERDA-funded) that "regional" planning/siting activities be undertaken to improve the current situation. Gene Cramer suggested that states and utilities should nominate sites for the WINB study.

Following discussion of procedures to obtaining site nominations, it was agreed that WSCC (Eyre) and WINB (Rogers) would work out details for contacting all appropriate organizations.

Gene Cramer moved that WINB and WSCC poll utilities and states to nominate siting areas for WINB/Dames & Moore to evaluate, and that responses should be sent in by May 1, 1977. Frank Davis suggested including LMFBRs wherever appropriate and that inland sites be restricted to wet/dry cooling systems. Kelly Woods further suggested including study of "mixed centers" involving one (1) reprocessing plant, one (1) fuel fabrication plant, and six (6) plutonium-burning LWRs. Other discussion on the Cramer motion included: (a) "threshold" sizes for different concepts; (b) use of the term, "megawatts generating capacity" instead of "number of reactor units"; (c) suggestion that two or more NECs might be considered in lieu of just one in the Region; and (d) the need to prevent premature publicity concerning sites.

It was finally decided that only LWR technology presently commercially available would be considered. To make this specific, Mr. Cramer amended his motion as follows:

1. Three sizes for "power only centers": 6,000; 12,000; and 18,000 MWe combined generating capacity.
2. "Mixed centers" and "multipurpose centers" to be sized at 12,000 MWe only.
3. Site screening criteria to include:
 - a. Water availability/cooling requirements
 - b. Population density, and electric load demands
 - c. Proximity to load centers and transmission considerations
 - d. Impact of cooling tower plumes on area meteorology
 - e. Seismic factors

Motion carried.

Motion was made and carried that the Project Work Plan be amended to reflect the cases cited above (a total of five (5) to be evaluated) and the site screening criteria adopted in the Cramer motion.

Meeting was adjourned at approximately 12:15 p.m.

SUMMARY OF WINB PROJECT STEERING COMMITTEE

REVIEW OF DRAFT REPORT

September 8-9, 1977

Las Vegas, Nevada

The WINB Project Steering Committee followed a general format of considering review comments in sequence as they occurred in the report text. Written comments from those not present were also considered. The following is a brief summary of the more significant comments and changes.

There were several questions concerning the relatively poor ranking of the Hanford site as presented in the draft report. It was pointed out, by Peter Gottlieb, that the seismic utility function used may have been inappropriate. Alternative utility functions were discussed, and two were selected for immediate testing. Instructions were telephoned to the Dames & Moore Los Angeles office where certain of the suitability maps were rerun. The results were sent to Las Vegas on the evening of September 8, 1977, and the revised maps were presented to the meeting on the morning of September 9, 1977. The change in utility function had made a significant difference in the character of the map in general and in the ranking of the Hanford site in particular. These changes emphasize the importance of determining the sensitivity to changes in various input parameters and assumptions. An expanded scope was agreed to to with specific sensitivity tests as the focus.

There was considerable discussion of possible inclusion of smaller population and load centers. Partly in response to the concerns expressed, the revised report has organized a load forecast in a more systematic manner and included twice as many load centers.

There were several questions about the lack of explicit consideration of alternatives involving the use of waste water for evaporative cooling. It was pointed out that such possibilities are implicitly included in the assumptions of water allocation, but the reasons for these assumptions are further clarified in the revised report.

It was suggested that land overlying high quality oil shale deposits (above 25 gallons per ton) might also be down-weighted along with potential coal development lands.

Most of the other comments concerned additional explanation or editorial revisions.

ATTENDANCE AT LAS VEGAS

T. E. Cole	(ORNL)
Wyatt M. Rogers, Jr.	(WIEB/WINB)
Fred A. Gross, Jr.	(WIEB/WINB)
Jack Westland	(WIEB/WINB)
Ernest Coriz	(New Mexico)
Dennis Eyre	(WSCC)
Leo Craton	(D&M)
Peter Gottlieb	(D&M)
Donald C. Gilbert	(Arizona)
T. W. Ten Eyck	(Rio Blanco Oil Shale)
Gene Cramer	(Southern California Edison)
C. W. Lewis	(Arizona)
Barney T. Baldi	(California)
William Fitch	(Washington)

APPENDIX E
E SUMMARY OF SURVEYS

1. WSCC SURVEY OF UTILITY INTEREST AND SITE NOMINATION

In early April the Western Systems Coordinating Council (WSCC) solicited expressions of interest and site nominations for nuclear energy centers from its 46 member systems. A copy of the solicitation letter and the questionnaire are included with this appendix. Replies were received from 23 systems by early May. Since the solicitation letter promised confidentiality for the responses, they cannot be reproduced here. The following is a brief summary of the returns.

Eight sites were nominated (considering Boardman, Oregon and West Roosevelt, Washington as one site). Hanford was nominated by three systems, Boardman by four, and the other six sites were nominated only once each.

In response to the first question, on the general role of energy centers, nine responses were pessimistic, six were neutral, and six were definitely positive. Most of the general comments and suggestions seemed to focus on the public acceptability issue. Eight replies suggested that public fears of safety and environmental impact would lead to considerable opposition. On the other hand, four replies suggested that the clustering of power plants would be a convenient way to confine the impact and reduce both the safety and safeguard problems.

WSCC
QUESTIONNAIRE

Western Regional Study on Nuclear Energy Centers

As noted on the "Project Description," three different energy center concepts (nuclear "power only" centers, combined nuclear power and related full processing operations, and multi-purpose energy complexes) will be studied varying in size from 6,000 MW to 18,000 MW. Please keep this information in mind as you complete the questionnaire.

Organization - _____

1. What role(s) do you foresee for "energy centers"? _____

2. To your knowledge, have your state agencies or other utilities in your area seriously considered the "energy center option" and/or expressed policies regarding such centers? _____

3. Is there a general siting area (or areas) which you would like to propose for further study? Yes _____ No _____ If "Yes" please identify briefly: _____

4. Do you have information on the above sites which could be provided to the WINB/Dames & Moore study team? Yes _____ No _____

5. Which person(s) in your organization should be contacted by a Dames & Moore representative for additional information on these sites?

Name, Title, Phone No. _____

6. Name other sources of information on the above-mentioned siting areas:

7. Comments and suggestions: _____

Please return by May 1, 1977 to Western Systems Coordinating Council,
540 Arapen Drive, Suite 203, Salt Lake City, Utah 84108.

Western Systems Coordinating Council

DENNIS E. EYRE
ADMINISTRATIVE MANAGER
UNIVERSITY OF UTAH RESEARCH PARK
540 ARAPEEN DRIVE, SUITE 203
SALT LAKE CITY, UT 84108
TEL.: (801) 582-0353

April 7, 1977

COUNCIL REPRESENTATIVES

Subject: Preliminary Assessment of
Nuclear Centers and Multi-
purpose Energy Complexes in
the Western Region

Gentlemen:

Western Interstate Nuclear Board (WINB) is conducting a six-month study designed to make a preliminary assessment of the potential for developing nuclear energy centers and/or multi-purpose energy complexes in the Western Region. The project is being funded in part by a \$77,000 contract to WINB from the U. S. Energy Research and Development Administration as part of a national program to identify and assess potential sites, and to assist private industry and state governments in the possible long-term development of nuclear energy centers. WINB requested WSCC participation in the study and the WSCC Executive Committee approved the Council's participation at its March 17, 1977 meeting.

The WINB study is being directed toward a preliminary evaluation of large land areas (20 to 100 square miles) which may be suitable for siting an energy center. Another objective is to evaluate the general attitude toward energy centers, and to determine the interest of the electric utility industry and state agencies in energy center concepts and the siting options for these facilities.

Attached is a brief description of the project's objectives, scope, and personnel. A 12-member steering committee and a research team of Dames and Moore, consulting engineers, are assisting WINB in carrying out the study.

As you will note, Mr. Frank Davis (UP&L), Mr. Gene Cramer (SCE) and I are members of the Project Steering Committee. We believe your input is necessary to assure that the study will be completed with valid conclusions and recommendations. We, therefore, need your

cooperation in completing and returning the attached questionnaire to my office by May 1, 1977. Please feel free to contact the members of the Steering Committee or Mr. Wyatt M. Rogers, Jr., Executive Director, Western Interstate Nuclear Board, P. O. Box 15038, Lakewood, Colorado 80315, telephone (303) 238-8383.

Sincerely,

Dennis E. Eyre

enclosures

cc: Frank Davis
Gene Cramer
Wyatt Rogers
w/enclosures

2. WIEB/WINB SURVEY OF STATE INTEREST

The Members of the Western Interstate Nuclear Board were requested to supply official responses reflecting the interest of their respective states in further efforts to identify and/or qualify specific Nuclear Energy Center or Energy System Complex sites within their states. The letters expressing these viewpoints are reproduced on the following pages.

No comments were received from the state of Idaho, Nevada and Washington and it is presumed that they have no interest in further efforts in specific site identification or qualification.

Alaska and Hawaii were not included in the study because of their low internal load forecast and because of their remoteness from external loads.

~~CONFIDENTIAL~~
GOVERNOR-WESLEY BOLI

ARIZONA SOLAR ENERGY RESEARCH COMMISSION

"Harvesting the sun"

January 4, 1978

Mr. Noel Clark
Chairman
Western Interstate Energy Board
2500 Stapleton Plaza
3333 Quebec
Denver, CO 80207

Dear Mr. Clark:

Reference is made to the Dames & Moore Study on nuclear centers.

The State of Arizona is interested in studying the further qualifications of the Yuma area as a potential nuclear energy center.

Sincerely,

James F. Warnock, Jr.
Executive Director

JFW:mb

ENERGY RESOURCES CONSERVATION
AND DEVELOPMENT COMMISSION1111 HOWE AVENUE
SACRAMENTO, CALIFORNIA 95825

(916) 322-6937

January 10, 1978

Mr. Fred Gross
Executive Director
Western Interstate Energy Board/WINB
2500 Stapleton Plaza
333 Quebec
Denver CO 80207

Dear Fred:

NUCLEAR ENERGY CENTERS

Neither this State nor the Commission has taken a formal position on the viability of NEC's in California. However, it is clear from the Commission-adopted Biennial Report that the preferred strategy for meeting the energy needs of the State is the maximum utilization of conservation, the development of geothermal and small, diverse, dispersed power plants such as fuel cells, solar and photovoltaic.

California law permits utilities to submit an application for a multiple unit, large baseload generating site and facilities. In doing so, they must demonstrate that the multiple unit site development is the best method of meeting the need for energy. Until this Commission and the State are presented with a specific proposal for an NEC or even a large complex of fossil fuel fired (gasified coal, fluidized bed), no definitive governmental position on such a need will be forthcoming. However, as an individual closely involved with the power plant siting policies, I would find it difficult for the utilities, given the present state of their alternatives analysis, to justify an NEC.

Sincerely,

F.J. Hahn, Administrator
Facility Siting Division

FJH:lw

State of Colorado

EXECUTIVE CHAMBERS

DENVER

RICHARD D. LAMM
Governor

December 30, 1977

Mr. John Watson
Western Interstate Energy Board/WINB
2500 Stapleton Plaza
3333 Quebec
Denver, Colorado 80207

Dear John:

With respect to Colorado's interest in the nuclear energy center siting project, we do not care to continue any participation in this project. As you probably know, the Colorado Senate has passed a very strong resolution indicating that they would not approve of any such site within our State. Therefore, we would request that no reference to Colorado be made in whatever project occurs under the auspices of WINB. If, for some reason, those working on any future projects find that there is an interest in Colorado, we would appreciate knowing this at the earliest possible date.

Thank you.

Sincerely,

A handwritten signature in black ink, appearing to be "Jim Monaghan".

Jim Monaghan
Assistant to the Governor
for Natural Resources

TED SCHWINDEN
LIEUTENANT GOVERNOR

E-9

State of Montana
Office of The Lieutenant Governor
Helena 59601

January 5, 1978

Mr. Fred A. Gross
Acting Director
Western Interstate Energy Board/WINB
2500 Stapleton Plaza
3333 Quebec
Denver, Colorado 80207

Dear Fred:

The Energy Planning Division of the Montana Department of Natural Resources and Conservation has reviewed the Dames and Moore Energy Center Study and has advised me that the State of Montana need not consider any further active involvement.

I would appreciate, however, receiving for informational purposes any follow-up work by the consultant or the interested states.

Sincerely,

A handwritten signature in black ink, appearing to read "Robert E. Hall".

ROBERT E. HALL
Administrative Assistant

cc: John Orth, Director, Department of Natural Resources and Conservation

ENERGY RESOURCES BOARD

WINB

POST OFFICE BOX 2770

SANTA FE 87501

TELEPHONE: (505) 827-2146

JERRY APODACA
GOVERNOR

December 9, 1977

Fred A. Gross, Jr.
Interim Director
Western Interstate Energy Board
2500 Stapleton Plaza
3333 Quebec
Denver, Colorado 80207

Dear Fred:

This letter is in response to your request for our recommendation concerning any future WINB study on the feasibility of siting a nuclear facility within the Tularosa Basin. As you know, the New Mexico Legislature has directed the Energy Resources Board to continue with such a study. Also, although the Dames-Moore study seemed to indicate that the Tularosa Basin was not a suitable site, primarily because of its distance from large load centers, we feel that the basin should not be discarded as a potential site at this time since there is always a future possibility of inter-connecting with ERCOT and the large Texas market. Therefore, we are continuing our study and contemplating a proposal, funded either by specific legislation or through our R & D fund, to determine the actual hydrological parameters of the basin. We feel that this is a necessary first step before future studies can be made on the site feasibility of the basin.

The Energy Resources Board would greatly appreciate any assistance from WINB on this and other studies concerning the Tularosa Basin and recommends that the basin continue to be considered in your site selection studies.

Sincerely,

FRED L. O'CHESKEY
Administrator

FLO/GC/vm

Western Interstate Energy Board/WINB

2500 Stapleton Plaza, 3333 Quebec, Denver, CO 80207 • 303/837-5851 FTS 327-5851

January 11, 1978

Mr. Noel Clark, Chairman
Western Interstate Energy
Board/WINB
2500 Stapleton Plaza
3333 Quebec
Denver, Colorado 80207

Dear Noel,

If WIEB decides to continue with Part II of the Nuclear Energy Centers study by Dames and Moore, please be advised that the State of Oregon has no interest in any further identification or qualification of potential sites for nuclear energy centers in Oregon.

Sincerely,

William A. Luch
9212 North Reno
Portland, OR 97203
(503) 286-1963

WAL/WKW:bj

E-12

STATE OF UTAH
OFFICE OF THE GOVERNOR
SALT LAKE CITY

SCOTT M. MATHESON
GOVERNOR

November 23, 1977

Fred Gross, Executive Director
Western Interstate Energy Board/WINB
2500 Stapleton
3333 Quebec
Denver, Colorado 80207

Dear Mr. Gross,

The State of Utah has awaited with anticipation receipt of the Dames & Moore study on the siting of nuclear power plants which was conducted for WINB. We note with interest that Green River, Utah has been identified as a potential site for a nuclear energy facility. This finding confirms the analysis of our major electric utility Utah Power and Light Company that the Green River area has many desirable characteristics for the location of such a plant. The State of Utah is definitely interested in a detailed, comprehensive investigation of the problems and possibilities associated with such a development. Our State stands ready, in conjunction with Utah Power and Light, to make a commitment of resources to such a project. We would like to explore, in detail, the possibilities of a joint State of Utah - United States Government siting study for a nuclear energy facility in that area.

Sincerely,

Governor

SMM:jek

Office of Industrial Siting Administration

SUITE 500

BOYD BUILDING

CHEYENNE, WYOMING 82002

TELEPHONE: 307-777-7368

December 8, 1977

Mr. Fred A. Gross, Jr.
Interim Director
Western Interstate Energy Board/WINB
2500 Stapleton Plaza, 3333 Quebec
Denver, CO 80207

Re: Dames & Moore Report on Nuclear Energy Centers

Dear Fred,

I must apologize for not meeting your December 2 deadline for comments on Dames & Moore's final draft of the above-referenced report. However, in reviewing the document I did not develop any substantive comments. The concerns I expressed with respect to the earlier draft were addressed in the final report. I do feel, however, that the report continues to paint an extremely optimistic picture concerning the availability of cooling water (both surface supplies and groundwater) throughout the study area. I feel that the analysis technique used to establish the existence of adequate water does not accurately reflect the legal, administrative, and political realities associated with the potential use of surface and groundwaters for nuclear generation of electricity.

It appears that with the exception of Washington, Oregon, California, and possibly Arizona, the nuclear energy center concept does not hold a great deal of promise. The absence of large load centers, scarcity of waters, and proximity to abundant coal reserves would seem to operate against significant nuclear development in Wyoming, Montana, New Mexico, Colorado and Utah.

I feel that overall the report represents a contribution to the literature on energy center siting in that the screening techniques and attempts at quantifying the more subjective siting parameters are somewhat novel. The concepts could be easily extended to other fields such as river basin management, etc.

I seriously doubt that the State of Wyoming is interested in pursuing further development of possible site areas within its borders. This is not an official position, however, the screening results are not favorable for nuclear center siting within the State and considering the relative scarcity of cooling water, and the abundant supplies of easily accessible

Mr. Fred A. Gross, Jr.

Page 2

December 8, 1977

low-sulfur coal, it is difficult for me to conclude otherwise.

Sincerely,

A handwritten signature in cursive script, appearing to read "Blaine E. Dinger".

Blaine E. Dinger, Director

cc: Steve Freudenthal, State Planning Coordinator

APPENDIX F
F STATISTICAL BACKGROUND FOR ISSUE COVARIANCE ANALYSIS

The variance of the utility values of an issue map is given by (approximately, for large n)

$$\text{VAR}(U_i) = \frac{1}{n} \sum_{k=1}^n (u_{ik} - \bar{u}_i)^2,$$

where u_{ik} is the utility value of issue i at location k ,

$$\bar{u}_i = \frac{1}{n} \sum_{k=1}^n u_{ik}$$

is the mean value of utility for issue i , and n is the number of non-restricted grid cells.

The covariance between issues i and j is

$$\text{COV}(U_i, U_j) = \frac{1}{n} \sum_{k=1}^n (u_{ik} - \bar{u}_i) (u_{jk} - \bar{u}_j).$$

This covariance can also be expressed in terms of the correlation coefficient, ρ_{ij} ,

$$\text{COV}(U_i, U_j) = \rho_{ij} \sigma_i \sigma_j,$$

where the standard deviation

$$\sigma_i = \sqrt{\text{VAR}(U_i)}.$$

If W_i is the importance weight for issue i , the suitability at cell k is

$$s_k = \sum_{i=1}^m W_i u_{ik},$$

where m is the number of issues considered. This functional form for the suitability implies that the variance of the suitability is

$$\text{VAR}(S) = \sum_{i=1}^m W_i^2 \text{VAR}(U_i) + \sum_{i \neq j} W_i W_j \text{COV}(U_i, U_j).$$

This equation, in turn, implies that the contribution of issue i to the $\text{VAR}(S)$ is

$$C_i = W_i^2 \text{VAR}(U_i) + \sum_{j \neq i} W_i W_j \text{COV}(U_i, U_j).$$

The issue maps used for this study give the variance-covariance matrix shown in Table F-1. The individual issue contributions, C_i , are given in the right hand column. They are determined by summing the elements of the corresponding row of the matrix, with each element multiplied by the appropriate importance weights according to the above formula for C_i .

Their sum is $\text{VAR}(S)$, which is equal to the variance computed from the suitability map.

	Seismic	Transmission	Cooling	Pop. Density	Coal Dev.	Landform	Transportation	C_i
Seismic	1.41	-.89	.16	.09	-.22	.14	-.22	4.09
Transmission	-.89	2.33	-.27	-.18	.73	.00	.12	2.58
Cooling	.16	-.27	1.8	.00	-.16	-.55	.13	3.32
Pop. Density	.09	-.18	.00	.40	-.02	-.02	-.16	.83
Coal Dev.	-.22	.73	-.16	-.02	1.41	.14	.00	.60
Landform	.14	.00	-.55	-.02	.14	3.20	-.23	.62
Transport.	-.22	.12	.13	-.16	.00	-.23	4.83	<u>2.25</u>
Total Suitability Variance								14.29

TABLE F-1
ISSUE MAP COVARIANCE MATRIX

APPENDIX G

G GLOSSARY

A great many technical and quasi-technical terms are used in this report. All are defined in the section in which they first appear. For the convenience of the reader, the following list of brief definitions has been prepared for those terms used most frequently and/or which have been specially adapted for this report.

Contribution - The influence of an individual issue map on the composite suitability map, defined as the variance of the issue map multiplied by the square of the importance weight for the issue plus the sum of the covariances with each of the other issues multiplied by the standard deviations of the issue pair.

Cost - Site related cost (in dollars per KW) for seismic design, transmission lines from generating source to load, or cooling system (wet/dry towers, pipes to transport water, and storage reservoir). The cost figures presented in this report are always the sum of all three.

Covariance - The summation of the cell by cell products of utility values on two issue maps divided by the number of grid cells with the product of the mean utility values for each of the two maps subtracted from the whole quantity. For further definitions, see Appendix F.

Delphi - A methodology for developing a rational consensus or group average opinion; in this study, the development of the importance weights for the individual issues through discussion and three ballots at a meeting of a group of representative energy facility siting experts.

Dry Cooling - A completely closed system using water as the working fluid (for purposes of this study) transferring all of the reject heat to the atmosphere.

Evaluation - Determination of utility values and composite suitability for each grid cell or site area.

Graphic Element - The computer generated character, usually indicating a shade of gray, appearing on the graphic map. The vertical dimension is approximately $2/3$ of the 10 mile grid cell and the horizontal dimension is approximately $4/10$ of the 10 mile grid cell. Consequently, the grid cell is represented by one or two graphic elements vertically and two or three elements horizontally.

Graphic Map - A computer generated graphic with printed characters representing shades of gray which, in turn, represent utility values, ranges of utility values, ranges of suitability values, or with numerical characters representing logical combinations of concepts. The vertical dimension of the computer graphic character represents approximately $2/3$ of a grid cell, while the horizontal dimension represents approximately $4/10$ of a grid cell, with these ratios varying slightly over the entire map area.

Grid Cell - Ten mile by ten mile geographical unit area for storage, manipulation, and analysis of site related data. The grid cell is represented by one or two graphic elements vertically and two or three graphic elements horizontally.

GWe - Gigawatts electric power (billions of watts); unit of generating capacity measuring nuclear energy center size.

Importance Value (Importance Weight, Importance Ratio) - The weight assigned to an individual issue for purposes of determining a composite suitability, with the weights for the individual issues normalized so that they sum to 10.

Issue - One of the ten siting topics discussed in Chapter 4 of this report; this specific list of significant issues was determined by the Dames & Moore study team following the guidelines, and with the concurrence, of the WINB Project Steering Committee.

kWe - Kilowatts of electric power used as the unit for measuring cost (dollars per kilowatt).

Map Sensitivity - The changes in a composite suitability map which reflects changes in the importance weight of an individual issue map; the mathematical measure of this sensitivity is identical with the "contribution" defined above.

Multi-Purpose Energy System Complex (MES) - A co-located group of facilities producing electric power, using that power or steam for industrial or agricultural purposes, and/or providing fuel cycle services.

MWe - Megawatts electric power, used in this study for describing certain power generating examples.

Nominated Sites - The eight sites suggested, for possible nuclear energy center development, by bulk electric generating organizations.

Nominated Site Areas - The eight grid cells which contain the eight nominated sites.

Nuclear Energy Center (NEC) - A group of co-located nuclear power plants, usually generating upwards of 5 GWe.

Nuclear Energy Center Concepts - The three generating capacity sizes (6, 12, and 18 GWe) used as the bases for the analyses presented in this report.

Nuclear Fuel Center - The co-location of facilities providing consecutive elements of the back end of the nuclear fuel cycle: spent fuel storage, fuel reprocessing, plutonium fuel element or mixed oxide fabrication, and radioactive waste disposal (or burial); the siting implications of these facilities were not examined in this report, for reasons described in Chapter 3.

Percentile - The percentage of the total number of grid cells which rank below a given grid cell (according to overall suitability or cost); some of the graphic suitability and cost maps are described in terms of upper percentile ranges, which are the complements with respect to 100 of the basic percentile rankings.

Power Only Concepts - The three nuclear energy centers having only electric energy generating facilities with total capacity of 6, 12, and 18 GWe.

Reject Heat - The waste heat from the electric generating process, which must be dissipated by a cooling system or by an application of low temperature heat.

Selected Areas (Selected Site Areas) - Individual grid cells which characterize all or part of a selected zone (selected site zone).

Selected Region (Selected Site Region) - Group of contiguous grid cells ranking in the top 20 percentile of suitability for all three power only concepts or in the top ten percentile for at least one of the three power only concepts.

Selected Zones (Selected Site Zones) - Groups of contiguous grid cells ranking in the upper ten percentile of suitability for all three power only concepts.

Sensitivity (Entire Map) - Contribution expressed in fractional form.

Sensitivity (Area) - The percentage of highly suitable cells which shift out of this category for each one percent change in the importance weight of a particular issue.

Site - A specific location for a nuclear energy center.

Site Area - A grid cell containing a site (as with the case of a nominated site area) or simply a designated grid cell.

Site Related Cost - Same as "cost," described above.

Site Zone Sensitivity (Site Area Sensitivity or Site Sensitivity) - The percentage of grid cells which move into, or out of, the upper ten percentile of grid cells ranked by suitability when an issue importance rate, or some other input parameter, is changed by a specified amount.

Suitability (Suitability Map, Composite Suitability) - The sum of the individual issue utility values multiplied by their importance weights, for an individual grid cell or displayed as a map for all the grid cells together (suitability map).

Utility Function - The relationship between the parameter characterizing an issue and the utility scale from one to nine; this function may be continuous or discontinuous.

Utility Value - The values from one to nine representing the ranking of an individual grid cell with respect to that particular issue.

Variance - The squares of the utility values (or suitability values) summed over all the grid cells and divided by the number of grid cells, with the square of the mean utility value (or suitability value) subtracted from the entire quantity. For further definition, see Appendix F.

Western States - The eleven Western States (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming) in the continental United States which belong to the Western Interstate Nuclear Board (now called the Western States Energy Board).

Wet Cooling - A system transferring reject heat to the atmosphere mostly by evaporation, and consequent loss, of water (typically 80% latent heat transfer and 20% sensible heat transfer).

Wet/Dry Cooling - A system using both wet and dry cooling towers, with the wet system dominating during times of highest temperature (when the dry cooling systems are least efficient).

APPENDIX H

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