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CANDIDATE SITING AREAS FOR NUCLEAR POWER
FACILITIES WITHIN THE STATE OF OKLAHOMA

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CHAPTER I

INTRODUCTION

It is increasingly evident that long range planning is essential if man is to live successfully with his environment. Nowhere is this more strongly demonstrated than in the case of electric power generation. The selection and evaluation of sites for large base-load power plants has become increasingly difficult in recent years as pressures from various special interest groups have resulted in new governmental restrictions on acceptable methods of power generation and the associated environmental impact assessment. Many electric utilities have experienced extensive delays in securing sites for any type of power plant as a result of citizen intervention. During a recent Congressional investigation it was stated that ". . . all too often those power plants that are being built are constructed in areas of least political resistance and often these sites make no economic or environmental sense at all" (U.S. Senate, 1972).

With the enactment of the National Environmental Policy Act of 1969 (NEPA), Congress responded to a concern for environmental quality which evolved in the late 1960's. This act had three major purposes: first, it made clear that there is a governmental mandate and responsibility for the environment; second, it established the Council on Environmental Quality (CEQ) in the Executive Office of the President to assist in formulating appropriate follow-up procedures for compliance with the legislation; and third, the Act provided for administrative procedures which require all Federal Agencies to prepare an "environmental impact statement" on proposed major Federal actions which could significantly affect the human environment. Section 102 outlined the factors to be considered in these environmental reports as follows (Public Law 91-190, 1969):

(i) the environmental impact of the proposed action;

(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented;

(iii) alternatives to the proposed action;

(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and

(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

The licensing of nuclear power plants by the Nuclear Regulatory Commission[1] and of hydroelectric plants by the Federal Power Commission are among those considered "major Federal actions" which require

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[1]Note that on January 19, 1975, the Atomic Energy Commission was abolished with the establishment of the Energy Research and Development Administration and the Nuclear Regulatory Commission. Hereinafter any references or inferences made to the agency "Atomic Energy Commission" apply solely to material developed during the period of its existence as a single agency. Citations change to the individual agencies where activities have substantially differed from the parent agency.

statement preparation.

Since passage of the National Environmental Policy Act, power plant siting procedures have undergone extensive change. In addition to environmental requirements that must now be satisfied, implementing procedures for new state and federal legislation require documented justification for sites chosen and public disclosure of the basis for the selection. Nuclear Regulatory Commission (NRC) guidelines strongly encourage a regional approach to site selection and require that the basis for the choice of a proposed site from among viable alternatives be defensible. While nuclear power plants have by far the most rigorous requirements for documentation of site selection and plant design, the application of the same general philosophies to fossil-fuel plants can be anticipated in the near future.

Ideally, power plant site selection involves the consideration of a myriad of factors including those relating to the broad areas of systems planning, public health and safety, engineering and design feasibility, economics, and the institutional or regulatory requirements as well as environmental constraints. Numerous states have enacted new legislation to deal with competing energy/ environmental requirements.

It would also seem clear that any national policy to minimize dependence on imports and to conserve fossil fuels must consider assigning a high priority to acceleration of the installation of nuclear fueled power plants. As a condition for this acceleration, nuclear power plants as now designed, built, and operated, would have to be recognized as adequately safe, environmentally desirable, and strategically necessary. Such recognition would eliminate the current practice of redeciding or reconfirming that same conclusion several times over for each individual project. However, at the present time site and plant review processes proceed concurrently and commencement of plant construction is often delayed by a complexity of permits, authorizations, certifications, and regulatory reviews at all levels of federal, state and local government. These independent and frequently duplicative approvals have often delayed licensing as a result of site related contentions that still existed at the hearing stage. To avoid these delays, it has been proposed that the entire site review process be decoupled from that of plant review (Atomic Energy Commission, 1973a). Several bills were introduced in the 93rd and 94th Congresses to permit sites for nuclear power plants to be selected, reviewed and approved or designated before decisions are needed to increase electrical generating capacity (U.S. Congress, 1974, 1975; American Nuclear Society, 1975a, 1975b).

The objective of the proposed site designation process is to enable utilities, state agencies, or regional electric reliability councils to qualify and establish an inventory or bank of sites which have been reviewed with respect to the characteristics of a standard or reference power plant. The review would consist of an evaluation in terms of the potential impact of site related characteristics on the plant and potential impacts of the plant on the site environs.

Although the proposed legislation would provide for a restructuring of the licensing process, the provisions of NEPA would not be amended. Any detailed environmental review would, of course, recognize that, unlike a construction permit proceeding, a specific design for the facility may not yet be proposed for the site at the time of the site permit proceedings. Thus where no actual facility has yet been proposed, the detailed environmental report will need to be prepared on the basis of an "envelope" of environmental parameters associated with the performance characteristics of a typical plant.

Much of the public controversy with respect to commercial power reactor site selections appears to be the result of the feeling of the public sector that it is brought into the site selection process too late, if at all, and consequently the public's input is not commensurate with their natural stake in the outcome. Here, as in all other areas of energy supply and development involving environmental impacts, the National Environmental Policy Act has introduced a new element of public participation in power plant siting as well as other licensing processes (Young, 1973). However, along with the earlier and more effective public participation has come a further extension of what was already a lengthy licensing process making more acute the tension between the need for electric power, on the one hand, and the need for protecting the environment during its production on the other.

The Energy Policy Staff of the President's Office of Science and Technology has estimated that some 71 sites will be needed for power plants in the National Power Survey South Central Region. Of this total, 22 sites would be for nuclear power stations (Office of Science and Technology, 1969:4-6). U.S. Environmental Protection Agency studies indicate that the number of operating power reactor sites within this region would increase from the single existing site to some three in 1980, thirteen in 1985, and finally twenty-two by the year 1990 (EPA, 1972).

In Oklahoma, electrical energy consumption has rapidly increased during the past two decades. The total demand for electricity in 1965, some 13.8 billion kilowatt hours (KWH), nearly doubled within eight years to the 26.5 billion KWH required in 1973. A study by the Oklahoma Energy Advisory Council (1974) produced projections of electrical energy demand and generating requirements through the year 1990 (Figure 1). By 1983, demand is projected to exceed 62 billion KWH with further increases expected to push the 1990 demand to over 100 billion KWH. The compound annual growth rate of 7.8 percent for the period from 1973 through 1990 reflects an increase of almost three and one-half times the current demand.

In generating electricity, Oklahoma's electric utilities have traditionally used the cheapest form of energy available for boiler fuel. At one time this came from coal; however, for the past 25 years natural gas has been used almost exclusively. With the current shortage and accompanying price rise of natural gas, the search for other fuels has broadened.

While neither coal nor nuclear energy are being used to

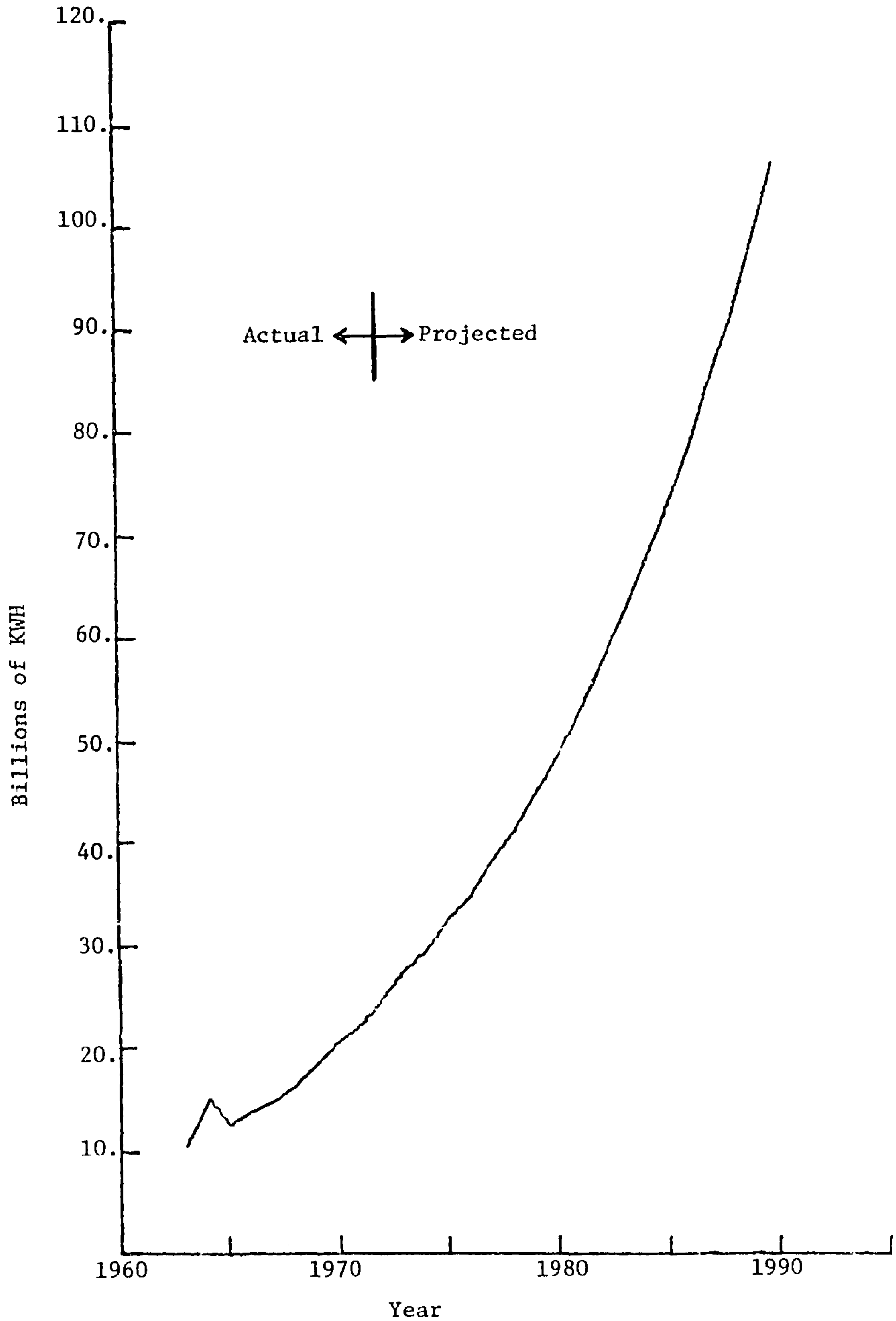


Figure 1. Projected Electrical Demand Within Oklahoma (after Oklahoma Energy Advisory Council, 1974).

any large extent in Oklahoma at the current time, seventy percent of the State's energy demand growth between the present and 1990 most probably will be supplied by coal and nuclear power (Oklahoma Energy Advisory Council, 1974:20). To meet this projected demand, the equivalent of about 10 or 12 one-thousand megawatt electrical power plants will be needed (Young, 1975:13).

The first nuclear powered electric generating facility in Oklahoma is scheduled for operation in 1983 with additional units to follow. Should the state choose to become a major electrical energy exporter, as it is currently with petroleum products, it would require, in addition to full utilization of other sources, a substantial number of nuclear power plants.

1.1 Purpose of the Study

The purpose of this study was to analyze the capacity of the natural resources of the State of Oklahoma to accommodate commercial nuclear power facilities with minimum negative impact in light of accepted environmental constraints and hypothetical model power plant site requirements. Regional environmental resources were evaluated against a list of parameters (siting criteria) that are considered fundamentally important to the selection of suitable power plant sites. The process involved a system of constraint mapping that eliminated (constrained) areas of potentially high environmental cost to reveal relatively large candidate areas that could contain one or more potential sites for locating commercial nuclear power stations. The candidate area designation was based on the results of a coarse exclusion screening effort involving geologic/seismologic, meteorologic, demographic, hydrologic, ecologic, land use, and hazardous industrial/military/transportation facility proximity factors which identified environmental variables that served as decision criteria.

Overlay mapping techniques have found widespread application to rapid acceptability/exclusion screening to determine those areas which satisfy the minimum requirements and to eliminate those which do not conform. However, the overlay technique has several serious limitations:

(1) the number of factors that can be considered simultaneously is severely limited by the problems in physically seeing through multiple layers of mylar or acetate,

(2) the process is time-consuming in that it is necessary to change the overlay maps each time a basic rating criteria is modified, and

(3) overlay techniques do not allow rapid analysis of maps with scale factors different from the base map.

In this study the digital computer was used to store spatial data, overlay maps for composite pictures, and display output through various graphics techniques. The digital computer is a powerful tool, providing flexibility of analysis permitting the rapid screening of candidate areas that cannot be achieved through the use of hand-drawn overlay maps.

1.2 Scope of the Study

While in the past licenses to operate nuclear power plants have been granted for specific plants located on specific sites, an AEC policy encouraging greater standardization of nuclear power stations to expedite licensing has been adopted (AEC, 1972a). As shown in Figure 2, standardization would be most effective if designated sites were available.

Separation of the site review from the plant review proceedings would save substantial time and effort. By this process, it would be possible to review and resolve all environmental and safety issues related to site selection well in advance of a need for additional power in the given area and before resources had been committed to the development of the site. If such issues were settled satisfactorily for a number of candidate sites, the result would be the creation of an inventory or bank of designated sites that would be available for later use as future power needs dictated.

Although site designation involves decoupling site approval from the review of the facility, some information about the facility is required to assess and resolve environmental issues. This site review process must involve assessment of both site suitability and environmental impact based upon characteristics of plant design and the potential effect of plant operation.

To accomplish the objective of this study a set of regional exclusionary criteria were defined. The exclusionary criteria applied related primarily to regulatory agency requirements, essential power plant functional requirements, and unique environmental considerations. This set of criteria were then combined with the existing macroscale data base obtained from published reports, public records, public and private agencies, and individuals knowledgeable of the region of interest to map out areas potentially suitable for power plant development. The coarse screening criteria represent the major

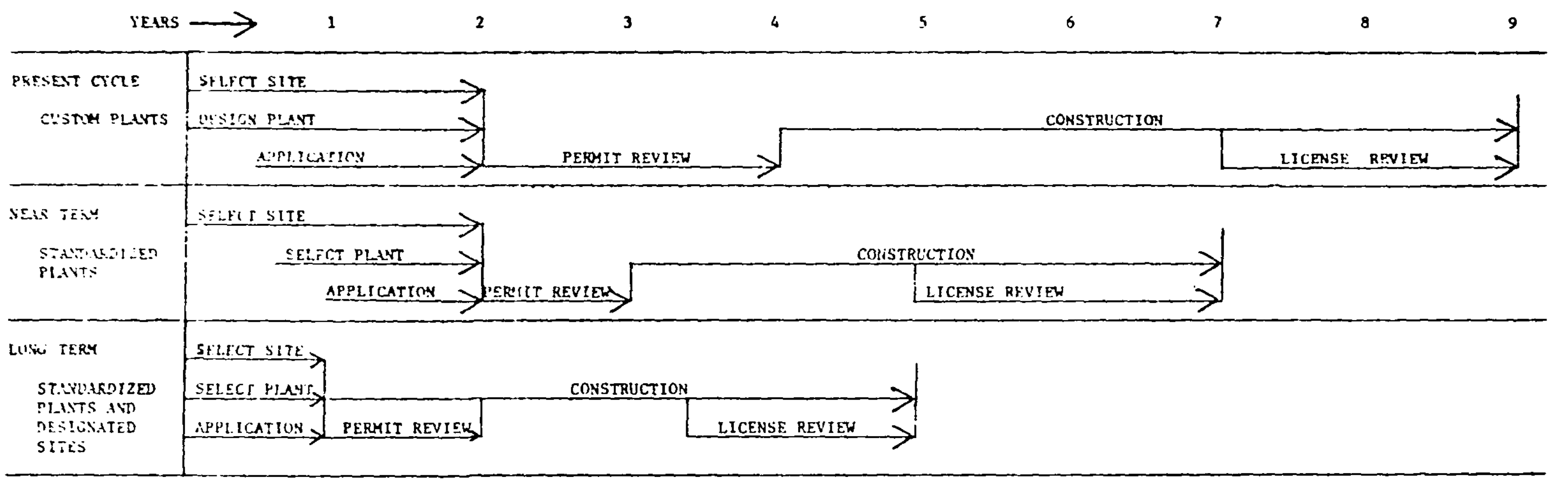


Figure 2. Reducing Nuclear Power Plant Lead Time (after AEC, 1973a).

constraints utilized in initial steps of site selection, i.e., from a regulatory standpoint some of these characteristics would almost be mandatory while from an environmental standpoint they would also be highly desirable.

The delineation of optimum candidate areas should provide a basis for specific site evaluation by electric utility companies and state or federal agencies to insure that licenseability, system reliability and other social and economic factors are ultimately considered. It should also be recognized that the selection of these candidate areas does not preclude the construction of plants at sites lying outside these areas. Some sites within the designated areas will undoubtedly prove unsatisfactory when they are evaluated more closely, and some suitable sites will be found outside the candidate areas.

This study does not deal in many substantive issues which are currently under review elsewhere like that of the relative merits of clustering power plants in energy centers (parks) as opposed to dispersed siting concepts (NRC, 1975c; Tinger, 1975). Nor does the study represent a detailed site analysis or site boundary identification. Rather, the report does reflect a procedural framework within which the process of resolving basic conflicts between environment and electric reliability can be undertaken. The process is not an end product; rather it is part of an iterative research effort to develop a comprehensive and comprehensible regional siting methodology. The decision that a nuclear power complex may be constructed and operated on a specific proposed candidate site must be further based on a detailed evaluation of the proposed plant-site combination and an environmental cost-benefit analysis comparing it with alternative plant-site combinations.

CHAPTER II

SITE SELECTION

Current estimates of lead time for nuclear power plants are about ten to twelve years from inception to operation. The existing system for site approval, which is rapidly changing in response to new governmental regulations, has contributed to the delay in building new power facilities.

Initial site selection may require well over 12 months, while studies to verify and support the preferred site often require an additional 12 to 14 months. The duplication of applications and independent resolution of issues by separate mission-oriented agencies often establishes site acceptability only after lengthy, uncoordinated, piecemeal processing of the many permits required. Others have suggested extensive legal reform and institutional changes to establish a joint Federal/State Siting Council composed of officials drawn from all agencies involved in site related issues acting as a one-stop forum for site review (American Bar Association, 1973; Haggard, 1975).

Some states have taken significant legislative actions during the past few years which affect power plant siting. A recent nation-wide survey found eighteen states with laws directly controlling the siting of power plants with numerous others involved in some aspect of the review and certification of proposed sites (SINB, 1974).

2.1 Historical Prospective

An appreciation of the evolving process of site selection requires some understanding of past procedures and experiences influencing power plant location. The history of central station base-load power plant siting philosophy has revolved around the attempt to provide bulk electricity at as low a cost as possible. Through the mid-1950's, the site selection process emphasized proximity to load center often resulting in locations within the central business district or industrial areas in order to minimize transmission costs.

As industrial expansion forced utilities to look to other areas, they faced some resistance because of local concern over property values, noise, or general appearances. Except in limited locations, there was little public concern with other environmental issues such as air pollution (Knapp, 1965), leaving an uncomplicated problem of balancing economic and engineering factors.

Siting processes consisted for the most part of defining the most economical area for power plant construction, conducting reconnaissance of the area to locate suitable topography and then turning the problem over to the right-of-way department with instructions to buy as much of the property as they could at as low a cost as possible without revealing the intended use of the land. When this had been accomplished and the plans for the generating station publicly revealed, the remaining acreage was obtained through further negotiation and/or condemnation. While this practice is still widespread (Calvert and Heilman, 1971, 1972), a new approach providing for full public disclosure and the utilization of an ad hoc environmental advisory committee of local planning and public interest groups has recently been initiated by several utilities (Seiple, 1974).

Originally health and safety considerations had been the primary determinants of the suitability of proposed sites for nuclear power stations, however, considerations of environmental impacts and public acceptance have become increasingly important in recent years. As early as 1962 environmental characteristics of the site were evaluated in relation to the proposed design of the facility (AEC, 1962). The emphasis of these first site reviews has now shifted from protection of the health and safety of the public to protection of the environment. This shift coupled with a shift from a simple evaluation of the relative merits of specific sites which have already been pre-selected to comprehensive site selection surveys marks the renewed interest in balancing the energy/environment dilemma.

2.2 Recent Approaches

The licensing of a nuclear power plant is a two step process involving two acts: the Atomic Energy Act of 1954 as amended which deals with radiological health and safety and the National Environmental Policy Act of 1969 which deals with environmental impact analysis. The process itself involves filing an application for a construction permit. Each application must be accompanied by a Preliminary Safety Analysis Report (PSAR) and an Environmental Impact Statement. These take about three years to prepare for a plant on a previously undeveloped site. The PSAR is reviewed by the NRC Licensing Staff and the independent Advisory Committee on Reactor Safeguards (ACRS). When these reviews and the environmental review are completed in about two years a public hearing is held at which the findings of these reviews are presented and intervenors have the opportunity to challenge the findings.

The construction permit, when issued, allows the physical construction of the plant to proceed; and, when the plant is completed, the entire process must again be repeated with the submittal of a Final Safety Analysis Report and another Environmental Impact Report. Once again, public hearings are held before an operating license is granted. The license may or may not grant permission to operate at full power.

Many detailed methodologies have been proposed and used for site selection. Elemental to all these is evaluation and treatment of the seemingly endless array of siting parameters. A recent study conducted by Commonwealth Associates identified six basic considerations: system planning in order to match generation and transmission capacity with demand, safety to protect the public, engineering feasibility and design, environmental protection, institutional regulatory requirements, and basic economics (Atomic Industrial Forum, 1974). The site selection process begins, in general, with consideration of a large region and progressively narrows the study to smaller candidate areas and then to candidate sites within this area. As the geographic area being considered is decreased, the depth of inquiry is increased.

The principal steps involved in the environmental aspects of a generalized site selection process are illustrated in Figure 3. The steps represent a progression from the establishment of the need for additional generating capacity through the formal review of the proposed site. Four basic phases can be identified in this process:

(1) The determination of candidate areas within the region of interest which will be investigated for potential sites.

(2) The investigation for potential sites in the candidate areas by evaluation of data obtained without extensive on-site investigation.

(3) The subsequent identification of candidate sites from potential sites suitable for evaluation as alternatives using detailed field investigations.

(4) The selection of a proposed site from evaluation of the alternative candidate sites.

The first stage of this process involving the selection of candidate areas was undertaken for the State of Oklahoma.

While numerous analytical methodologies have been developed over the past few years, there is no one method of site selection and evaluation that can be considered superior or that can represent a standard for nuclear power plant site selection (Rossin and Nichols, 1974, 1975). The available methodologies range from simple qualitative observations based on regional characterizations to complex matrix multiplication models. The methodologies used in initial candidate area screenings are replaced by detailed analysis for final

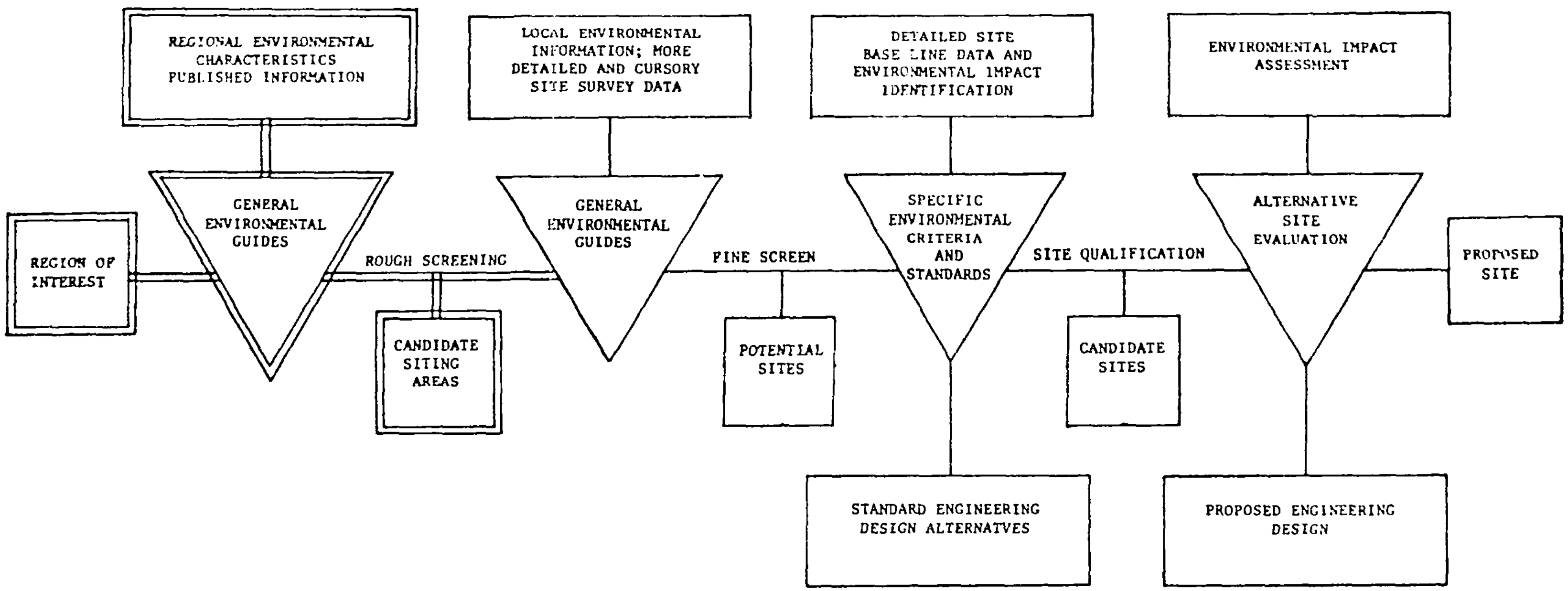


Figure 3. Environmental Aspects of a Site Selection Process.

site evaluations. The level of detail with which each factor is addressed varies in an inverse relationship with the size of the area under examination. During the early stages of the siting process, the analysis is primarily to determine if sites exist that meet certain fixed or absolute criteria of acceptability. For example, one requirement might be a dependable source of cooling water within some specified distance of the site. Areas which can not meet this criterion, or any other similar parameter, may be discarded from the selection process at this point. In latter stages the evaluation is directed towards narrowing the range of alternatives and is most often comparative or relative in nature.

Several generic methodologies currently being employed in the determination of candidate sites have been identified (AIF, 1974). One of the more commonly used and straight-forward techniques for eliminating less desirable sites from further consideration has been the successive screening process. Several sets of siting considerations are evaluated in succession each in effect acting as a go/no-go evaluation. Thus the sites which meet or exceed minimum criteria of the first set are then candidates for further evaluation against the second set, etc. The order in which the various considerations are selected influence the outcome since each step of the evaluation is based upon the results of the previous set. It is thus possible that a potential site which is satisfactory in all but one respect may be eliminated from further consideration early in the process. This go/no-go screening technique is that basically involved in an acceptability/exclusion method. This screening technique has alternately been cited as threshold screening or the key factor concept.

The comparative evaluation technique avoids the possible premature elimination of sites by treating a group of siting considerations collectively and evaluating the aggregate effect on each site. Each site is rated for each consideration with the aggregate score reflecting the preferable location. This method requires the assignment of a relative weighting factor to each consideration. These weighting factors are often region-dependent and influenced not only by the judgment of relative technical importance of the siting consideration but also reflecting the likely public acceptance aspects of the region affected. A forced consensus through the application of the Delphi Technique has been found useful in establishing regional values associated with the assessment of environmental considerations (Toussaint, 1975).

Classification and rating schemes are generally more formalized methods for listing and combining a large number of individual considerations to obtain a composite or aggregate assessment of site acceptability. These schemes range from a qualitative assessment of potential impacts and their importance displayed in a matrix form (Calvert and Heilman, 1972) to an environmental evaluation system using value functions as a measure of the impact and consensus weighting to determine the importance of the factors (Tamblyn and Cederborg, 1975, 1974; Fischer and Ahmed, 1974; Beer, 1974; Smith and Heilman, 1974). The basic siting considerations are broken down into a finer sub-factor structure to be judged against the established criteria. Each site is evaluated for each sub-factor and a numerical value is assigned to reflect its relative degree of favorability, the findings are multiplied by a weighting factor, and the aggregate of weighted numerical values for all factors summed to provide a measure of a composite suitability for the site. Here again the dilemma created by the judgmental nature of the selection of the relative significance or weight of each factor might be reconciled through the implementation of the Delphi method of estimation.

During the final stage of the site selection process, identifying the proposed site, the greatest amount of detail and depth of study are involved. On-site evaluation of any potential problems identified earlier in the screening process are often utilized to provide reasonable assurance of the licenseability of the proposed plant-site combination. A cost-effectiveness analysis of alternative candidate sites in terms of both economic and environmental costs is required by the Nuclear Regulatory Commission to show why the proposed site is preferred over all other candidate alternatives (NRC, 1975a).

As siting options narrow, a regional approach to power plant siting takes on an ever-increasing importance with the need for documented, comprehensive and defensible site selection that is responsive to societal needs.

2.3 Novel Siting Concepts

As the acceptability of conventional sites is increasingly constrained by new, interrelated environmental regulations and land-use planning concerns, it is obvious that few perfectly suited sites remain. A number of advanced siting concepts have been proposed and/or studied to a varying degree in the last few years. The objectives of these concepts have been to better isolate the power facility from the surrounding environment while enhancing safety. For example, underground nuclear power plants, which provide better radiological protection in the case of a major accident, could be located closer to urban areas and still provide safety assurance equivalent to that of more distant surface sites (Karpenks and Walter, 1975). The concept of siting nuclear reactors underground is not new as evidenced by the construction of several small underground plants in Europe (Crowley et al, 1974; Yadigaroglu and Andersen, 1974; Doan et al, 1974; Willet and McCreath, 1974). Current conceptual design options include the surface mounding technique where the plant is essentially constructed above ground and then covered with backfill material of controlled permeability and porosity; cut-and-cover, where the plant is built in an open-cut excavation and then backfilled with roughly three feet of cover; and deep-in-competent-rock (such as unfaulted igneous or sedimentary rock) where the plant is assembled in excavated caverns either horizontally into a mountain or vertically deep below the earth's surface. Several disadvantages of the underground concept have been identified: increased construction time caused by the mining operation, increased costs due to longer piping and cable runs due to the extended distance between buildings, and perhaps the greatest concern, the possibility of elevation of the ground water table resulting in the leakage of water into the plant.

The offshore floating plant concept for power plant siting, in which the plant is mounted on a floating platform and moored a few miles from the shoreline, reduces the problem of waste-heat rejection while to some extent being seismically isolated. Open water siting schemes vary with the depth of coastal waters and are grossly categorized as shallow water and deep water concepts. For units moored in shallow water, a conventional plant is mounted on a floating platform within a breakwater (Nichols, 1973; Ashworth, 1974). Other shallow water options include siting on natural or artificial islands (AEC, 1965; Arnold et al, 1966) and plants built on the ocean bottom (Klepper and Bell, 1968; EPA, 1971). In addition to the ocean siting, Maniago and Erandon (1973) have suggested riverine and inland lake siting of floating nuclear power plants. Although these concepts solve some of the problems inherent in land-based siting, the problem of sea storm waves and seiche hazards as well as those introduced by the transportation of fuel and radioactive material over water must be addressed.

Clustering of nuclear facilities into energy centers has been suggested as a way of reducing environmental impact while offering the advantages of reduced construction costs due to the economics of scale. A nuclear energy center could consist of several commercial power reactors and other nuclear fuel cycle facilities (AEC, 1974a; NRC, 1975c) as well as other energy intensive manufacturing or processing industry (Office of Science and Technology, 1969; Young, 1975). There are, however, questions related to the environmental impact of large concentrations of waste heat rejection and electric transmission facilities that must be explored.

While the land-based above ground power plant siting concept continues to be the principal concept used, a large number of alternative siting concepts are possible. Site selection studies in California have identified some seventeen alternative schemes (Holmes and Narver, 1973; Perla, 1973; State of California, 1973). In addition, satellite nuclear power stations in outer-space have been proposed for the near future (Williams and Clement, 1973).

CHAPTER III

ENVIRONMENTAL CONSIDERATIONS IN SITE SELECTION

Although conceptually it should be possible to identify a comprehensive list of environmental topics that should be considered in the process of screening candidate areas and to develop measures for acceptable levels for environmental indices, the procedure is complex. Technical agreement on environmental principles is at the core of the problem since both Federal and State governments (with possibly several agencies within each of these levels of government) have roles in power plant siting which tend to overlap. Yet principles accepted by one agency or governmental level may be unacceptable to another or by other private technical experts.

While the following criteria were developed as definitively as possible, precluded sites might have a facility constructed which has specifically engineered safety features for that site. For example, if the reference plant has been engineered to withstand a seismic acceleration of 0.3 g., this does not preclude the use of a site with 0.5 g. acceleration. It would, however, mean that more attention and engineering must be given to that particular plant-site combination resulting in a much less attractive site because of increased cost and extended regulatory review time.

3.1 Geology/Seismology

The seismic and geologic aspects of siting are important factors that must be considered in the selection and evaluation of proposed sites for any major industrial development, particularly those sites proposed for a large electric generating complex such as a nuclear power station. The possibility of an uncontrolled release of radioactivity into the environment either during or after a severe seismic event necessitates a more extensive evaluation of the earthquake potential at a nuclear power plant site than might otherwise be appropriate for comparable industrial activities.

Generally, the most restrictive safety-related site characteristics considered when determining the suitability of a site are (1) potential vibratory ground motion, (2) surface faulting, and (3) foundation conditions (NRC, 1975d:2). The detailed seismic and geologic investigations required for licensing approval of specific sites are found in Appendix A of Title 10, Part 100, of the Code of Federal Regulations (AEC, 1973b) and to some extent detailed in WASH-1301 (Hall et al, 1974). The final objective of most of the investigations is to establish the ground motion that would result from the Safe Shutdown Earthquake (SSE) and the Operating Basis Earthquake (OBE). The SSE is often defined as the maximum possible earthquake that could ever affect the site whereas the OBE represents the maximum probable earthquake that would affect the facility during its life expectancy.

As the names imply, if the SSE occurs it is only necessary that the plant be capable of being shut down without releasing radioactive material to the environment, whereas the plant should still be operable following the occurrence of the OBE.

3.1-1 Vibratory Ground Motion

Several relative seismic risk maps based on an analysis of historical records of United States earthquake intensity and frequency have been published. These maps have varied significantly over the past decade as seen in Figure 4. The wide variation in the location of regions of probable maximum risk is due in part to the historically short period of record coupled with an apparent lack of correlation in the observed seismic activity with known tectonic structures for geological provinces east of the Rocky Mountains (Nuttli, 1973; Moeller, 1975). Some believe that research will lead to the confirmation of Oklahoma as an area of equal seismic risk (Tryggvason, 1965; Reiter, 1975).

Ideally, the acceleration experienced as the maximum vibratory ground motion is determined instrumentally from strong-motion seismographs but due to the short history of seismograph monitoring in the central United States, it must often be estimated from the amount of damage or felt motion of historic disturbances. While there have been more than one-hundred intensity scales developed over the years, current evaluations rely on the Modified Mercalli (MM) scale (Wood and Newman, 1931) as a subjective measure of ground shaking.

The Safe Shutdown Earthquake (SSE) is defined in Appendix A to 10 CFR Part 100 as

> . . . that earthquake which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake which

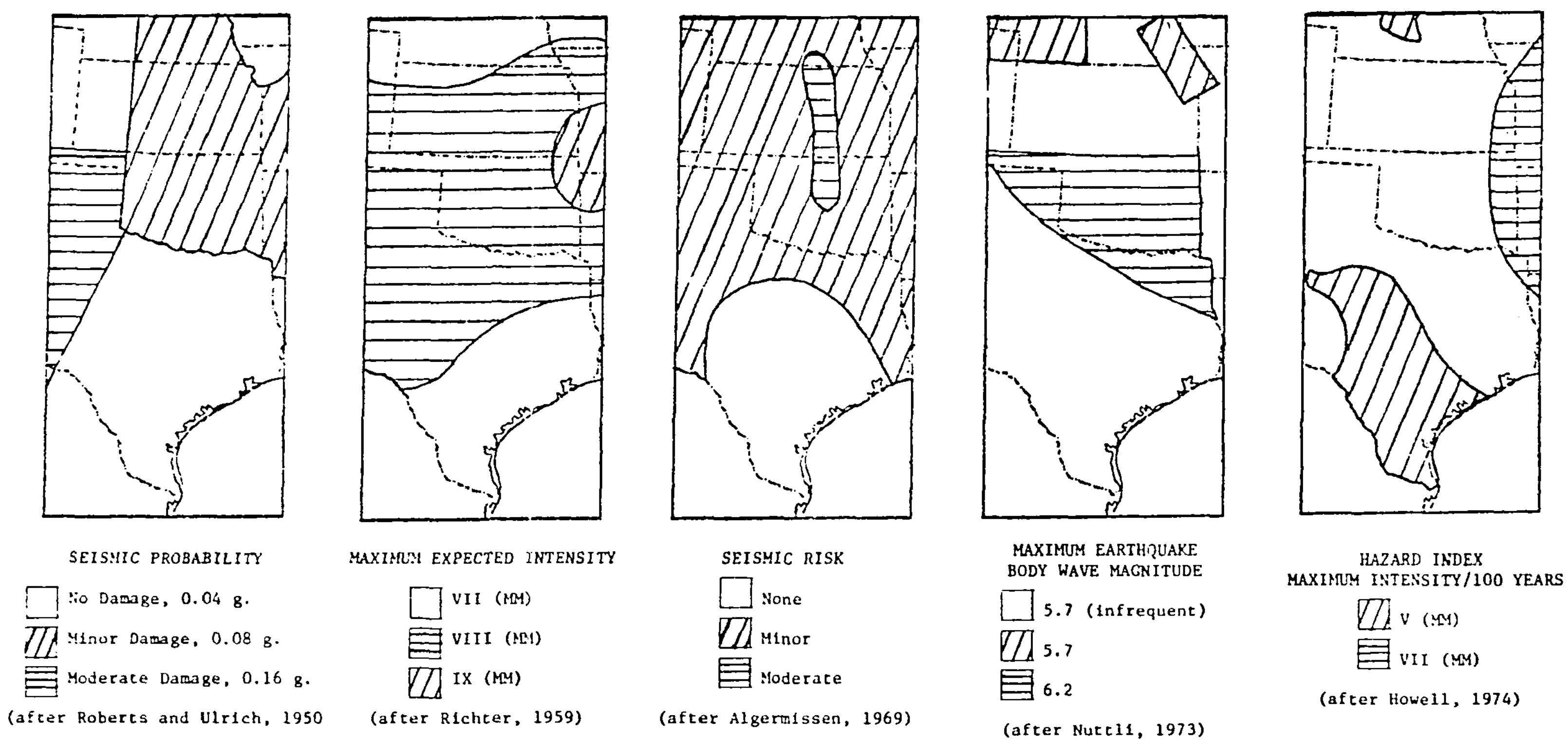


Figure 4. Seismic Risk Estimates for the Central United States.

> produces the maximum vibratory ground motion for which certain structures, systems, and components are designed to remain functional. These structures, systems, and components are those necessary to assure: (1) the integrity of the reactor coolant pressure boundary, (2) the capability to shut down the reactor and maintain it in a safe shutdown condition, or (3) the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of this part.

Through compilation and evaluation of all recorded earthquakes that could have been reasonably expected to have affected a proposed site, the maximum intensity historical disturbance is selected as the Operating Basis Earthquake (IAEA, 1972; AEC, 1973b). In general the practice of going "one intensity higher" than the maximum historical earthquake (or the OBE) is expected to be a conservative approach to establishing the Safe Shutdown Earthquake (Lineham, 1970).

Many earthquake intensity-acceleration relationships have been postulated (Gutenberg and Richter, 1942; Hershberger, 1956; AEC, 1963; Cornell and Mertz, 1974). The most widely accepted correlation accounts for variations in local geology and was developed by the U.S. Geological Survey (Coulter, 1973). It was utilized in this study as presented in Figure 5.

About eighty percent of the commercial power reactor sites in the United States lie east of the Rocky Mountains and have maximum expected ground acceleration of 0.20 g. or less associated with an approximate SSE of Intensity VIII or less (Dames and Moore, 1974; AEC, 1975a:4-5). Using data of Algermissen (1969) and Cornell (1974), the AEC calculated that for sites located randomly with respect to earthquake epicenters, the probability of exceeding an average SSE

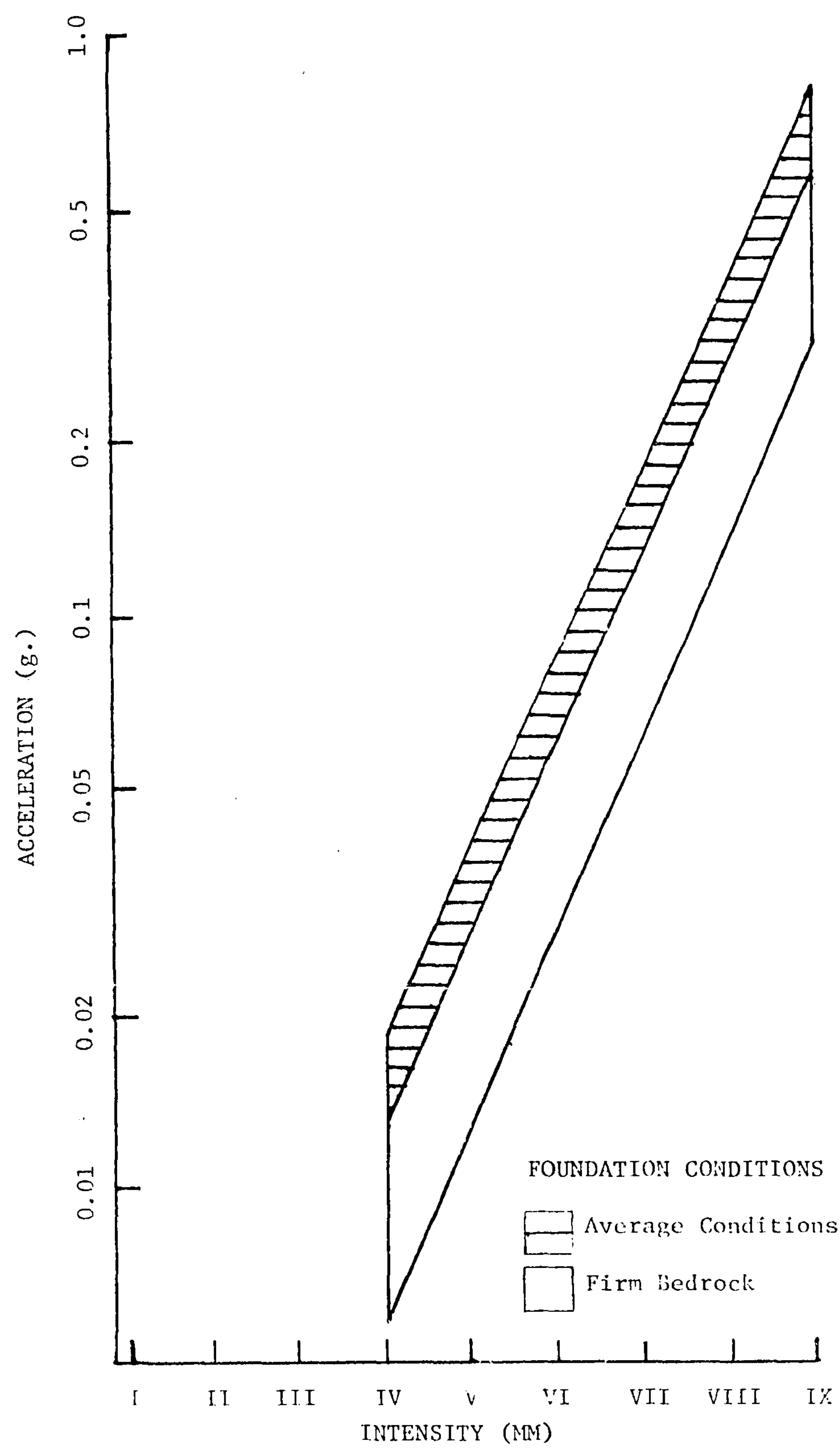


Figure 5. Earthquake Intensity/Ground Acceleration Correlation (after Coulter, 1973).

(for many eastern U.S. reactor sites) of MM Intensity VIII at a site would be from 3.6×10^{-5} to 9×10^{-6} per year (AEC, 1974c:138-144).

3.1-2 Surface Faulting

Although surface faulting is generally not a problem throughout much of the United States, and according to Richter (Benioff and Gutenberg, 1955) conclusive surface evidence of faulting has been associated with earthquakes in only some 20 instances throughout the world, regulatory criteria dictates extensive investigation to determine if such faulting is capable of directly causing differential ground displacement (AEC, 1973b). Classification of a fault in terms of its activity is based upon the assumption that a fault is likely to slip if it has slipped in the recent geological past, and is not likely to slip if it has not slipped for a sufficient length of time. Determination of whether a fault is "capable" is based on several lines of evidence indicating whether or not the fault is active. Some of the criteria defining an active fault are of necessity conservative and somewhat arbitrary due in part to the extremely short period of monitoring as measured by geological time standards.

For all faulting within two hundred miles of a proposed site which exhibit lengths greater than the minimums prescribed in Table 1, it must be determined whether the fault is capable of new movement in the future. Appendix A of 10 CFR Part 100 numerates three accepted criteria for establishing capability. They are (1) well documented macro-seismicity at the present time based on instrumental records, (2) geological evidence of movement within the last 35,000 years (the approximate limit of Carbon-14 dating techniques), and (3) geological evidence of more than one movement within the last 500,000 years. Sites that include capable faults or those within about five miles of capable fault with lengths greater than one thousand feet are not acceptable and the site will almost surely be disqualified (NRC, 1975d:8).

Table 1. Length/Proximity Requirements for Fault Capability Investigation.

Minimum Fault Length (miles)	Distance to the Proposed Site (miles)
0.19	0-5
1.00	5-20
5.00	20-50
10.00	50-100
20.00	100-150
50.00	150-200

One of the best guides to the location of possible future faulting is the location of past faulting. All fault traces in the vicinity of a proposed site are mapped as zones of potential faulting to delineate areas requiring detailed investigation. The minimum width of this zone is one-half mile and is assumed to be capable of surface displacement.

To establish the capability of faulting in near surface bedrock, the date of the most recent fault displacement must be estimated. This is normally done by tracing the fault into an area where the faulted rock is overlain by younger dateable deposits which may or may not have been offset by the fault. This technique has sometimes failed to reveal adequate positive or negative evidence simply because no younger dateable deposits are transected by the fault.

3.1-3 Foundation Conditions

The foundation problems encountered in the design and construction of nuclear power station projects are not essentially different than for any other heavy construction. Foundations must be designed for an adequate factor of safety against failure. In the case of nuclear facilities environmental and safety implications dictate more conservative design than is usually evident in routine construction practices.

Soil instabilities as well as gross foundation failures may also arise from various environmental phenomena other than earthquakes. Differential compaction, subsidence, uplift or collapse and liquefaction may result from natural features such as underground solution cavities in karst terrain or human activities such as extensive petroleum mining and groundwater withdrawal (AEC, 1973c:14-18).

While withdrawal of fluids is by far the most common type of man-made subsidence, irrigation or other extensive application of surface water to dry lands can also cause subsidence by a phenomenon known as hydrocompaction (State of California, 1969). Areas requiring further investigation to evaluate possible geological hazards include limestone areas of karst topography, areas underlain by weak materials such as clay or shale, areas associated with such evaporites as gypsum and potash, and deformational zones such as shears, joints, fractures or folds.

General site suitability criteria states that areas with unfractured bedrock generally are found to have suitable foundation materials but if no such suitable sites exist within the region, areas of low liquefaction or competent and stable solid soil, such as dense sands or glacial tills, are necessary for satisfactory foundation conditions (NRC, 1975d:9). Recent work by Scott and Schoustra (1974) indicates that many inland valleys, such as those found in California and Arizona, where as much as 4,900 feet of recent alluvium is underlain by relatively soft sedimentary rock, are dynamically stable and exhibit low potential for liquefaction and vibration induced settlement. Soil-structure interaction may actually provide more favorable results for "softer" sites (Majumdar, 1975).

3.2 Meteorology

Atmospheric phenomena affect the siting of nuclear power plants as well as their subsequent operation. The atmospheric characteristics at a site are an important consideration in evaluating the dispersion of radioactive effluents both from postulated accidents and from routine releases of gaseous effluents. The utilization of regional climatology studies can delineate the areas where low wind speed and low mixing heights severely limit dispersion of potential releases.

Although a tornado affects a relatively small area and is of short duration, its potential for damaging safety-related structures, system, and components of a nuclear power complex merits consideration not only during design and construction but also during operations in order to minimize any potential environmental risk from this severe natural phenomenon.

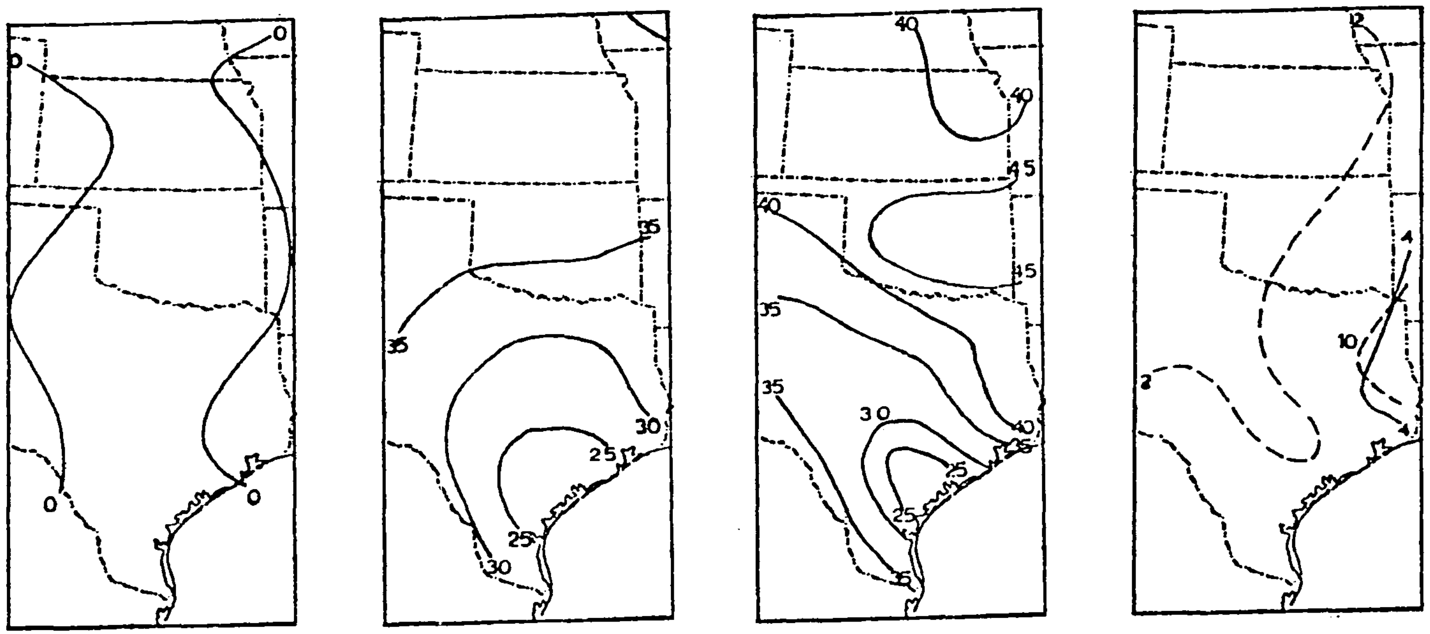
3.2-1 Dispersion Climatology

Radioactive materials as aerosols, vapors, or gases released in gaseous effluents of a nuclear power station are dispersed through variations in wind direction and stability of the atmosphere. The actual dispersion not only depends upon atmospheric variables but also on surface geographical features such as surface roughness, hills, valleys, water bodies and vegetation cover.

Numerous studies have depicted the dispersion potential of various regions or selected areas of the United States (Hosler, 1961, 1964; Korphover, 1967; Holzworth, 1964, 1972). Figure 6 presents the results of some of these studies for the region. While sites with similar geographical features may display somewhat similar dispersion patterns, the actual detailed dispersion will be unique to a particular site. Thus the NRC requires at least one year of onsite hourly observation of wind direction, wind speed, and atmospheric stability be made to allow the calculation of the annual average dilution factors (AEC, 1972b, 1974d; NRC, 1975). With this detailed information it is possible to predict whether cooling tower plumes or other gaseous releases to the atmosphere could possibly affect nearby vegetation, crops or residential housing.

3.2-2 Extreme Winds and Vortex Phenomena

The potential effect of extreme variations in weather or meteorological behavior on safety and environmental-related systems of a nuclear facility dictate their consideration both in design of the plant



HIGH AIR POLLUTION DAYS

East: 8/1/1960 - 4/3/1970

West: 10/1/1963 - 4/3/1970

(after Holzworth, 1972)

ANNUAL INVERSION FREQUENCY

Percentage of Total Hours

(after Hosler, 1961)

FALL INVERSION PERCENTAGE
500 FEET OR LESS

(after Hosler, 1964)

DISTRIBUTION OF STAGNATION
1936-1965

- - Total Cases

—— Total Days

(after Korshover, 1967)

Figure 6. Estimates of Dispersion Potential for the Central United States.

and site selection. Meteorological extremes, with the possible exception of a tornado, will not prevent the continued routine operation of the plant. Facilities that contain equipment vital to the safe shutdown are designed to resist the worst meteorological irregularity ever experienced or expected within the region.

The annual extreme fastest mile wind speed as recorded at the standard level of 30 feet has been adopted as the best available measure of wind for design purposes (Thom, 1960) and defined by the AEC as the Operating Basis Wind Speed (OBWS) to which all plant structures, systems and components must be designed to maintain normal operations (AEC, 1975a). The AEC has assigned an OBWS value of 130 miles per hour which exceeds the expected 100 year annual mean recurrence value for all but a few coastal areas (Figure 7).

The NRC has included tornadoes as one of the natural phenomena for which nuclear power plants must be constructed to successfully withstand any additional forces that might be imposed without a loss of capability to protect the environment. The design-basis tornado for these plants is defined in Regulatory Guide 1.76 (AEC, 1974e). The analysis performed to establish regional tornado design criteria found that the significant properties of tornadoes are (1) geographical distribution of frequency of occurrence, (2) rotational wind speed, (3) translational wind speed, (4) pressure drop across the tornado, (5) rate of this pressure drop, and (6) radius of maximum rotational wind. The results of the NRC study establishing these parameters are summarized in Table 2 and Figure 8. An additional factor associated with vortex phenomena is their ability to pick up loose objects and

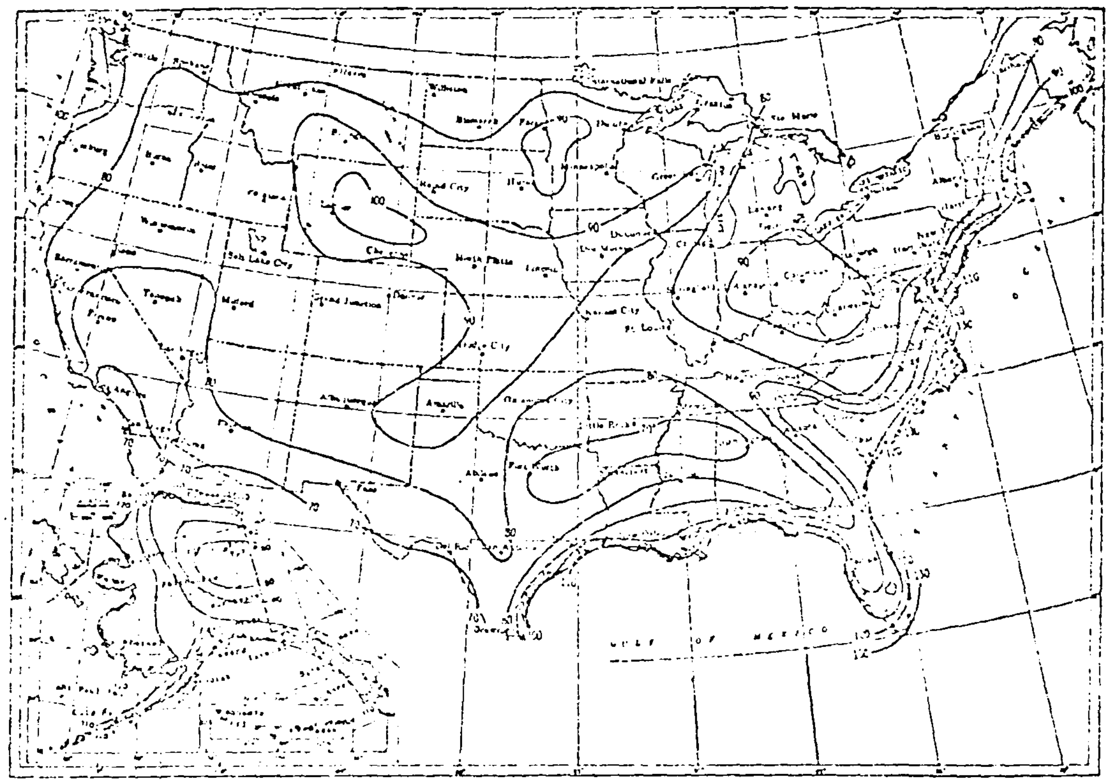


Figure 7. Annual Extreme-Mile Wind, 100-Year Mean Recurrence Interval, 30 Foot Height (mph) (after Thom, 1968).

Table 2. Design Basis Tornado Characteristics (after AEC, 1974e).

Region	Maximum Wind Speed (mph)	Rotational Speed (mph)	Translational Speed (mph) Maximum	Translational Speed (mph) Minimum	Radius of Maximum Rotational Speed (feet)	Pressure Drop (psi)	Rate of Pressure Drop (psi/sec)
I	360	290	70	5	150	3.00	2.0
II	300	240	60	5	150	2.25	1.2
III	240	190	50	5	150	1.50	0.6

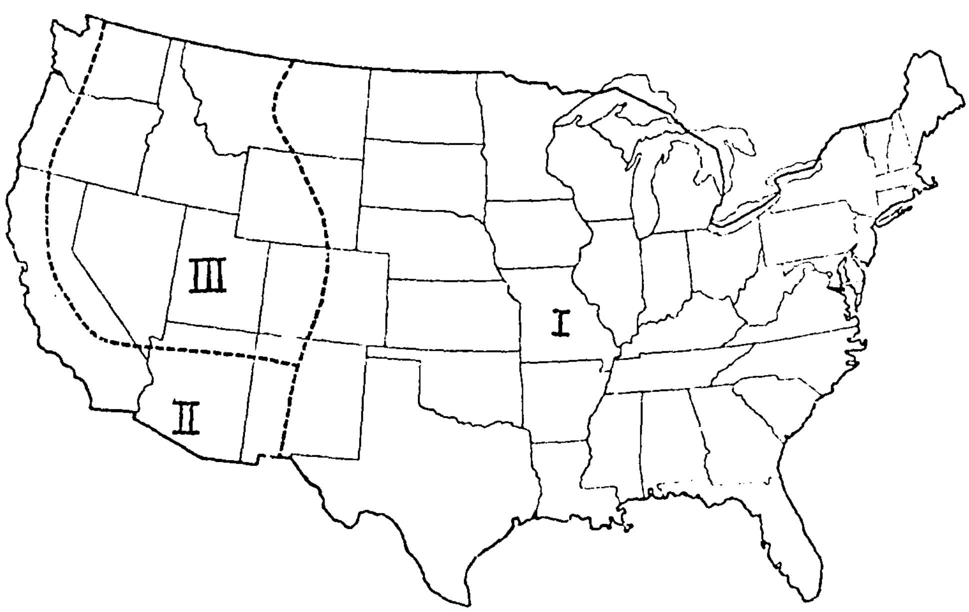


Figure 8. Tornado Intensity Regions (after AEC, 1974e).

by propelling them at high speeds, project destructive missiles (McDonald et al, 1974; Dunlap and Wiedner, 1971).

While tornadoes have been observed in every state, the frequency of reported funnels is thought to be influenced, among other things, by the population density which is available for spotting (Markee, Beckerley, and Sanders, 1974; Thom, 1963). The frequency of tornadoes in the contiguous United States has been reported by Thom (1963) and Pautz (1969) for areas bounded by lines spaced at one degree latitude and longitude. From his Iowa and Kansas studies, Thom found an average damage path length of 3.935 miles and an average damage path width of 466 feet. By utilizing a log-normal distribution, he calculated the mean damage path area to be approximately 2.81 square miles.

The probability that a tornado will strike a particular location is

$$P = \frac{a\,\bar{n}}{S}$$

where P = probability per year of a point within area S being hit by a tornado

a = average damage area of a tornado in square miles

$\bar{n}$ = average number of tornadoes expected in area S per year

S = the total area in which the tornado frequency has been determined

Using this equation, Pautz's frequency data, and Thom's mean path area, Markee, Beckerley and Sanders (1974) computed the tornado strike probability for five-degree squares (Figure 9). The five-degree square was

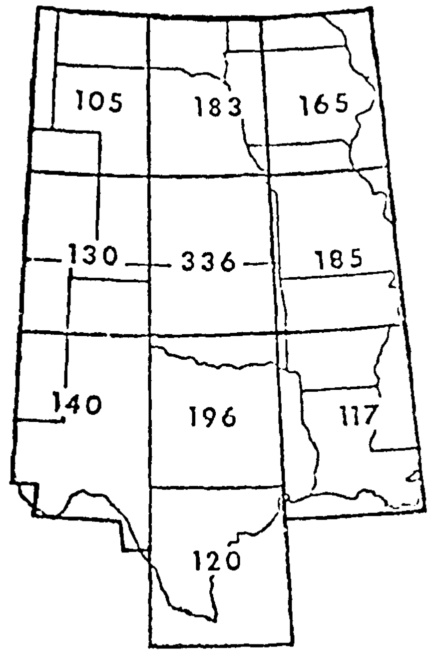


Figure 9. Tornado Strike Probability within Five Degree Squares in the Central United States, Chances per 100,000 per year (after Markee and Beckerley, 1974).

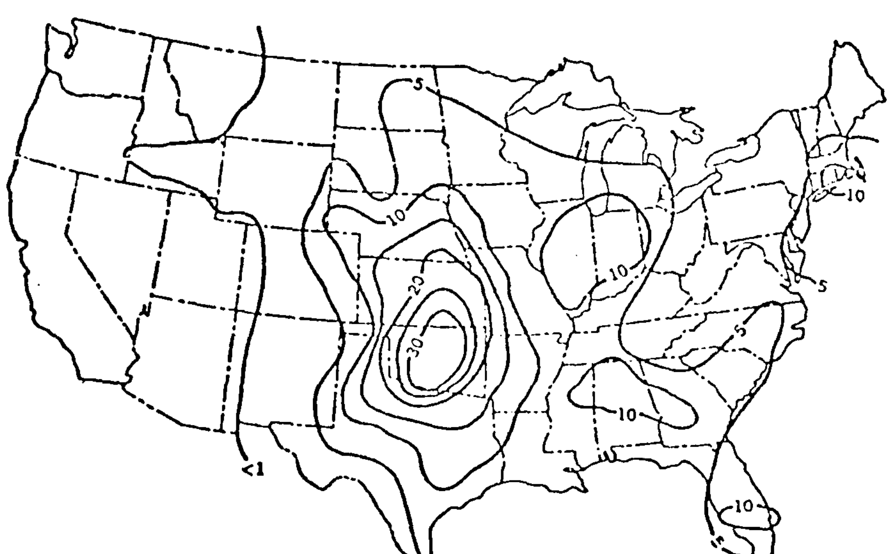


Figure 10. Annual Probability of Tornadoes, Chances per 10,000 (after Dunlap and Wiednes, 1971).

selected to minimize the effect of population on tornado reporting. Figure 10 presents isograms indicating the probability in chances per 10,000 for annual tornado occurrence in the contiguous United States which were developed from Thom's data by Dunlap and Wiedner (1971).

Tornado strike probabilities for existing power reactor sites range from about 10^{-3} to 10^{-4} (AEC, 1974c:144-145) with the average for those in the contiguous 48 states of 6.0×10^{-4} strikes per year (Shelby et al, 1975). Using Thom's data Doan (1970) calculated the "worst" site strike probability of 3.62×10^{-3} per year for an area of central Oklahoma. "However, the atmospheric extremes that may occur at a site are not normally critical in determining the suitability of a site because safety related structures, systems, and components can be designed to withstand most atmospheric extremes" (NRC, 1975d:2).

3.3 Demography

Population distributions around a nuclear power facility are considered primarily to assure that risks to the public from any accidental release of radioactivity are adequately taken into account in the selection of the site. The AEC has had a long-standing policy that encouraged the siting of commercial power reactors away from densely populated areas until additional operating experience had been obtained. This policy was established in the Statement of Considerations-Reactor Site Criteria (AEC, 1962) to provide assurance that in the event of a serious accident it would be possible to take effective action to minimize radiation exposure of individuals of the general public outside the facility.

Proposed sites are evaluated by postulating a hypothetical design-basis accident releasing a large quantity of fission products after failure of a whole sequence of redundant engineered safety features. Off-site radiation exposures are calculated for comparison to the guidelines established in 10 CFR 100. While suitable sites, less densely populated, remain available there is no need to take the additional incremental risk, however small, of incurring doses to a large metropolitan population as the result of any accident in the nuclear facility.

Methodologies for the calculation of distance requirements for reactor sites first appeared in TID-14844 (Di Nunno et al, 1962). However, as operating experience increased and technological advances in engineered safety features reduced potential hazards to the public, actual distances of about one-quarter to one-half those calculated were approved after evaluation of the characteristics of each reactor-site combination.

3.3-1 Site Requirements

As set forth in 10 CFR 100, "Reactor Site Criteria", a commercial nuclear power plant site must establish an "exclusion area" within which the applicant must control all activities, including the preclusion or removal of persons and property. This area must be of such size that upon a hypothetic accident the radiation dose received by individuals at any point on its boundary is less than certain prescribed values. Residential use is normally prohibited in this area unless specific means are provided for rapid evacuation of residents.

Immediately surrounding this "exclusion area" is a "low population zone" in which the number of people is sufficiently limited to allow rapid evacuation or other protective measures. Once again 10 CFR 100 establishes the boundary of this area on the basis of radiation dosages to individuals on the outer boundary following the hypothetical accident.

A proposed site must also have a "population center distance", defined as the distance from the reactor site to the nearest boundary of a densely populated center containing more than about 25,000 residents. The "population center distance" must be at least one and one-third times the distance from the reactor to the outer most boundary of the "low population zone" as seen in Figure 11. New NRC amendments add the provision: "In applying this guide, the boundary of the population center shall be determined upon consideration of population distribution. Political boundaries are not controlling in the application of this guide" (American Nuclear Society, 1975b). This clarification was the result of recent court challenges regarding the NRC interpretation of distance requirements in the case of Northern Indiana Public Service's Bailly Nuclear Power Plant. In November 1975, the U.S. Supreme Court reversed a lower court decision which had rejected the distance of the Bailly site to the nearest population center. During licensing hearings the then AEC Regulatory Staff, the Atomic Safety and Licensing Board and the utility had agreed that the minimum distance should be two miles. They estimated that the point of highest nearby population density was four and one-half miles and thus acceptable. However, a three-judge panel of the U.S. Seventh Circuit

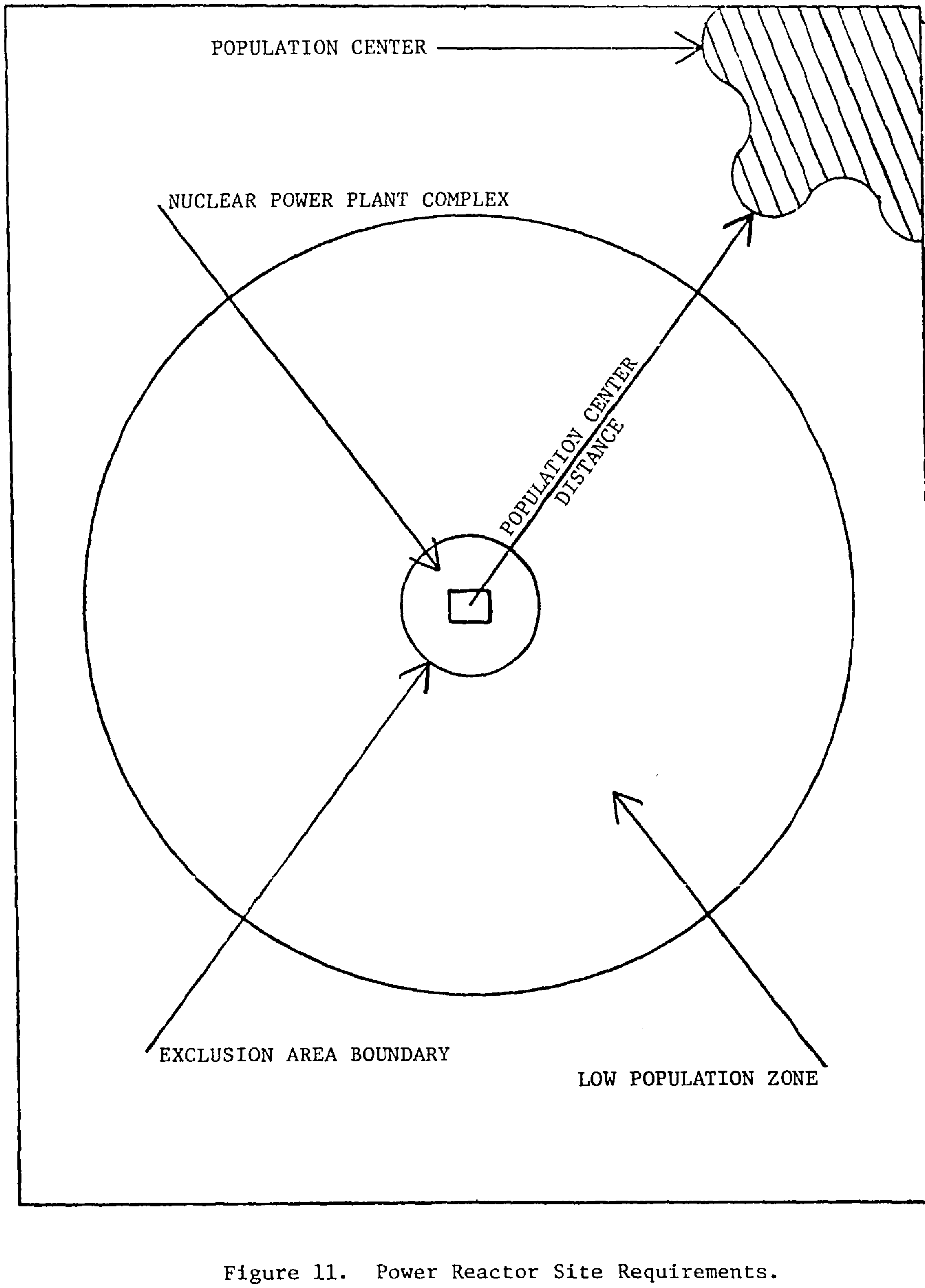


Figure 11. Power Reactor Site Requirements.

Court of Appeals said the city political boundary was only 1.1 miles and ruled that this was the determining distance and thus ordered that the issued construction permit was illegal. In overturning the Appeals court panel, the Supreme Court ruled that NRC's reliance on the actual boundary of population density conformed to the purpose and wording of the applicable regulations (ANS, 1975d).

Based on an AEC analysis of more than 60 power reactor sites in 1973, the average area of a nuclear power station was about 1160 acres, with a range of 84 acres to well over 30,000 acres (AEC, 1973d). A more recent review of the characteristics of nuclear power facilities found that the average land surface required was dependent on the type of condenser cooling system utilized. If a once-through system or cooling towers were utilized, 1,100 ± 900 acres were needed whereas the size of cooling ponds influenced the total site size dramatically as seen in Figure 12 (AEC, 1974h:96-98).

The average distance from the station to the nearest boundary of the exclusion area was about 0.46 miles with a range of 0.11 mile to 1.0 mile. Distance to the boundary of the low population zone was found to range from 0.44 miles to 7 miles, with an average distance of 3.3 miles. The actual distances to the nearest metropolitan area of 50,000 or more inhabitants ranged from about 4 to 100 miles with a typical distance of 30 miles (AEC, 1973d).

The current NRC published regulatory position with regard to selection of these zones follows:

> Based on past experience, the NRC staff has found that a minimum exclusion distance of 0.4 mile, even with unfavorable design basis atmospheric dispersion characteristics, usually

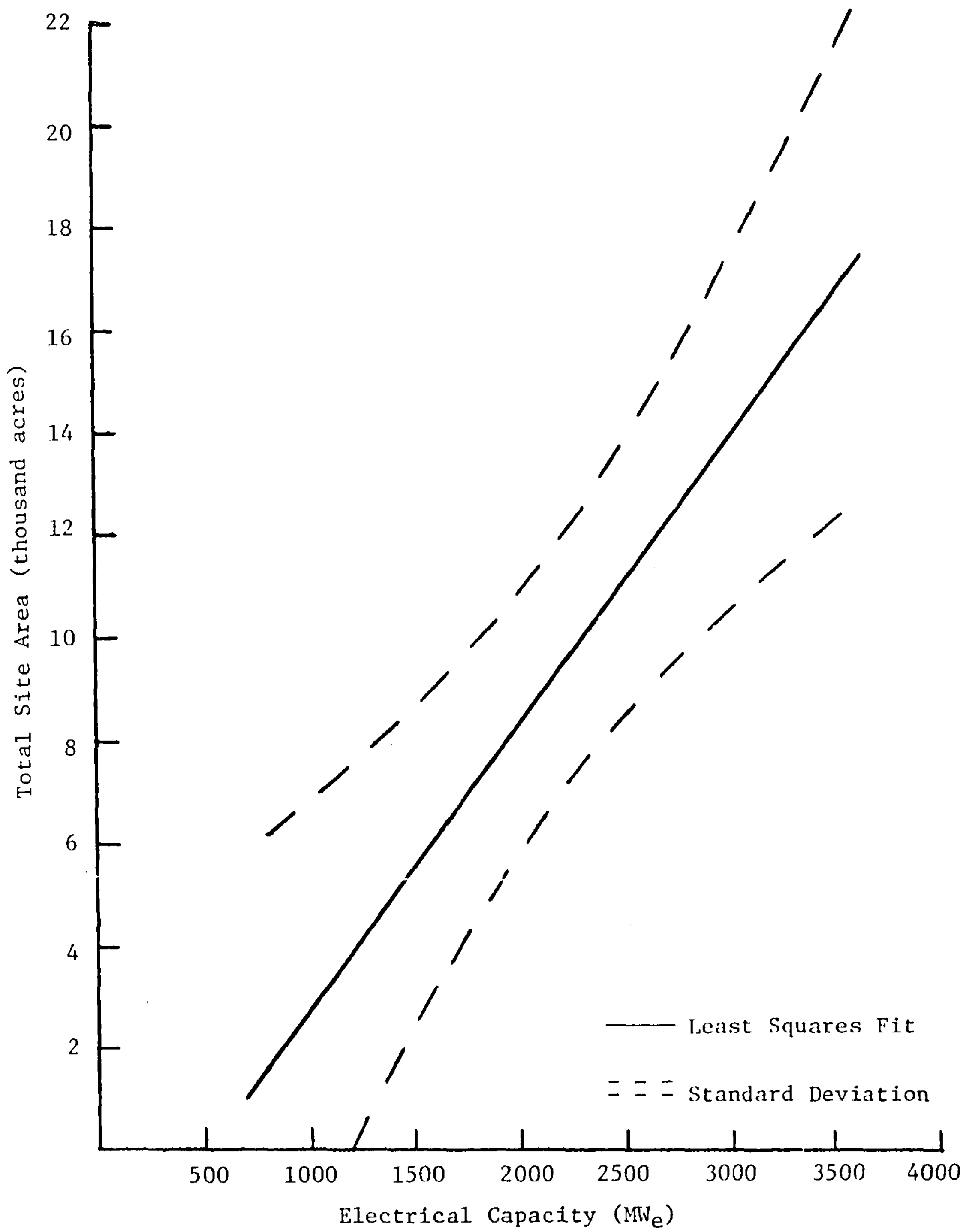


Figure 12. Land Requirements for Cooling Ponds (after AEC, 1974h).

> provides assurance that engineered safety features can be designed to bring the calculated dose from a postulated accident within the guidelines of 10 CFR Part 100.
>
> Also, based on past experience, the staff has found that a distance of three miles to the outer boundary of the low population zone is usually adequate (NRC, 1975d:9).

This would allow the consideration of a site at a distance of four miles from a city of 25,000 people.

If a relatively sparse population distribution exists around a proposed nuclear facility and land acquisition costs are relatively low, the utility may choose to establish a relatively large exclusion distance and a large low population zone. By selecting large distances, they can take advantage of the natural dose reduction by meteorological dispersion that occurs as the distance from the source of radioactivity increases. Thus, somewhat less sophisticated mechanisms to assure the containment of any released radioactivity at the source (engineered safety features) would be required.

3.3-2 Population Density

As part of the NRC's current technical procedures for evaluation of proposed nuclear power plants, the utility is required to submit the following information concerning a proposed site: the population distribution within 1, 2, 3, 4, 5, 10, 20, 30, 40, and 50 miles of the plant for the first year of operation, as well as the projected population by decade through the expected life of the plant. When a significant number of people work, reside part-time or engage in recreational activities but are not permanent residents of the area, the transient population must also be taken into account according to the fraction of the time they are in the area.

In mid-1974 the AEC publicly released a "Staff Working Paper" on population density which was apparently intended to be reviewed and disseminated as a proposed regulatory guide (AEC, 1974i). The basis of the proposed guide was that the projected cumulative population at the date of application for a construction permit would be 30,000 or less within five miles, 500,000 or less within 20 miles, and 2,000,000 or less within 40 miles. This was approximately equivalent to a uniformly distributed population density of 400 people per square mile. However, this guide was never formally instituted. Instead NRC site suitability criteria were issued requiring the consideration of alternative sites of lower population density if the proposed site, at the time of initial startup, would have a population density of greater than 500 persons per square mile averaged over any radial distance out to 30 miles or would have a projected population density of over 1,000 persons per square mile over the lifetime of the facility within this same distance (NRC, 1975d:9). These densities represent the cumulative population at a distance divided by the area included within that distance.

The results of an AEC study of 37 proposed river sites (Figure 13) indicate that the majority of the sites when examined from the standpoint of cumulative population fit the current requirements. Table 3 presents a comparison of three high population density sites. Note that the earlier proposed AEC guide and the current NRC site suitability criteria are also given for reference.

Should the projected population density at a proposed site be high, the utility must consider alternative sites with lower den-

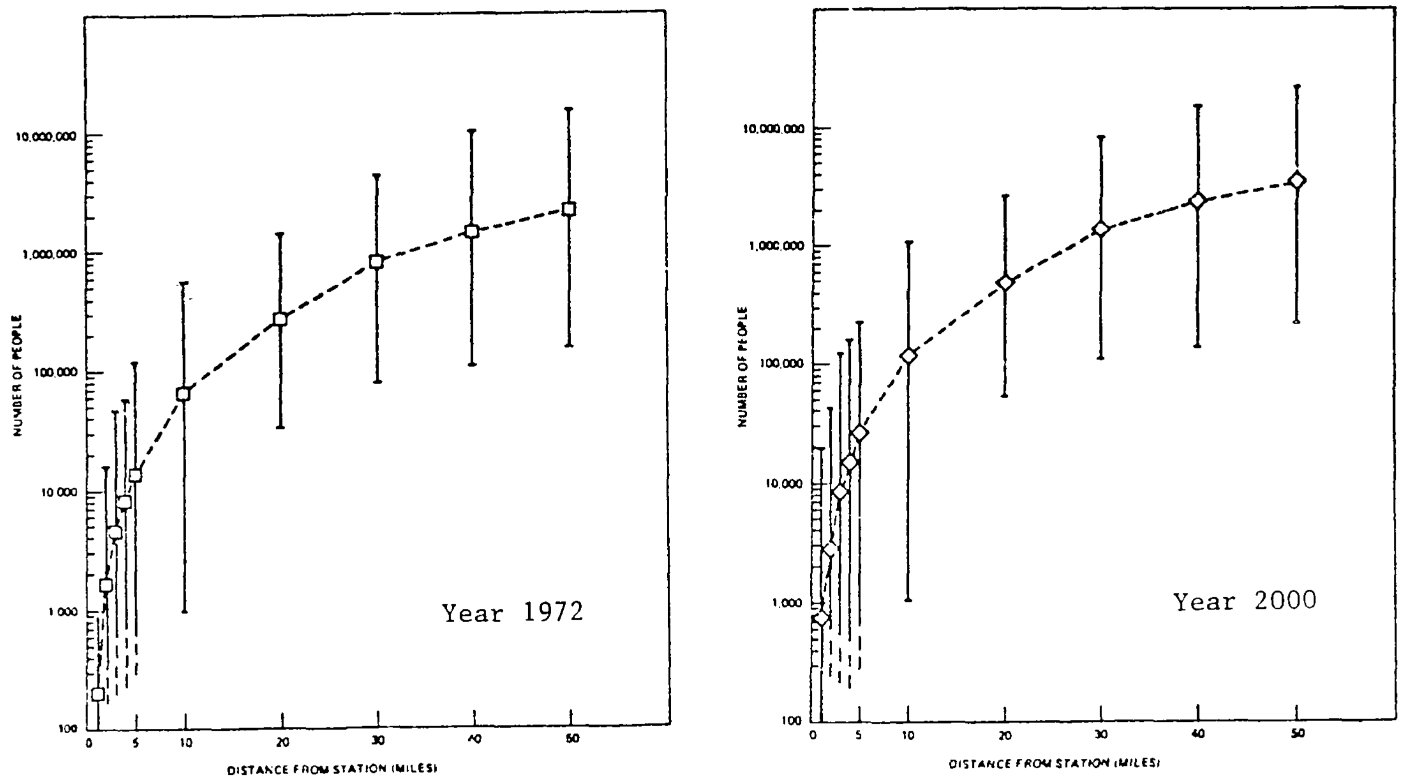


Figure 13. Averages and Ranges of Cumulative Population for River Sites (after AEC, 1973d).

Table 3. Projections of Cumulative Population.

	5 Miles	20 Miles	30 Miles	40 Miles
Zion Plant Site (1980)	106,615	846,515		5,184,515
Indian Point Plant Site (1980)	70,053	1,179,611		12,882,240
AEC, 1974i (WASH-1308)	30,000	500,000		2,000,000
NRC, 1975d: Initial Operation	39,250	628,000	1,413,000	
Plant Lifetime	78,500	1,256,000	2,826,000	

sities. Kohler et al (1974, 1975) developed an index for use in comparing population distribution at alternative sites. The Site Population Factor (SPF) weights discrete annular ring elements of population by a decreasing function of the distance from the site. The SPF is defined as

$$SPF(r_n) = \frac{\sum_{J=1}^{n} W_{(J)} \cdot P_{(J)}}{\sum_{J=1}^{n} W_{(J)} \cdot Po_{(J)}}$$

where: r_n = the outer radius of the largest annular circle

$W_{(J)}$ = the weighting factor for the J'th annular ring

$P_{(J)}$ = the population in the J'th annular ring

$Po_{(J)}$ = the hypothetical (normalizing) population in the J'th annular ring

The weighting factors are dimensionless and are defined as $W_{(J)} = (r_J)^{-1.5}$. The negative 1.5 power is an approximation of the distance dependence of meteorological dispersion. The total weighted population within a bounding radius is normalized to a hypothetical site having a uniform population density of 1,000 people per square mile. That is: $Po_{(J)} = 1{,}000\pi(r_J^{\,2} - r_{J-1}^{\,2})$. Thus, a proposed site having a SPF equal to 0.5 within a bounding radius of 30 miles is numerically equivalent to the hypothetical site having 500 people per square mile uniformly distributed out to a distance of 30 miles.

This method of population weighting accounts for a non-uniform distribution of population that could occur between specified distances and by so doing represents a potential tool for evaluating alternative sites. Figure 14 presents the SPF at 20 miles for Oklahoma

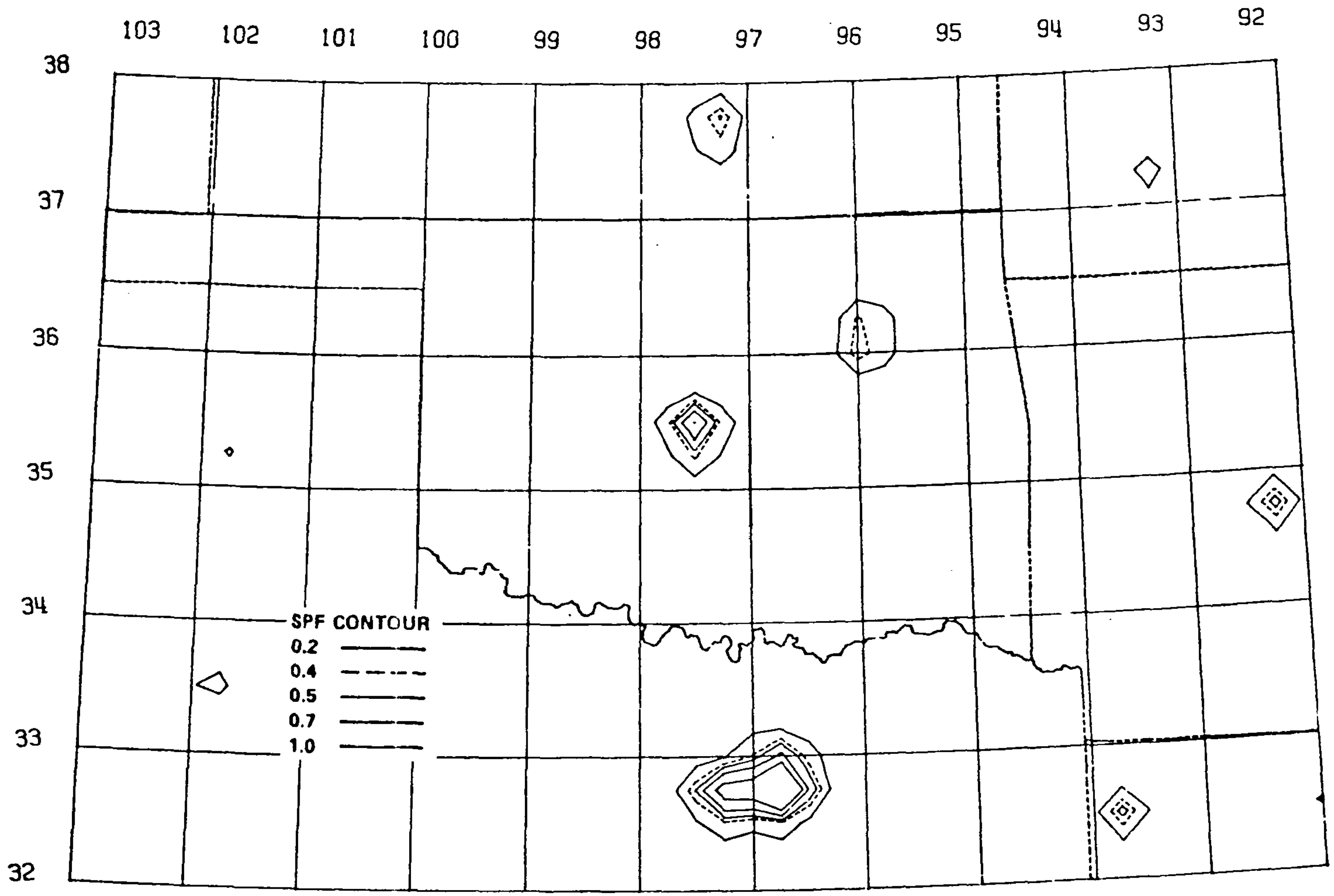


Figure 14. Oklahoma 1970 SPF at Twenty Miles (after Kohler et al, 1974).

and surrounding area as computed from 1970 census data (Kohler et al, 1974, 1975).

Accurate projection of population growth in the vicinity of a proposed nuclear facility requires a detailed analysis of economic and cultural considerations within the region which may be influenced by the construction of the power plant itself. An average of some 1,300 workers will be engaged in construction activities during the six-year peak construction period of a nuclear power station. While 25 to 30 percent of the construction labor force are likely to become new residents in communities near the site, some 100 operating personnel would ultimately be employed at such a facility (AEC, 1974h).

3.4 Hydrology

An important consideration in selection of a site for any power plant is the availability of condenser cooling water; thus nuclear power stations, as well as fossil fuel plants, are generally located on seashores, bays, estuaries, large lakes, man-made reservoirs or riverine sites.

The essential water requirement for a nuclear power plant is for a sufficient and highly reliable source of water available for cooling during plant operation, normal shutdown, and for nuclear safety, as well as for fire protection.

The availability of the required water during periods of low stream flow or low reservoir water level is an important first consideration in the screening of sites located on rivers or smaller shallow lakes (NRC, 1975d:5). In a water-short region, the evaluation of a water source must consider the quantity available for consumption and the continuity of supply.

3.4-1 Adequate Water Quantity

Cooling modes currently in use by nuclear power stations are classified as once-through cooling, evaporative tower cooling, and cooling ponds. Most recently nuclear facilities have utilized closed-cycle heat dissipation systems such as natural or mechanical draft cooling towers to meet increasingly more stringent thermal discharge limits. Environmental Protection Agency guidelines now require that closed-cycle cooling systems be constructed for new plants, and by July 1, 1981, be added to all power plants of 500 MW or greater which were placed in operation after January 1, 1970 (Davis, 1975; EPA, 1974).

In addition to water required for condenser cooling, service water is necessary for radwaste treatment, sanitary waste treatment, cooling of pumps, turbines, and motors, and also emergency services such as fire protection.

The consumptive use of water supplies depends principally upon the type of condenser cooling system. In closed-cycle systems condenser cooling water is circulated to a pond, impoundment, canal or cooling tower where heat rejection takes place by evaporation and surface heat transfer. A fraction of the circulating water is continuously discharged to a receiving waterbody to control chemical build-up within the system. At the same time water is removed from a source and added to the circulating water to make up for that lost by natural and induced evaporation or discharged from the system. Evaporative losses from several cooling systems have been estimated by Hauser and Oleson (1970) and the Atomic Energy Commission (AEC, 1974h). Table 4 outlines some estimates of both make up and total water requirements for light-water-cooled reactor power stations.

An appropriate basis for the determination of the adequacy of streams with an average flow of 5,000 cfs or greater is the seven-day, once-in-ten-years low flow. The total consumptive withdrawal from smaller streams should not be greater than 50 percent of the historical monthly mean low flow (AEC, 1973c:40). The consideration of extremes of low flow of the water body is an essential principle in judging proposed site acceptability.

To assure safety in depth the NRC requires a highly reliable water supply capable of providing sufficient cooling water to permit the safe shutdown and cooldown of all reactor units in the event of an accident. This ultimate heat sink must be of such capacity as to allow safe cooldown for the period of time needed to evaluate the situation and take corrective action. A thirty-day supply of water is required to be available under the meteorological conditions resulting in maximum evaporation and drift loss based on the most severe regional climatological information for the critical time period.

3.4-2 Water Quality

All liquid discharges from the nuclear power plant must conform to the effluent limitations established under the Federal Water Pollution Control Act (Public Law 92-500) as well as state and local restrictions.

Table 4. Estimates of Water Requirements for Cooling Towers (cfs/MW_e)

Source	Consumptive Loss	Total Makeup
State of Maryland, 1969		0.044
Arkansas Power & Light Co., 1972	0.027	0.033
National Academy of Engineering, 1972	0.032	0.040
Atomic Energy Commission, 1973c	0.028	
Atomic Energy Commission, 1973d		0.042
Northeast Utility Service Co., 1973	0.026	0.052
State of California, 1973		0.027
Atomic Energy Commission, 1974h	0.028 - 0.030	0.036
Atomic Energy Commission, 1974j	0.031	
Mean Value	0.029	0.039

Extensive guidance on regional site reconnaissance survey of aquatic environments for power plant site selection have been published (National Academy of Engineering, 1972:83-99). Existing areas of marginal water quality may not be capable of providing input water over the lifetime of the nuclear facility and should be avoided.

Water quality management is not a major constraint in site selection because adequate design alternatives can generally be developed to meet regulatory standards and minimize any stress imposed on local ecological or biological communities (NRC, 1975c:5).

3.4-3 Water Rights

The availability and assurance of an adequate, long-term water supply for a nuclear power plant is dependent upon the limitations imposed by existing laws and water allocation policies. Consumptive use of water may necessitate an evaluation of existing and projected water uses in the region of a proposed site to ensure adequate water supply for power plant operation and downstream private and public requirements during periods of drought.

Established water rights in highly developed regions may account for nearly all surface and subsurface water. Unavailable water rights usually necessitate the purchase of an adequate water supply. The multiple use of agricultural or municipal waste water for power plant cooling avoids the consumptive use of scarce fresh water; however, there are several important environmental as well as technical problems related to the use of waste water. These problems include the disposal of blowdown, dispersion of drift containing high concentrations of total dissolved solids and the effects on the cooling system of chemical concentrates.

Prior to 1963, Oklahoma water rights functioned largely on a matter of vested rights because generally enough water was available for appropriation in most areas of the state. Broadly speaking, a vested surface water right is one based on a priority date and beneficial use before June 10, 1963. Since that time, filing an application for a permit to use surface water is necessary (O.W.R.B., 1975). This California-type doctrine is a combination of riparian (common law) rights and appropriations rights (AEC, 1973c:33-38).

3.4-4 Floods

The sites for nuclear power plants are often selected in river valleys on flood plains, or along coastlines where there is a finite probability of flooding. The potential hazard associated with floods requires that all reactors be designed and sited to survive a hypothetical flood called the Probable Maximum Flood (PMF) which represents the most severe flood conditions that can reasonably be predicted to occur at the site as a result of hydrometeorological conditions, seismic activity, or any combination of these parameters (AEC, 1973e). The facility must either be located such that water from the PMF would not reach the facility, or the facility must be afforded the necessary protection by dikes, diversion channels, etc., to remain unaffected by the water from the flood.

On the basis of historical data it is possible to perform statistical analyses to determine the probability of occurrence on site of a reference event of given characteristics. The Probable Maximum Flood approach has been developed from the design considerations of dams and other major structures subject to floods (Corps of Engineers, 1968). The PMF value is based on an estimate produced by combining the worst extreme value of all factors, such as a maximum probable precipitation, seismically induced dam failure and any attendant wind-generated wave action, that could contribute to producing a flood. This method of risk assessment is believed to be a highly conservative approach as compared to studies of observed historical flood frequencies. For example, the PMF for the Mississippi River at the Monticello Reactor Site was based on the heaviest snow pack observed in the last 100 years subjected to the maximum temperature sequence with the largest postulated rainstorm occurring simultaneously. The resulting river flow was calculated to be 365,000 cfs which is nearly 10 times higher than the maximum observed flood of 47,000 cfs. Wall (1973) examined the probability of such a flood using extreme value theory and concluded that the probability would be negligibly small.

3.5 Biota/Ecological Systems

The impact resulting from power plant construction and operation can in general be mitigated through conservative design proper construction techniques and operating practices. However, the construction and operation of plant structures may block pathways or severely interfere with daily or seasonal migrational movements of "important" species.

Regulatory Guide 4.7 (NRC, 1975d:5) defines animal or plant species as important if a specific causal link can be identified between the nuclear power station and the species and if one or more of the following criteria applies:

(1) if the species is commercially or recreationally valuable
(2) if the species is endangered or threatened (as defined by the Endangered Species Act of 1973 and listed periodically by the Secretary of the Interior in the *Federal Register*)
(3) if the species affects the well being of some important species within criteria (1) or (2) or if it is critical to the structure and function of a valuable ecological system or is a biological indicator of radionuclides in the environment.

The extent of station-induced alteration of habitat and the resultant change in species composition and abundance, in relation to the total remaining unaltered habitat and associated species population, is the primary basis for evaluating acceptable change. Such habitats include breeding, nesting, spawning, nursery, feeding, resting, and wintering areas.

3.5-1 Temperature Sensitive Aquatic Species

No other single environmental factor affects aquatic life as profoundly or in such an all-pervasive manner as temperature. Unfavorable temperature may affect reproduction, metabolic rate, growth and survival of larvae forms, juveniles as well as adults. Thus waterbodies containing important aquatic species currently living near the extremes of thermal tolerance should be avoided.

Heat may produce direct, indirect, or chronic effects on fish. Published evidence suggests that certain freshwater organisms, especially fish, are able to tolerate higher temperatures by acclimation

(Hawkes, 1968). Yet problems arise when plant discharges hold fish at "summer" temperatures, inhibiting natural movement out of the area that would normally be triggered by the onset of winter time water temperatures. Fish kills have resulted from the abrupt drop in temperature after unscheduled plant outages and thus, siting must include cold-shock considerations (Coutant, 1974).

Warmwater fishery areas provide habitat for species that are generally more temperature-tolerant, such as bass and catfish. For the most part, the warmwater game fish can tolerate moderate increases in temperature but are susceptible to rapid substantial rises. Cold water fishery areas, such as trout streams, are much more temperature sensitive (State of California, 1973).

In most cases, maintaining the applicable water quality discharge standards will provide adequate assurance that the resulting changes will be environmentally acceptable.

3.5-2 Rare/Endangered Species

With the exception of rare or endangered species the destruction of a number of members of a particular plant or animal population is generally acceptable provided that reproductive capacity and vitality of the population (or crop) are not adversely affected (NRC, 1975d:10).

"Rare species" are considered as those which are present in such small number that they may become endangered if their environments are altered. "Endangered" and "threatened" species are considered as those whose prospects for survival are in immediate jeopardy. An endangered or threatened species' decline may have been due to one or more causes--loss of habitat or marked change in habitat quality, overexploitation, predatory competition, or disease.

Special consideration should be given to any rare or endangered species living in the vicinity of a proposed or potential nuclear power plant site which would be susceptible to any environmental alterations resulting from either the construction or operation of the plant. The development of a site may through plant design options provide improved habitat and afford protection for some rare, threatened, or endangered species within the plant's exclusion zone. Much of the undisturbed area of some nuclear power plant sites have been dedicated to game and wildlife preserves (Ransay and Reed, 1974).

In many cases, the potential adverse impact of a particular plant-site combination can be effectively mitigated through the application of special designs making many such problems become economic rather than environmental per se.

3.6 Land Use

The question of undesirable land use patterns resulting from the utilization of a proposed site must be addressed in the environmental impact evaluation (CEQ, 1973). There is not, however, a widely accepted standard for land-use compatibility as illustrated in the wide variety of recently introduced state and federal legislation (Haggard, 1975). The American Bar Association (1974) has proposed land use legislation emphasizing state-wide jurisdiction over the sites for "key facilities" which as defined include power generating facilities. Currently these sites are controlled by local zoning and often subjected to delayed approval (Stimac, 1974, 1975).

An AEC case study (Ramsay and Reed, 1974) illustrated some of the potential direct effects of land use change ("land conversion") as well as indirect "spillover" neighborhood effects. Commercial nuclear power stations can pre-empt large land areas especially when new lakes or cooling ponds are constructed. This land requirement is often an important issue when a proposed site will inundate productive agricultural land. Potential siting on lands devoted to specialty crops (e. g., artichokes, cranberries, etc.) may represent a type of land conversion involving unacceptable economic dislocation (NRC, 1975c:7).

Certain lands held "in trust" by the Federal Government for Indians, Aleuts, and Eskimos may be incompatible with intensive power generation development and should be avoided whenever possible. Additional lands which may be sensitive, restricted or otherwise marginally acceptable can include local, state, and national parks; wilderness and recreation areas; historical and archaeological sites; and wild or scenic rivers. "It should be recognized that some as yet undesignated areas may also become unsuitable because of public interest in future dedication to public scenic, recreational or cultural use. Relatively rare land types such as sand dunes and wetlands are prime candidates for such future designation" (NRC, 1975c:7).

3.6-1 Natural Resource Areas

The visual impact of man-made developments, such as nuclear power plants or transmission lines, may adversely change natural settings and thus reduce the aesthetic quality of public scenic, recreational, or cultural use areas such as: National and State parks, National monuments and similar sites of important state and local interest, wilderness/primitive areas, wildlife refuges, wild/scenic/recreational rivers or unique local land forms.

The use of lands close to scenic or recreational areas may cause unacceptable impacts regardless of station design or landscaping. Electric generating facilities, substations, and associated transmission facilities must be considered incompatible with natural-resource oriented areas such as Yellowstone National Park (Office of Science and Technology, 1969, FPC, 1970). However, recreation-oriented areas may still be suitable provided buffer zones or other mitigating designs are sufficient to protect the public interests.

3.6-2 Archaeological/Historical Sites

The protection of historically significant areas recognized by the U.S. Department of the Interior, National Park Service, National Register of Historical Places and those recorded by state and local historical preservation societies should be assured by careful site selection.

The same protection authorized by the National Historic Preservation Act (P.L. 89-665) is afforded archaeological areas of scientific or historical significance. In this instance utility companies have often sponsored comprehensive archaeological surveys of proposed sites and excluded or protected areas within the facility boundary.

The problem of increased scavenging and vandalism that often accompanies the public listing of archaeological or historic sites is a complicating factor in the planning process. Archeologists are keenly aware of the vital necessity of making site locations available to planners or others involved in land use alterations during the decision-making process. There is, nonetheless, hesitation to make detailed information generally available. Instead, a professional assessment or "best guess" based on known sites, general archeological knowledge, and other environmental factors must be made as to the probable presence, intensity, and significance of cultural resources which might occur in the particular area to be affected (Neal, 1975).

3.7 Hazardous Man-made Facilities

Potential accidents at nearby industrial, transportation, or military installations may pose a threat to the safety of nuclear power plant operations and in turn to environmental protection systems. Special considerations are required in site selection to avoid environmental interaction, either directly or indirectly with hazardous materials or products associated with manufacturing plants, chemical processing or storage facilities, oil or gas pipelines, or any other nearby industrial operation. Accidents could produce missiles, shock waves, flammable vapor clouds, toxic chemicals, incendiary fragments, or corrosive gases which in turn could affect the safe operation of the nuclear facility (Grimes, 1975).

3.7-1 Industrial Operations

All significant manufacturing plants, chemical processors, petroleum refineries, mining and quarrying operations, oil or gas wells, and petroleum storage installations within five miles of a proposed power plant site should be identified and evaluated with respect to possible adverse impact on the plant or operating personnel (NRC, 1975d:11). These evaluations might include the potential effects of accidental releases of toxic gases from nearby industries, the effects of explosions or fires at adjacent oil and gasoline refineries or storage facilities, the effects of explosions of large natural gas pipelines that pass close to the site, and the effects of accidental detonation of a large amount of explosives stored at mining or quarrying operations nearby.

3.7-2 Military Facilities

Nearby military bases or other military facilities such as munition storage areas, ordnance test ranges or missile installations may threaten plant safety in the event of an accident. Thus the acceptability of a site adjacent to a military installation is dependent upon establishing a power plant design to insure that plant safety will not be affected by severe accidents within the military reservation.

3.7-3 Land and Water Transportation Routes

An accident during the transfer of hazardous materials via waterway, railway, highway, or pipeline near a commercial nuclear power plant may also generate shock waves, missiles, and toxic or corrosive gases which can interfere with the safe operation of the plant. The extent of possible consequences of such accidents are dependent on the distance to the site and the nature, as well as the maximum quantity of the hazardous material involved.

A plant built to withstand the design-basis tornado wind loading would be protected against the equivalent peak overpressure created as a result of an explosion on a major transportation route in the vicinity of the site. The maximum explosive cargo was analyzed for each surface transportation mode to establish the closest approach distance where the potential effects of such an explosion would be equivalent to that of the applicable design-basis tornado. Table 5 summarizes the minimum distances shown in Figure 15 for the maximum postulated explosive cargo for a single highway truck, single and multiple railroad boxcars, and a ship (AEC, 1975a:10-14; AEC, 1975b). The figure presents the function of distance and TNT equivalent explosive charge for Tornado Intensity Region I. The function is

$$R_G = 41\ W^{1/3}$$

where R_G is the distance in feet from an exploding charge of W pounds of TNT.

Table 5. Acceptable Minimum Approach Distances to Major Surface Transportation Routes* (AEC, 1975b:2).

Route	Mode	Feet	Miles
Highway	43,000-lb. Truckload	1,500	0.2841
Railway	132,000-lb. Boxcar load	2,100	0.3977
	396,000-lb. Multiple Boxcars	3,000	0.5682
Waterway	1,000,000-lb. Shipload	9,000	1.7045

*Tornado Intensity Region I

3.7-4 Airports

Airports are transportation facilities that pose specialized

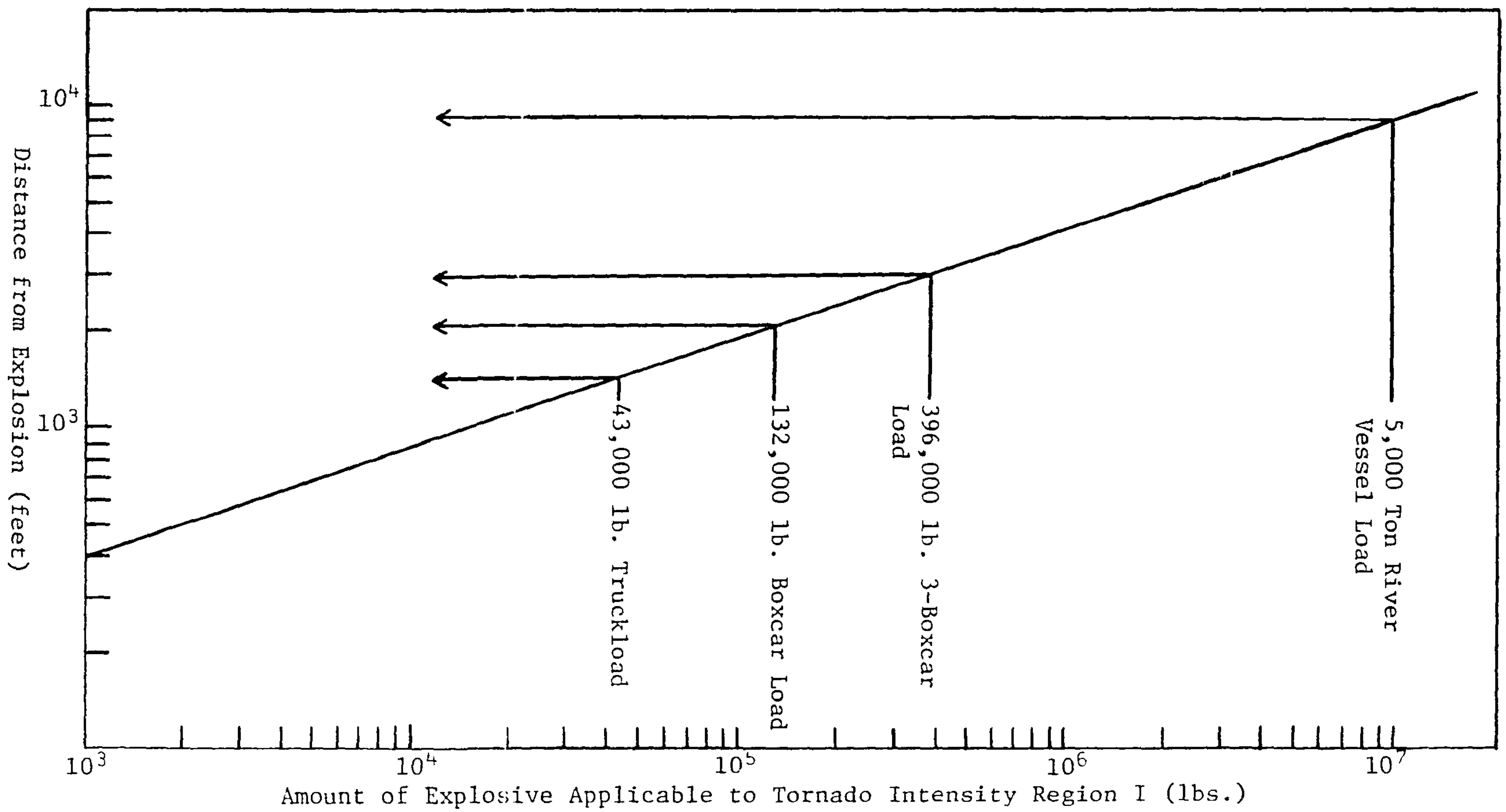


Figure 15. Minimum Approach Distance Function for Surface Transportation Modes (after AEC, 1975a).

hazards to nearby nuclear power plants. The potential threats to plant safety are two-fold. The probability of an aircraft impacting on critical structures and the secondary effects of a crash, such as fire, must be carefully considered during site selection.

Recent research into aircraft accident probabilities are based on extrapolations from the history and distribution of recorded crashes near airports (Wall and Augenstern, 1970; Eisenhut, 1973; Hornyik, 1973; Boonin, 1974; Wall, 1974). The Atomic Energy Commission has evaluated the probability of potentially damaging crashes at selected sites located within five miles of airports. The AEC study reported that the probability for a damaging crash was found to be between 10^{-6} and 10^{-7} per year at the sites examined (AEC, 1974c: 146-147). This study served as the base of the current regulatory position which requires specific analysis to substantiate that the probability of aircraft accidents potentially affecting plant safety is less than about 10^{-7} per year for sites located (1) within five miles of an existing or projected commercial or military airport, (2) between five and ten miles from airports with more than approximately $500 \times d^2$ aircraft movements per year (where d is the distance in miles to the airport), and (3) at distances greater than ten miles from airports with more than approximately $1{,}000 \times d^2$ aircraft movements per year (AEC, 1974b:21; NRC, 1975e:2-6).

CHAPTER IV

EXPERIMENTAL DESIGN AND METHODS

After more than thirty years of research, development, and large scale demonstration, nuclear power plants are now being utilized on a rapidly increasing scale by electric utilities throughout the world. Within the south central United States, which has historically utilized natural gas for boiler fuel, the need to conserve fossil fuels as well as a need to minimize any dependence on imported oil has prompted an acceleration in the planning and construction of uranium fueled base load generating capacity.

The Energy Policy Staff of the President's Office of Science and Technology estimated that some 71 new sites will be needed by 1990 for power plants in the South Central Region of the National Power Survey. Of this total, 22 sites would be needed for nuclear plants (Office of Science and Technology, 1969:4-6). The U.S. Environmental Protection Agency also suggests that the estimated number of operating reactor plant sites would increase from one in 1975 to three in 1980, 13 in 1985 and finally total 22 by the year 1990 (EPA, 1972). Nuclear energy is projected to provide only about two percent of all the energy needs of Oklahoma in the early 1980's and yet will provide nearly eleven percent of the State's total by 1990 (Oklahoma Energy

Advisory Council, 1974).

The candidate area siting study was accomplished in several phases. The first phase of the siting study established the definition of the hypothetical facility in terms of type, size, number of generating units, condenser cooling system, and projected schedule for commercial operation. From this definition, the second phase identified plant functional and regulatory requirements that served as exclusionary criteria. In phase three, site attributes that influence the ability to accommodate plant construction and operation with least negative impact on site environs were investigated and general screening criteria established. Phase four involved the definition of the primary region of interest. The fifth phase entailed the development of a computer graphics routine for rapid output display. Phase six consisted of a literature search for relevant environmental resource data on the region of interest which was analyzed and hand digitized into a computer compatible form. The final phase of the study utilized a composite screening process to identify those areas of the state which might prove feasible for the installation of a large commercial nuclear power plant.

The information needed in this initial reconnaissance stage of an overall site selection process was assumed to be limited to that information which may be obtained from published reports, public records, public and private agencies, and individuals knowledgeable about the region of interest.

4.1 Selected Hypothetical Model Plant Functional and Regulatory Requirements

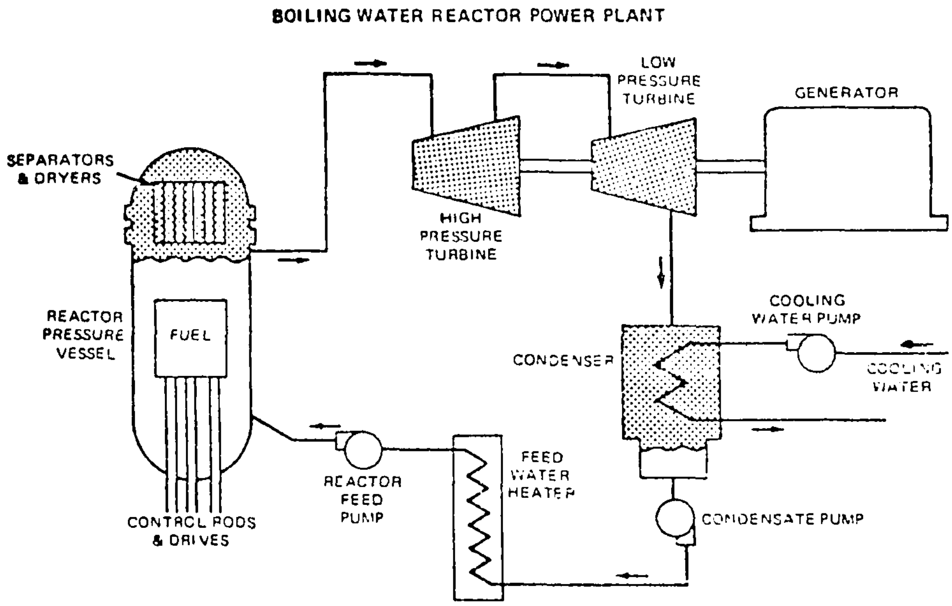
The generation of electricity presently depends upon energy conversion from water power or primary fuel sources such as oil, gas, coal, and uranium. In a fossil-fuel steam-electric power plant, coal, oil or gas is burned in the firebox of the boiler. In a nuclear electric power plant, the nuclear steam supply system replaces the boiler and the nuclear fuel core replaces the fossil fuel. A nuclear core contains uranium fuel which has been enriched in its fissionable U-235 content. When U-235 is bombarded by neutrons, the uranium atoms release energy in the form of heat plus additional neutrons which sustain the nuclear reaction. The heat generated within the fuel element is transferred through the fuel cladding to the primary coolant where it is used to convert water into steam. The steam enters a multi-stage turbine consisting of one high-pressure stage and at least one low-pressure stage. The turbine consists of a common central shaft attached to a circular array of curved blades. The steam impacts on these blades turning the rotor at high speeds. The turbine shaft is connected to a wire-wound armature in the generator. This armature rotates in an applied magnetic field producing electric current. After passing through the turbine, the low pressure steam passes through a condenser where the steam transfers its remaining heat to the condenser cooling water. The condensate is then recycled through the reactor.

To assess the impact of environmental site-related characteristics on a nuclear power station, the concept of a hypothetical model plant was adopted. The attributes of the facility were determined from the design data of present light water-cooled power reactors (AEC, 1974h; Heddleson, 1972), "black box" reactors from which the emissions or effluents have been described (NUS, 1969; AEC, 1973d), or where possible, standardized balance-of-plant designs currently being reviewed for possible licensing AEC, 1973g,h,i).

There are two basic types of commercially available light-water-cooled reactor systems (LWR), the boiling water reactor (BWR) and the pressurized water reactors (PWR). Both types are fueled with slightly enriched uranium dioxide in zirconium tubing. They are cooled with ordinary water which also serves to moderate or slow down the neutrons to the desired lower energy at which most fissions take place.

In a BWR, the primary coolant is boiling water. Steam generated by boiling water is dried to the maximum extent in the reactor vessel and directed to the turbine-generator. In a PWR, the system is kept under high pressure to maintain the water in a liquid state. The water heated in the reactor is circulated through a steam generator where it transfers its heat to water and steam. The steam is then used to drive a turbine. Highly simplified versions of these two reactor systems are shown in Figure 16.

The first step in the statewide screening process was to define minimum site requirements in terms of the type, size and number of generating units, condenser cooling system, and schedule for commercial service. Thus, the definition was established that the site must accommodate two or more nuclear generating units using commercially



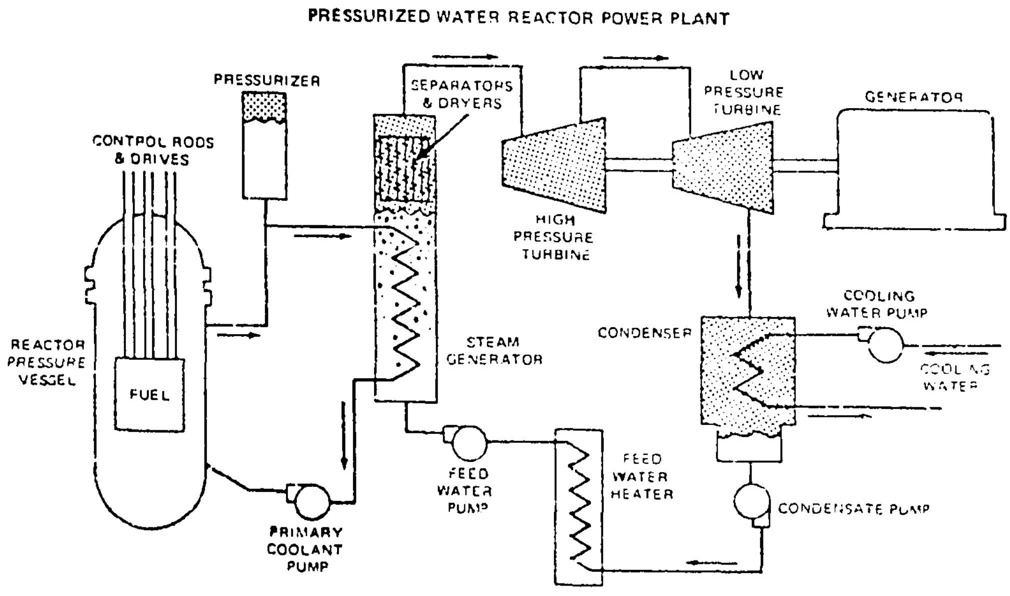


Figure 16. Light-Water-Cooled Power Reactor Systems.

available light water reactors of a full thermal load output equivalent to 3,800 MW per unit and allow scheduling of the first unit for commercial service in 1980. This timetable would only be possible by utilizing both designated sites and standardized plant designs (see Figure 2).

At present the overall efficiency of nuclear power facilities is about 33 percent, including all thermal, mechanical, and electrical losses. Because of limitations on temperature and pressures in the reactor, this efficiency is somewhat less than present fossil fuel plants. The hypothetical model plant, however, was assumed to possess an efficiency of 35 percent which is considered to be technically feasible using reasonable extrapolations of today's technology. This efficiency results in a net electrical generating capacity of 1,330 MW per reactor unit.

For the purposes of this study both types of LWRs have been grouped as a single generic category even though their typical site requirements might differ somewhat. An evaporative cooling system of either natural or mechanical draft cooling towers was adopted as the condenser cooling system to duplicate the trend toward closed-cycle cooling.

Portions of a reference work by the AEC Office of Site Safety, *Safety-Related Site Parameters for Nuclear Power Plants* (AEC, 1975a), were interpreted and adopted when establishing the model plant functional requirements. Although this work deals solely with the parameters for developing reference design to encourage standardization of nuclear power stations, there were parts of the study that were easily integrated into the definition of the hypothetical model plant.

Another related work dealing with the attributes used to define a hypothetical nuclear power facility is documented in *Nuclear Power Facility Performance Characteristics for Making Environmental Impact Assessments*, (AEC, 1974h). This work involved the derivation of a set of performance characteristics which could be used to quantify a facility's effect upon the environment and thus was also utilized in this study's model plant.

Reactor site evaluations must take into account the design and operating characteristics of the reactor that could potentially be affected by environmental factors. Many siting parameters are examined during the engineering design of safety systems simply because potential sites may have characteristics that subject the power plant structures to a variety of environmental challenges. Criteria of Appendix A of CFR Part 50, "General Design Criteria for Nuclear Power Plants", similarly requires that structures, systems, and components that are important to safety be designed to withstand the environmental stress exerted by extremes of natural phenomena and remain functional.

From this definition of the hypothetical model plant, the selected functional and regulatory requirements used to determine site suitability were assembled as shown in Table 6.

4.2 Site Environmental Characteristics

The conversion of any form of energy to another, in this case nuclear energy to electrical energy, can never be 100 percent efficient.

Table 6. Selected Hypothetical Model Plant Functional and Regulatory Requirements.

Consideration	Measuring Parameter	Value	Basis
Geology/Seismology			
Safe Shutdown Earthquake	Max. Ground Acceleration	0.3 g	Gilbert & Quick, 1975: AEC, 1974h, 1973g, 1973i
Capable Surface Faulting	Site Proximity	Table 1	AEC, 1973b; NRC, 1975d
Meteorology			
Sustained Winds	Maximum (100 yr recurrence)	130 mph	Gilbert & Quick, 1975; AEC, 1974m
Tornadoes	Six Characteristics	Table 2	AEC, 1975a
Demography			
Land Requirements	Minimum Exclusion Radius	0.4 miles	AEC, 1975a; NRC, 1975d
	Minimum LPZ Distance	3.0 miles	AEC, 1975a; NRC, 1975d
Hydrology			
Condenser Cooling Water	Minimum Quantity (per Unit)	50 cfs	AEC, 1974h; Table 4
Maximum Precipitation	Roof Runoff	16 in./hr	Gilbert & Quick, 1975
Snow Loading	Accumulation	80 lb./ft^2	Gilbert & Quick, 1975
Flooding	Max. Water Level (below Grade)	1 foot	AEC, 1973i
Potential External Man-made Hazards			
Transportation Accidents	Highway Proximity	1500 ft.	AEC, 1975a, 1975b
	Railway Proximity	3000 ft.	AEC, 1975a, 1975b
	Waterway Proximity	9000 ft.	AEC, 1975a, 1975b
	Airport Proximity	Sec. 3.7-4	AEC, 1975b

Thus byproducts are created in the process and certain impacts at the plant site are unavoidable. Efforts to optimize environmental compatibility and minimize negative environmental impacts entail the consideration of the influences of site characteristics on the design, construction, and operation of the facility, and conversely, the potential impact of the facility upon the site environs.

The two types of closed-cycle cooling systems which were considered were wet evaporative cooling tower with and without reservoirs. The reservoir concept entailed the use of an existing impoundment of water, either natural or man-made, to provide makeup water during periods of critically low river flows.

The exclusionary criteria applied to rivers were based upon three considerations: (1) sufficient water quantity during periods of low flow, (2) availability of water rights, and (3) general water quality. The criterion used for lakes and reservoirs required sufficient surface area and capacity to enable them to be used directly as cooling ponds as well as simply sources for cooling tower makeup water.

For streams with average flow in excess of 5000 cfs, the seven-day once-in-ten-year low flow was selected as the basis of acceptability, whereas streams of lower average flow were required to exhibit an historical thirty-day low flow of record of at least twice that required for all plant needs. These needs were assumed to be 40 cfs for consumptive use in condenser cooling and 10 cfs for service water (National Academy of Engineering, 1972:117) or about 100 acre-feet per day per reactor unit.

The capability of lakes and reservoirs to supply condenser cooling requirements was based upon a minimum required surface area of six acres per MWe and a minimum storage capacity of 40,000 acre-feet at the minimum pool level. While surface areas in excess of three acres per MWe have negligible effect on the cooling performance of the water body (Hauser and Oleson, 1970), this value was increased by a factor of two recognizing the need to avoid any interference with other planned uses of these water bodies. In general the lakes and reservoirs of the region of interest were not created for the sole purpose of providing a source of cooling water for power plants but rather for flood control, municipal water storage, navigation, and recreation. The six surface acres per MWe figure compares favorably with values used by the Federal Power Commission in a national review of existing reservoir cooling capacity (FPC, 1969:40-41) and values cited by Rittenhouse (1975) of up to five acres per megawatt. Minimum storage capacity criteria were based upon a doubling of the 100 day water requirements of both units of the hypothetical model plant.

The environmental screening for the region of interest was based upon an analysis designed to reflect the region's ability to accommodate the operations of a large nuclear power station. The selected screening criteria presented in Table 7 should aid in the identification of candidate areas which exhibit a high probability of having favorable environmental attributes.

4.3 Defining the Region of Interest

Delineating the study area raises all the classical arguments and questions involved in defining regions. In multidisciplinary

Table 7. Selected Environmental Site Requirements.

Consideration	Measuring Parameter	Value	Basis
Meteorology			
Dispersion Climatology*	Stability Category	Pasquill F	Gilbert & Quick, 1975; AEC, 1973d
Demography			
Uniform Population Density	Initial Operation	500/mile^2	NRC, 1975d
	Plant Lifetime	1000/mile^2	NRC, 1975d
Hydrology			
Large River Source	7 Day/10 Year Low Flow	50 cfs/unit	AEC, 1973c
Small Stream Source	30 Day Historical Low Flow	100 cfs/unit	AEC, 1973c
Reservoir	Minimum Surface Area	6 acres/MWe	
	Minimum Storage Capacity	40,000 acre-ft	
Ecology			
Rare/Endangered Species	Habitat Areas	Avoid	AEC, 1974c
Temperature Sensitive Species	Habitat Areas	Avoid	
Wild and Scenic Rivers	Proximity	Avoid	
Land Use			
Park/Recreational Areas	Proximity	5 Miles	FPC, 1970
Historical/Archaeological	Proximity	Avoid	
Hazardous Man-made Facilities			
Hazardous Industrial Areas	Proximity	5 Miles	AEC, 1975b
Military Installations	Proximity	5 Miles	AEC, 1975b

*Enlarged site exclusion area can provide safety margin for sites with unfavorable atmospheric dispersion characteristics (NRC, 1975d).

research efforts such as power plant siting, the spatial boundaries employed by different disciplines vary substantially. Whereas in the past site searches were frequently confined to a utility's own service area, the enlarged scope of site investigations required by state and federal legislation has led to examination of siting possibilities over much wider areas in order to encompass a number of viable alternatives.

The State of Oklahoma was the primary region of interest selected for this study. Electrical consumption in Oklahoma has increased somewhat more rapidly during the past two decades than the total energy requirements within the state. Further increases in the demand for electrical energy are expected to accompany the forecasted growth of the State's population and industrial base and will inevitably require additional generating capacity. The boundaries of the region of interest were defined along state lines after reviewing the service areas of the principal electric power suppliers and federal jurisdictional boundaries. The study area includes that portion of Power Supply Area 33 in the Federal Power Commission's South Central Region enclosed by the borders of the State of Oklahoma (Figure 17). Three Oklahoma counties in the panhandle of the state are not included within this area. In general, sufficient environmental data were found to be available on most applicable indices to allow a reconnaissance study of this geographical region for candidate siting areas.

4.4 Procedures of Evaluation and Presentation

There are several procedures for evaluating the data. While in

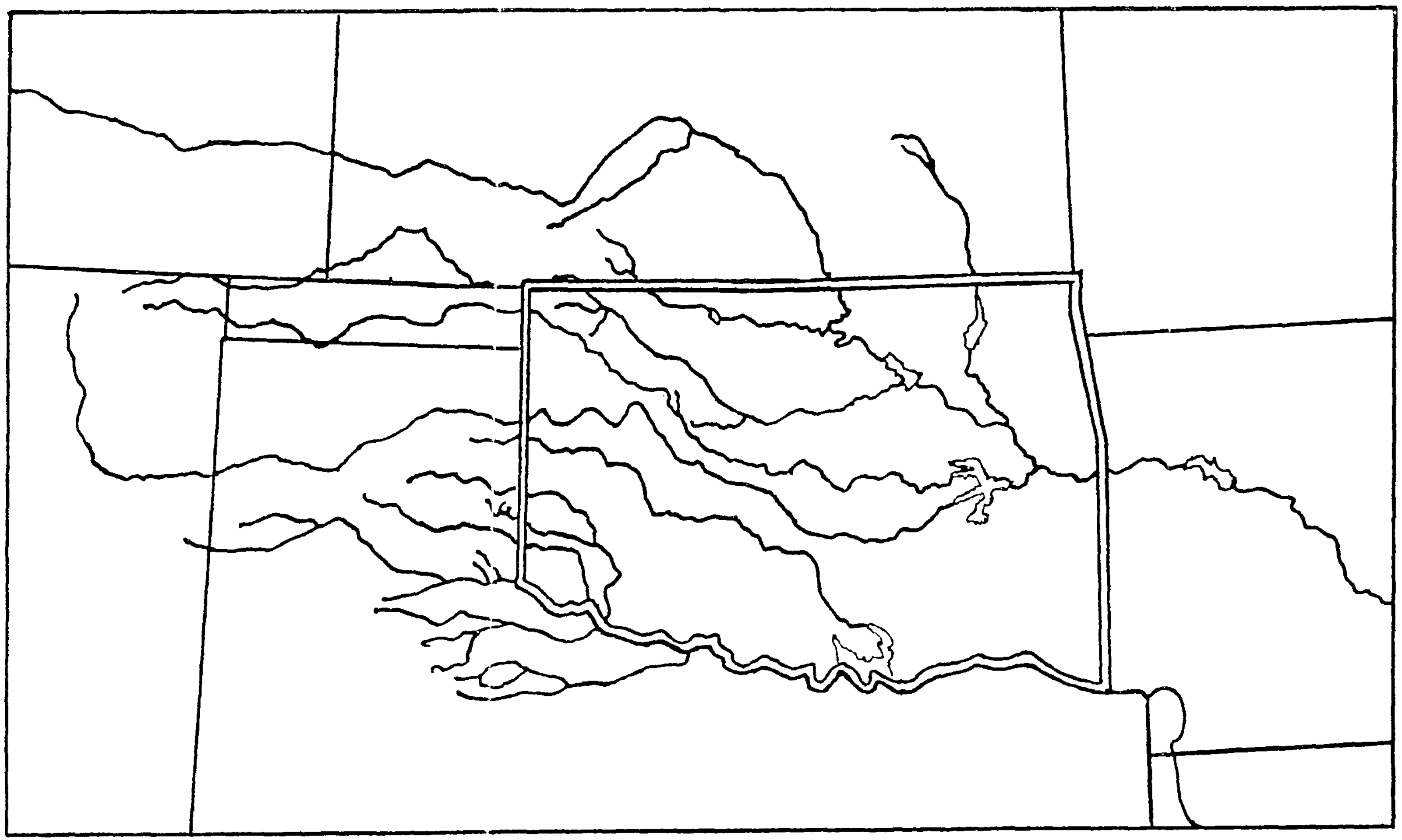


Figure 17. The Study Area.

later stages of the site selection process the evaluation is directed towards narrowing the range of alternatives through the use of comparative techniques such as weighted matrix methods, the initial selection of candidate areas relies upon an analysis to determine those areas which meet certain fixed or absolute criteria of acceptability. For this reason a go/no-go restrictive overlay mapping technique was found to be most applicable to the determination of candidate areas. Conventional overlay mapping techniques which have been applied in the past have had several serious limitations:

(1) the number of factors that can be considered simultaneously is severely limited by problems in physically seeing through multiple layers of mylar or acetate,

(2) the process is time-consuming in that it is necessary to change the overlay maps each time a basic rating criteria is modified, and

(3) overlay techniques do not allow rapid analysis of maps with scale factors different from the base map.

Perhaps the most significant advance in the use of overlay methodologies came in the area of route/corridor alignment where the assumption is made that two end points have been preselected. McHarg (1968; 1969) described an approach for the screening of alternate highway routes employing transparencies of environmental characteristics overlaid on a regional base map. An overlay technique designed for highway route selection employing computer graphics was developed by Krauskopf and Bunde (1972). Their technique made use of a computer for storage of environmental characteristics on a cellular basis of a grid system of one kilometer square cells. This "REMAP" was designed as a four-phase process consisting of: development of objective data reflective of the region under study, establishment of a list of and models for determining factors which would influence the location of the facility under examination, combination of factors to form alternative surfaces upon which an optimum location may be found, and finally the analysis of these alternatives. This approach which requires considerable amounts of data is at present not practical for the analysis of programs of broad geographical scope.

Computerized refinements to standard overlay techniques have also been utilized in land use suitability mapping and evaluation (Kiefer and Robbins, 1973; Ragan and Rebuck, 1974). Ragan's approach suggests that computer derived maps be used to support rather than replace overlay techniques through photographic scale transformations. Ragan's computer derived maps were photographically transformed into transparencies of the scale desired.

Computer graphics have also been developed for electric transmission line site selection (Hulett and Patterson, 1973). The computer output consist of a cell-by-cell map of the study area shaded by over-printing to visually correspond with the criteria of interest such as environmental impact. The computerized analysis can be revised to adjust the relative weight of the various criteria or strategies. One disadvantage of any grid-cell method which divides the study area into arbitrary domains is that the data associated with each cell are effectively averaged over the entire cell. Using similar cell size will give more accurate data, but, at the same time, impose much greater demands on the researcher to supply a large inventory of environmental data.

The Bureau of the Census has developed computer programs for generating maps in which the various densities of census data variables are represented by various printed symbols (Jaro, 1972). Haaland and Heath (1974) have extended the use to line-plotting facilities which overcome some of the limitations of the Jaro GRID technique. An isometric projection technique was developed by Tucker (1973) and used by Haaland and Heath (1973, 1974) to generate population density views for many cities.

Computer methods have also been used for the storage, analysis, and display of data needed when compiling environmental impact assessments. Computer assisted mapping allowed Steinitz Rogers Associates, Inc., to effectively present the potential environmental impacts of project and route alternatives for an interstate highway construction project (State of Rhode Island, 1972). Rogers' study used maps produced by the GRID computer graphics program (Sinton and Steinitz, 1971).

The cartographic display capabilities generated by Version 5.17 of the SYMAP digital computer program (Dudnik, 1972) was the principal display mechanism used in this siting study. The SYMAP computer assisted mapping routine utilizes a line-printer over-print technique and is capable of performing a wide variety of mapping tasks. To produce the maps, input to the computer in the form of a deck of punched cards was prepared indicating the two-dimensional coordinates of the grid cells composing the base map. Since the available data characterizing the region of interest existed on maps of many scales, the study was standardized by transforming all data to a U.S. Geological Survey Lambert conformal conic projection base map of scale 1:1,000,000. The computer generated output maps were then further photographically reduced for ease of presentation within the restrictions of the final documentation.

The computer used for the output mapping printed ten characters per inch horizontally and six characters per inch vertically resulting in a rectangular grid system. An odd cell size of 1.60 miles by 2.67 miles was selected to ensure a one to one correspondence with the U.S. Geological Survey base map. The spatial accuracy of the data is limited by this cell size. However, while using smaller cell size would give more accuracy it would also impose a much greater demand to supply large quantities of input data which may not be justified within the initial coarse screening process. The magnitude of manual data acquisition influenced this efficiency-versus-accuracy decision. During the evaluation process, the data gathered was effectively averaged over the applicable grid cell with a predominate type coding decision level required. For example, should 50 percent or more of a grid cell be influenced by a characteristic, the entire cell was coded to reflect only that dominating characteristic.

Using the selected siting requirements presented in Tables 6 and 7 with an existing macroscale data inventory collected from published reports, public records, public and private agencies, and individuals knowledgeable of the region of interest, it was possible to apply acceptability/exclusion screening techniques to identify a significant portion of the region of interest which appears to be unsuitable for major thermal power plant development and to identify remaining areas which appear to offer potential sites.

In the course of pursuing the study, it became apparent that the large quantities of water necessary for an evaporative cooling system would be a key factor in the selection of power plant sites within the region of interest (as defined in Section 4.3). The Oklahoma water supply problem is essentially one of maldistribution. On this basis, large portions of the State can virtually be eliminated and accordingly the search area was dramatically reduced.

Both the site environmental and functional/regulatory requirements were assembled into major criterion due to restrictions imposed by time and economics. In each case, after the basic water resources evaluation and potential cooling water source identification, individual portions of the reduced search area were eliminated if they failed to meet or exceed the requirements of each of the remaining individual criteria.

The second criterion was geological/seismological conditions. Areas were analyzed for adequate foundation conditions and for high seismic risk resulting from close proximity to known active faulting or historical records indicating earthquake damage had occurred in the past. Meteorology was identified for the third criterion for potentially suitable candidate areas. When considering nuclear power plants, meteorological conditions generally will not impose major constraints upon siting if no great topographic obstructions exist to inhibit dispersion. The fourth principal constraint was demography. Lands were restricted on the basis of proximity to urban areas calculated from the projected population density over the expected lifetime of the hypothetical power facility. The fifth principal constraint grouped ecological screening considerations. Areas classified as sensitive were avoided and excluded from further investigation. Conflicting land use areas identified as major parks, natural resource areas, monuments, reservations, preserves, and refuges were eliminated. Additionally, exclusion criteria required the identification of areas of potentially hazardous man-made activities.

Each evaluation process first began with analysis of the reduced search area to delineate restricted zones which failed to meet the minimum requirements quantified in Tables 6 and 7. The geographical grid cell location of these zones were then hand-digitized into computer compatible form to be excluded from the base map by opaque over-printing.

A composite representation of the excluded areas was derived from maps prepared during the individual criterion evaluations. From this composite screening it is possible to identify candidate areas which appear to have suitable site characteristics and to suggest areas for further detailed investigation.

CHAPTER V

RESULTS AND DISCUSSION

5.1 Preliminary Statewide Hydrological Screening

A characteristic of the operation of any steam-electric power plant is that a large flow of water is required through the condensers to convert the turbine exhaust to water in order to maximize the energy conversion prior to recirculation to the boiler or reactor. The substantial commitment of water is essential over the entire life of a nuclear power plant for waste heat dissipation, fire protection, and nuclear safety. The consumptive use of a portion of this water represents a net diversion of water in a region which has seen this natural resource sited as Oklahoma's number one problem as well as the key to its future (Reid et al, 1963; Bureau of Reclamation, 1967). Hydrological requirements, therefore, must be a key factor in examining the region of interest for any potential power plant siting study.

The problems involved in finding sufficient cooling water are not new. The concern for adequate water supplies originally was to facilitate the maximization of the thermodynamic efficiency of a plant's heat cycle. However, once-through cooling systems at inland locations are not now used becuase of State and Federal temperature control standards. In many water-short regions, the needed quantity of water is simply not available for full protection of aquatic biota.

A preliminary statewide screening to narrow the search area to the most promising portions of the state on the basis of the hydrological criteria was undertaken. This water resource screening was the first criterion used to identify potentially suitable areas. The initial reduction of the search area effectively increased the computer efficiency by reducing the quantity of environmental data handled.

Surface water and groundwater were both initially considered as sources of condenser cooling water. Groundwater resources generally were found to lie in disassociated bodies along the surface stream alluvium and can only be recovered in moderate amounts insufficient to support a 7600 MWt power facility. Under these circumstances, the use of groundwater was not pursued as part of this study.

The Oklahoma Comprehensive Water Plan Interconnected System is a proposed aqueduct conveyance system which will transport 1,308,000 acre-feet of water per year from southeast Oklahoma to central and southwest Oklahoma (OWRB, 1975b). Because of the possibility of delay in the project, the Interconnected System water was not considered as a prime water source but is viewed as a future alternative supply when available.

Water quality could present problems for the economical use of the waters of some sections of both major river systems within the state. Natural sources of pollution (other than municipal and industrial wastes) have rendered some water resources unuseable without extensive pretreatment. These pollutants are in general salt (sodium chloride) and gypsum (calcium sulfate). From the state of Colorado to the Cimarron River, high concentrations of dissolved solids exist in the Arkansas River. The combination of highly mineralized Cimarron water with the salinity of the Arkansas presents a sodium potassium sulfate-chloride problem (Peterson and Schrotke, 1972). The Red River varies but is predominately sodium potassium sulfate-chloride type with the salinity problem primarily upstream of Lake Texoma (Peterson and Schrotke, 1972). For the purpose of this preliminary screening only those streams and other surface waters cited by the Oklahoma Water Resources Board (OWRB) as "unusable due to natural pollution" were excluded during this first cut (OWRB, 1975). Similarly, OWRB data were also utilized to establish basins in which the surface water rights have been substantially or fully appropriated (Figure 18). On this basis, large areas of the State can be virtually eliminated. Portions of the two major river systems (Arkansas and Red) and five lakes or reservoirs were found to be of adequate capacity to satisfy the requirements of the hypothetical model plant facility.

As a result of the evaluation of this basic site requirement the original search area was reduced to that shown in Figure 19. This reduced search area was defined along the 97 degree longitude with the exception of that portion of the Lake Arbuckle drainage basin in which no surface water rights are available.

5.2 Regional Screenings

After having narrowed the search area, these additional criteria

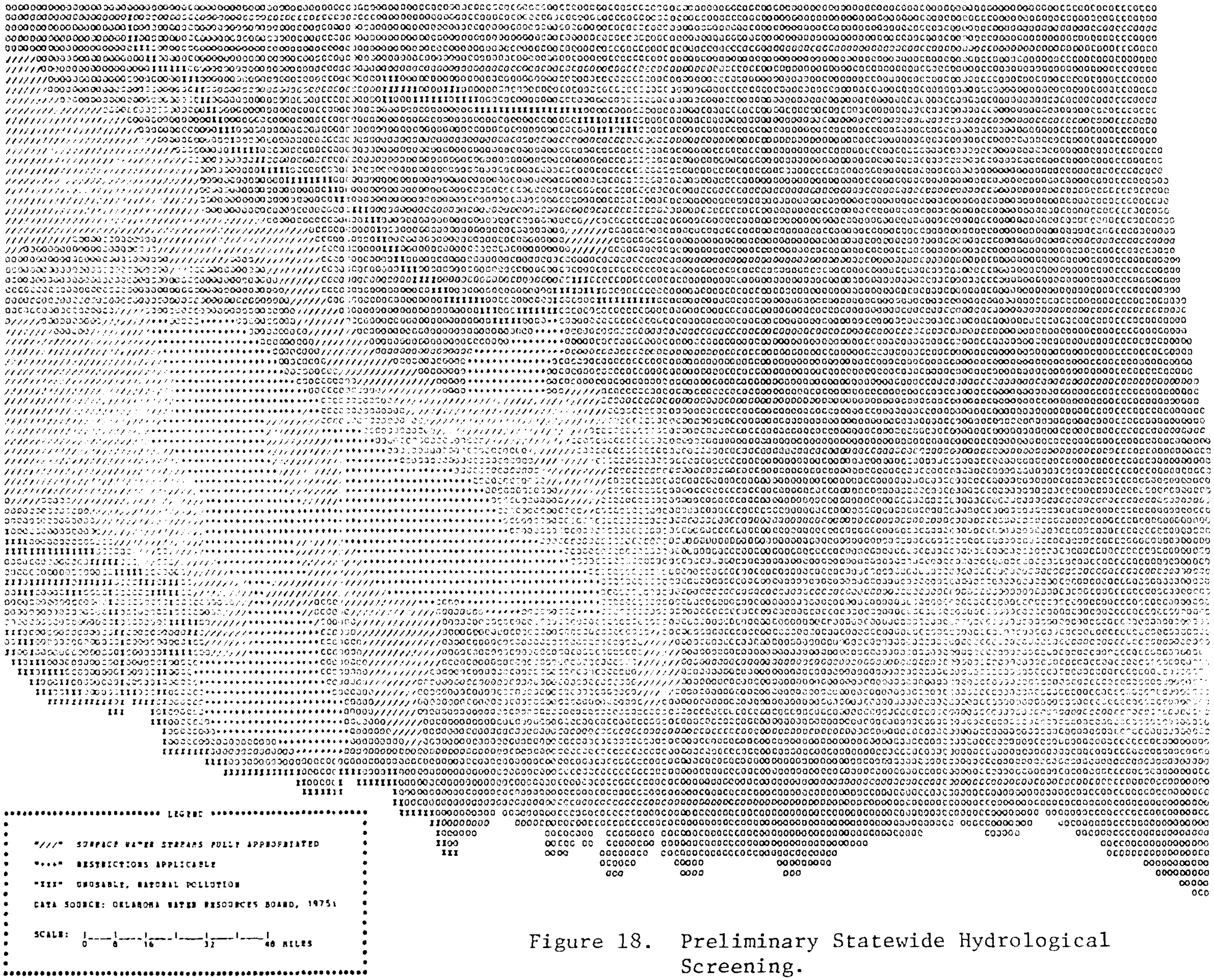


Figure 18. Preliminary Statewide Hydrological Screening.

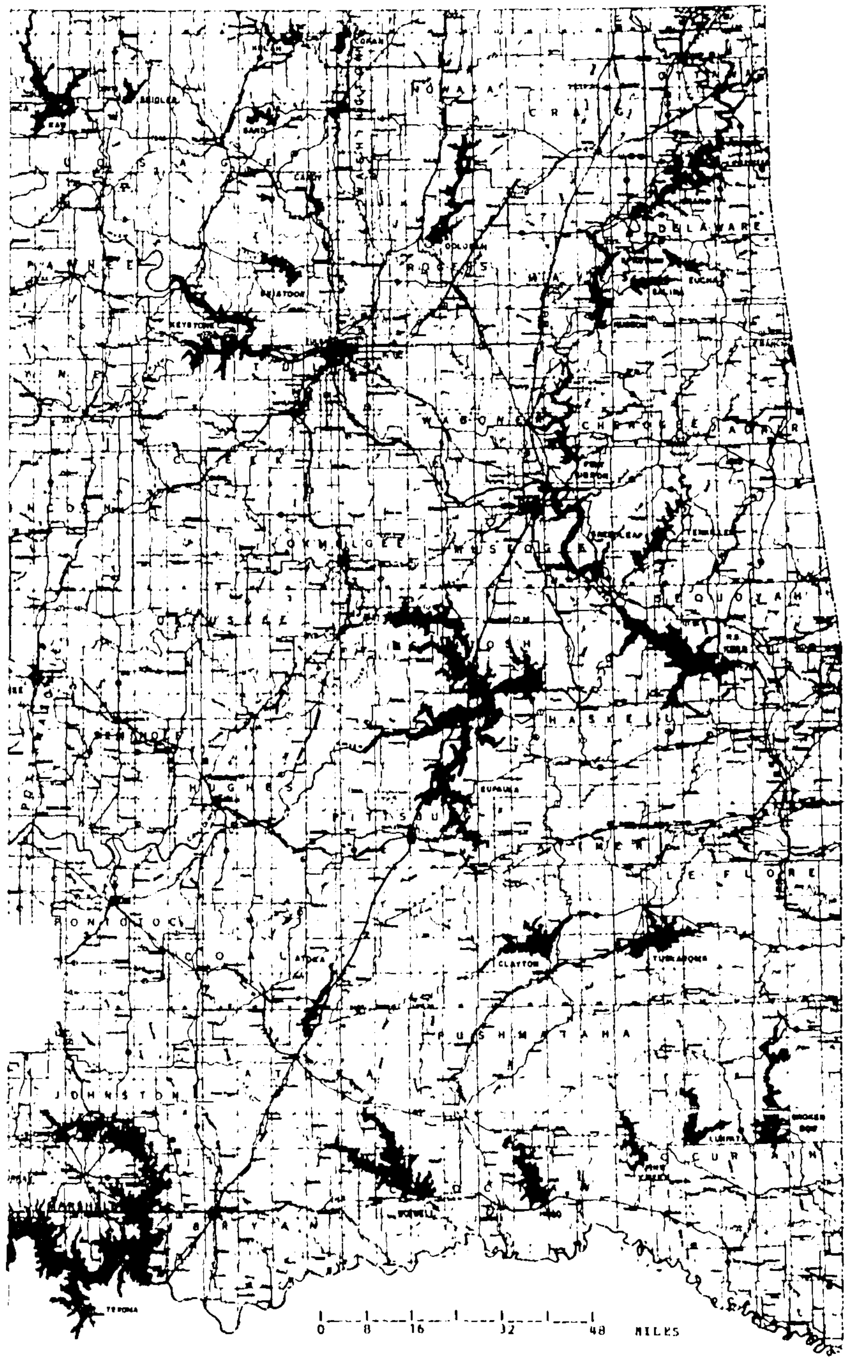


Figure 19. Reduced Search Area.

were utilized to exclude additional unsuitable lands: geology/seismology, meteorology, demography, ecology, land use, and proximity to man-made hazardous activities. The information contained in the following sections is intended to be only as extensive as is necessary to identify principal environmental features of the reduced search area affecting candidate area selection.

Water resource requirements were not included because the reduced search area was itself delineated on the basis of hydrological potential and as a result the remaining study area did not differ sufficiently to provide a means for further discrimination. The surface waters identified as potential cooling water sources appear as totally unshaded areas on the computer output maps of the remaining acceptability/exclusion screenings.

5.2-1 Geology/Seismology Screening

Evidence of seismically active areas is of two major types: (1) historical or instrumented recordings of earthquakes, and (2) geologic evidence of recent movement along faults.

Earthquake data can be utilized in several ways to give some idea as to relative earthquake activity of various areas. Figure 4 which is a summary of isoseismal maps of the Central United States indicates where various maximum intensities might be expected based on interpretations of historical data and geological information. Over the period of record Oklahoma has experienced only eight earthquakes which approached destructive intensities. Epicenters of the two damaging earthquakes (Modified Mercalli Intensity VII) have been located near El Reno and Catoosa (Coffman and Hake, 1973, 1974). A complete chronological listing of major earthquakes originating and felt within the state is presented in Appendix B.

The Oklahoma Geological Survey has found no evidence that any of the surface faulting within the state has moved at or near the surface within the past 35,000 years and not more than once within the past 500,000 years. Surface faulting throughout the state is believed to be Pennsylvanian and Permian in age (about 270 and 320 million years old respectively). Movement along the faults has been interpreted by Johnston (1973) to have ceased before Triassic times some 220 million years ago as evidenced by undisturbed Quarternary deposits which overlie the faults at many places. Folding related to the major structural features of the state is also suspected to have occurred during Pennsylvanian and Permian times.

Liquefaction, subsidence, and landslide potential were sufficiently localized or sufficiently low in intensity that no parcel of the reduced search area was excluded due to inadequate foundation conditions.

Figure 20 identifies areas having high seismic risk resulting from close proximity to epicenters of known damaging earthquakes by opaque shading. Detailed investigation for any proposed power plant may very well lead to the conclusion that there are many areas outside the restricted areas delineated in Figure 20 which must be avoided because of active faulting or other geologic hazards not presently identified.

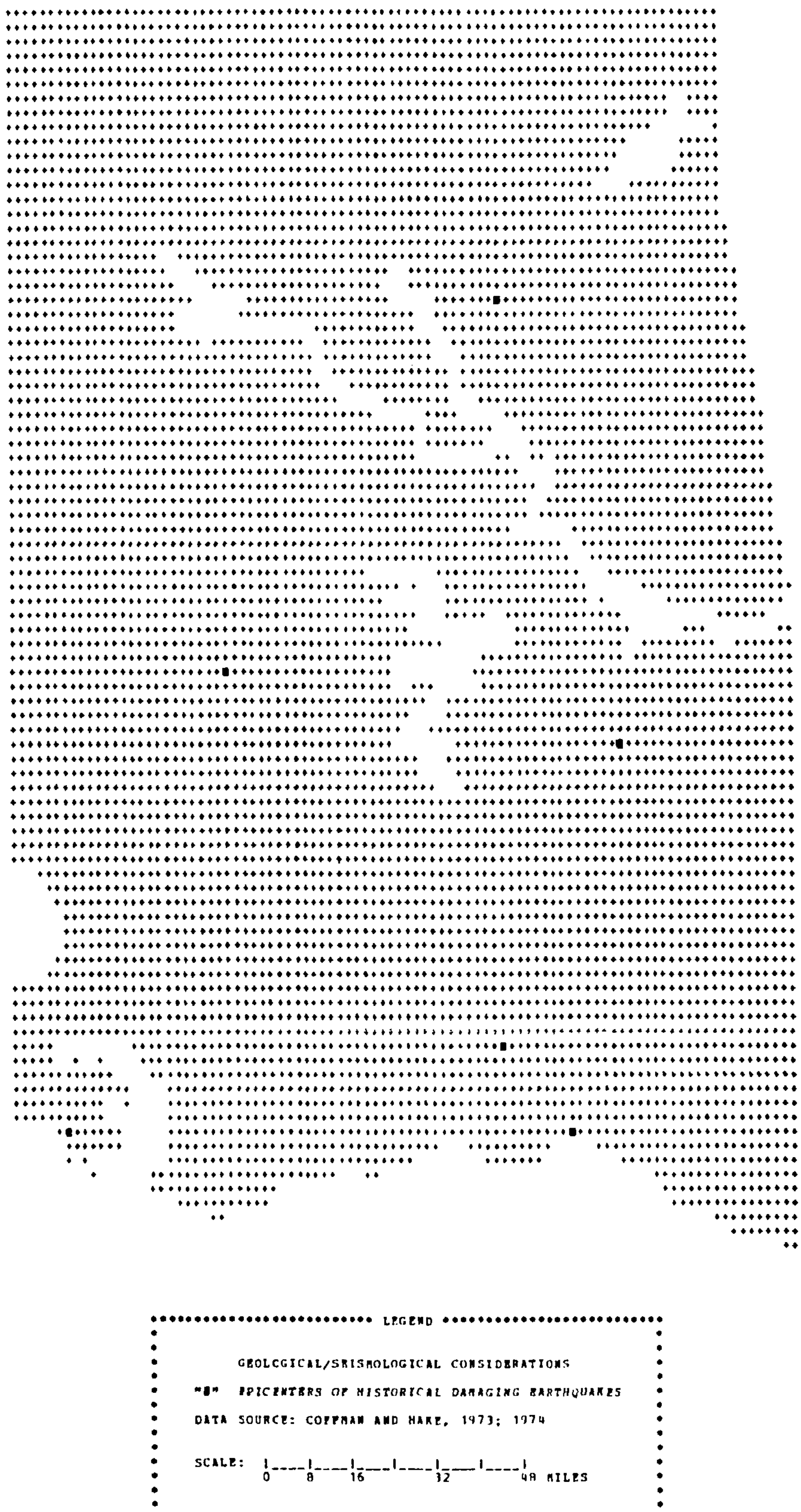


Figure 20. Geologic/Seismologic Screening.

5.2-2 Meteorology

When considering nuclear power facilities, meteorological conditions generally will not impose major constraints upon siting. The analysis of regional climatology must consider dilution (dispersion) potential and extreme winds. The frequency of recorded air pollution episodes (Figure 6) illustrates the relatively homogeneous dispersion of the region. No area differed sufficiently to be excluded on this basis alone. It should be understood, however, that detailed site reviews of proposed sites may delineate minor topographic obstructions to dispersion that will require special consideration during plant design.

Regulatory Agency requirements dictating plant design must accommodate the additional stress imposed by extreme wind phenomena. Therefore, extreme winds were not considered in the initial stages of the siting process.

5.2-3 Demography

The demographical screening process considered 1970 population, estimated 2020 population and distance requirements for a low population site. Since the concentration of people will most likely continue to increase in the immediate area of a power facility during the 40 year operational lifetime of the hypothetical model plant, projected population data for the year 2020 were used to exclude areas exhibiting an expected uniform population density of 1000 people per square mile. These areas were determined by identifying population centers of 10,000 or more in 1970. Then using their projected year

2020 population coupled with the 2020 population density of the neighboring county an exclusion area equivalent to the desired uniform population density of 1000 people per square mile was established as follows:

$$R = \sqrt{\frac{P}{\pi(1000 - D)}}$$

where R is the radius of area with uniform population density of 1000 people per square mile, P is the projected 2020 urban center population, and D the 2020 population density of the county adjusted for the urban center population (see Appendix C).

The results of this screening are presented in Figure 21, which shows those lands restricted on the basis of proximity to urban areas as opaque grid cells. All other lands in turn were identified as potentially available.

5.2-4 Ecology

Terrestrial and aquatic ecological screening for candidate areas was based on several criteria. Sensitive areas of habitat or unique ecological systems are found in almost any region of the state but for the most part these areas are small with respect to site requirements and can be avoided. Those terrestrial areas that have been set aside for public hunting and/or wildlife management and wild or scenic rivers were classified as sensitive areas to be excluded from further investigation. Also the areas which were found to contain temperature sensitive aquatic species were removed from consideration. These areas were the trout waters of a short reach of the Illinois River between Tenkiller Ferry Reservoir and the confluence

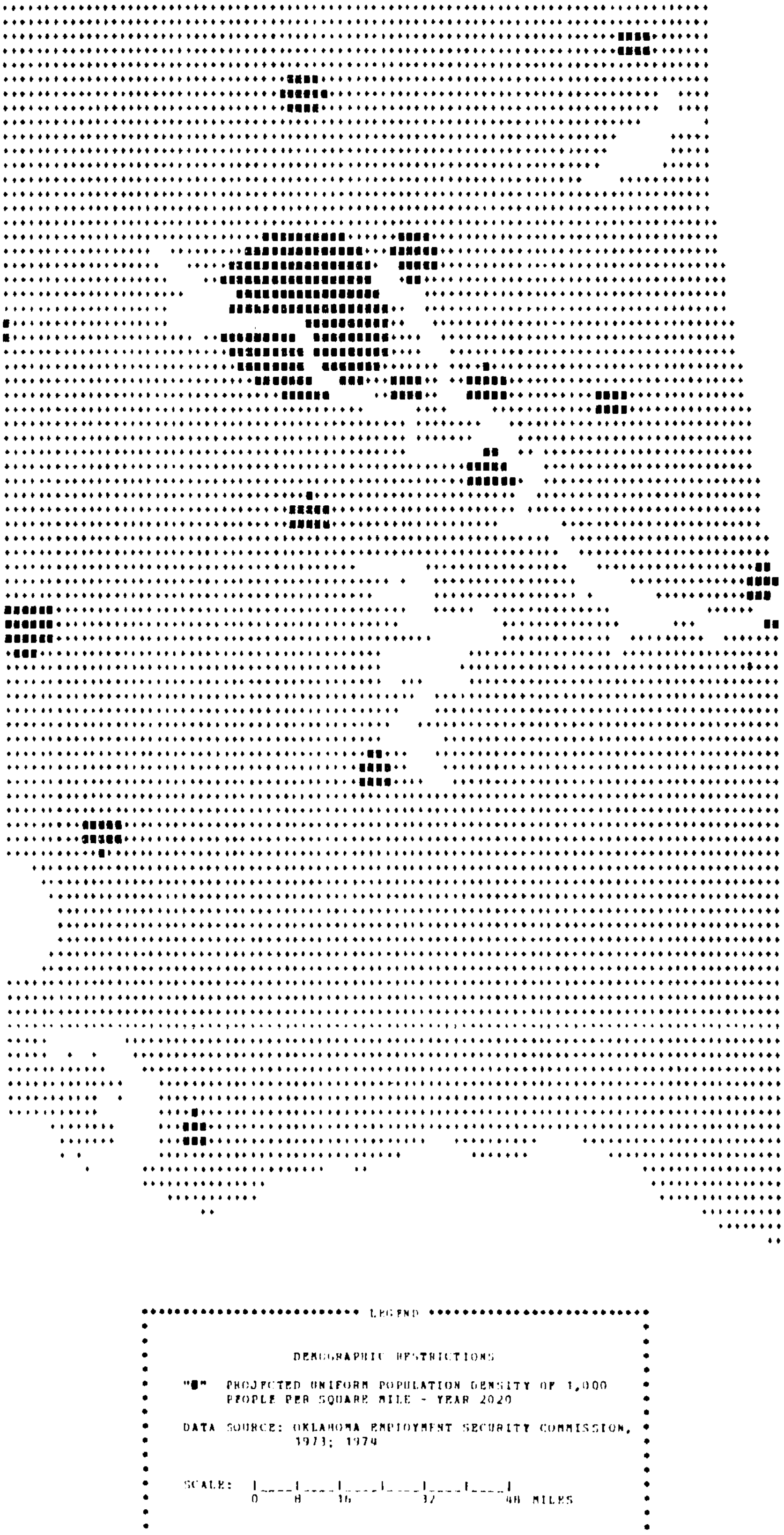


Figure 21. Demographic Screening.

with Arkansas River at the upper part of Robert S. Kerr Reservoir and a portion of the Blue River annually stocked by the State Wildlife Department. The Arkansas, Cimarron, Canadian, and Red Rivers are classified as warm water streams.

Many of these same areas might well have been excluded during a consideration of conflicting land use later in the study. Figure 22 presents the major cold water fisheries and wild or scenic rivers within the reduced search area.

5.2-5 Land Use

Existing areas of specialized land use were reviewed in terms of restricted or sensitive siting areas. The land use criteria were based on the extent of competitive land use in or near the region and the historical and/or archaeological significance of the area. The specific criteria restricted further consideration of unique natural resource areas and extensive historical sites. These areas included: state and national parks, wilderness and recreational areas, public wildlife refuge and game management areas, national forests, and public lands held in trust by the federal government. Appendix D lists the restricted areas delineated during the land use screening. Figure 23 shows lands already dedicated to specific public and reservation uses and considered incompatible with power plant development.

5.2-6 External Man-made Hazards

The exclusion of areas immediately surrounding potentially hazardous military or industrial operations was undertaken to provide

LEGEND

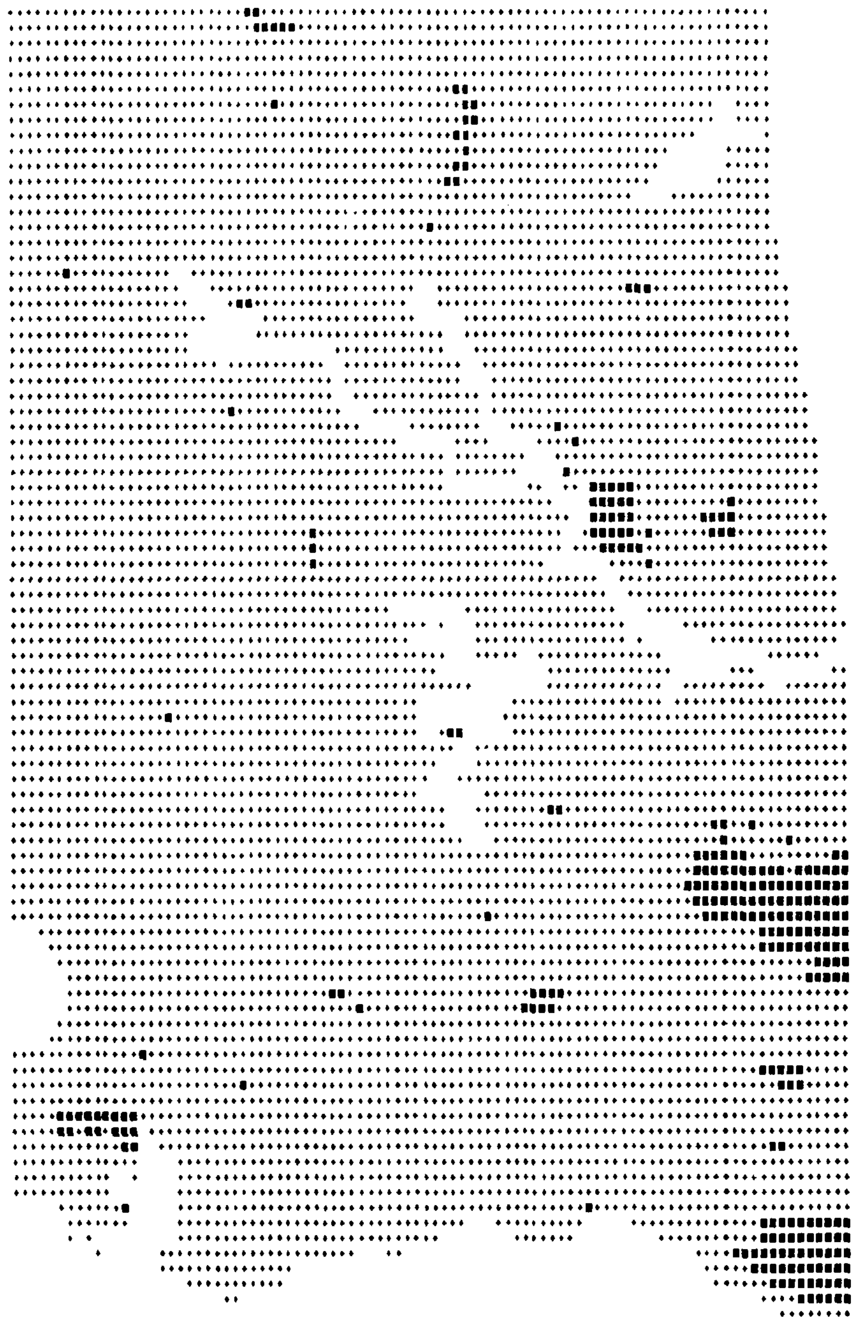
SENSITIVE ECOLOGICAL AREAS

"■" COLD WATER FISHERIES; WILD AND SENIC RIVERS

DATA SOURCE: STATE OF OKLAHOMA, 1975; OKLAHOMA WATER RESOURCES BOARD, 1975A

SCALE: 0 8 16 32 48 MILES

Figure 22. Ecological Screening.



LEGEND

SPECIALIZED LAND USES

"■" NATURAL RESOURCE AREAS

DATA SOURCE: STATE OF OKLAHOMA, 1972; OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION, 1973

SCALE: 0 8 16 32 48 MILES

Figure 23. Land Use Screening.

assurances that accidents at these facilities would not endanger either the structures or personnel of a nearby power station. Similarly, accidents involving large quantities of potentially hazardous material on nearby transportation routes necessitates the establishment of buffer zones proportioned according to the magnitude of the potential threat to plant safety.

An exclusion zone of five mile radius was established as minimum for each of the industrial activities listed in Table 8.

Table 8. Potentially Hazardous Industries

SIC Division	SIC Major Group
B - Mining	12 - Bituminous Coal
	13 - Oil and Gas Extraction
	14 - Mining and Quarrying of Nonmetallic Minerals
D - Manufacturing	28 - Chemicals and Allied Products
	29 - Petroleum Refining and Related Industries
	34 - Ordnance and Accessories

In addition to these zones Figure 24 identifies restricted lands surrounding commercial airports as determined by the number of aircraft movements per year (Section 3.7-4). Table 17 (Appendix E) summarizes the minimum approach distances for the major air transportation facilities of the state.

While accessibility of a candidate area is an important consideration during the construction and operation of a large power facility, potential accidents on nearby surface transportation routes requires the determination of minimum setback distances beyond which

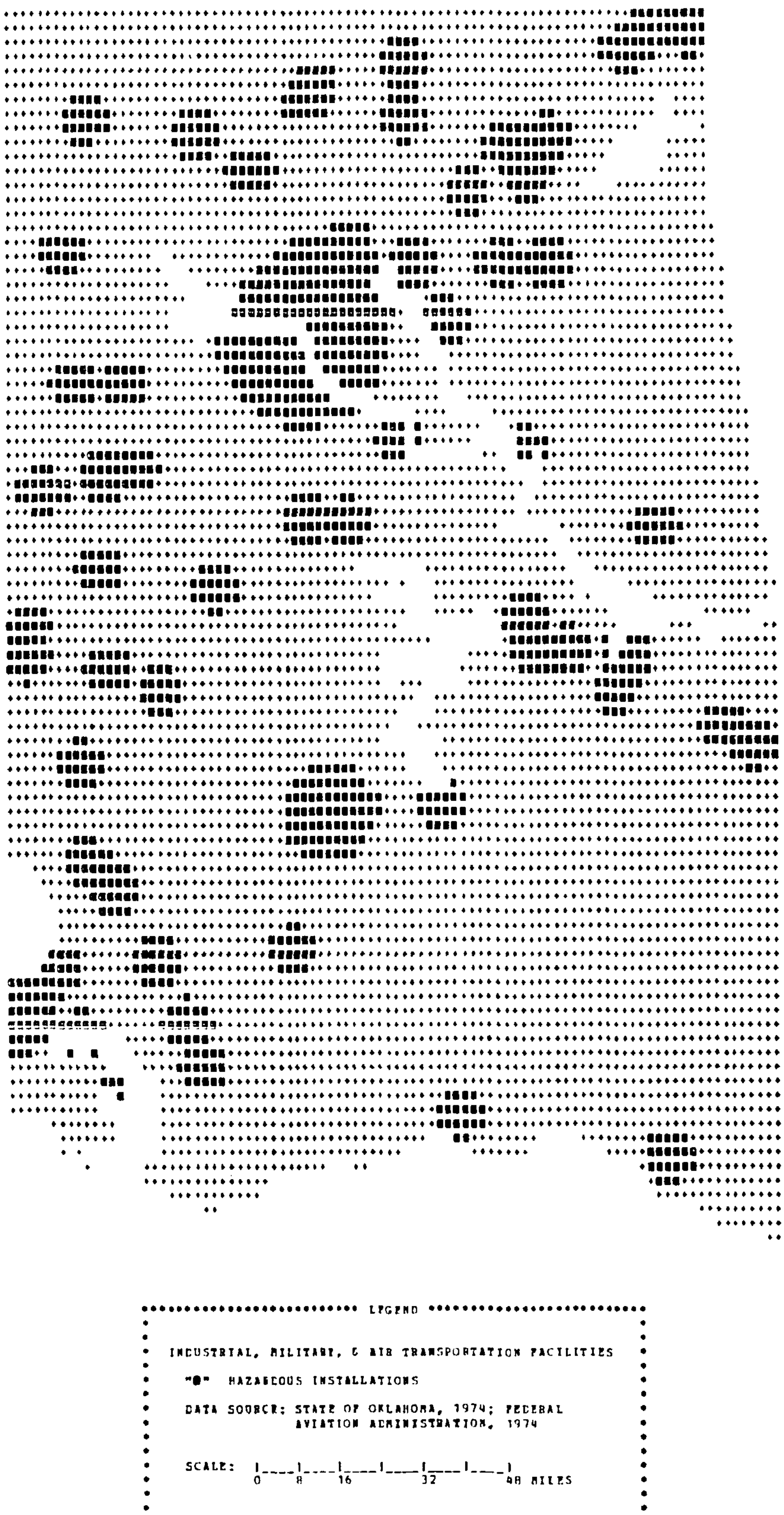


Figure 24. Industrial, Military and Air Transportation Facilities.

any explosion that might occur on these routes is not likely to have an adverse effect on safe plant operation. Table 5 presents the minimum distances from the power plant's physical structures to major surface transportation routes. Buffer zones were established for the major highways, railways and navigable waterways of Table 16 (Appendix E) and are illustrated in Figure 25. These buffer zones are not used as exclusion areas in the composite screening but must be considered in the final stages of siting.

5.3 Composite Screening

Figure 26 is a composite representation of all lands excluded during the previous screenings. On this map, the opaque areas are rated as unsuitable because of a failure to meet one or more of the general siting requirements of the hypothetical model power facility.

While significant portions of the original region of interest have been eliminated, there remain numerous areas suitable as optimum candidate areas. The designation of an optimum candidate area in no way reduces the need for detailed site investigations to validate the suitability of a specific site. The decision that a power plant may be built on a specific site must be based on a detailed evaluation of the proposed plant/site combination and a cost-benefit analysis comparing it with alternative plant/site combinations in terms of both economic and environmental costs.

Undoubtedly, there will be specific sites in the candidate areas that are found to be unsuitable. Also, some of the areas outside those designated as candidate areas might provide suitable sites when fully evaluated. It should be recognized that a power plant

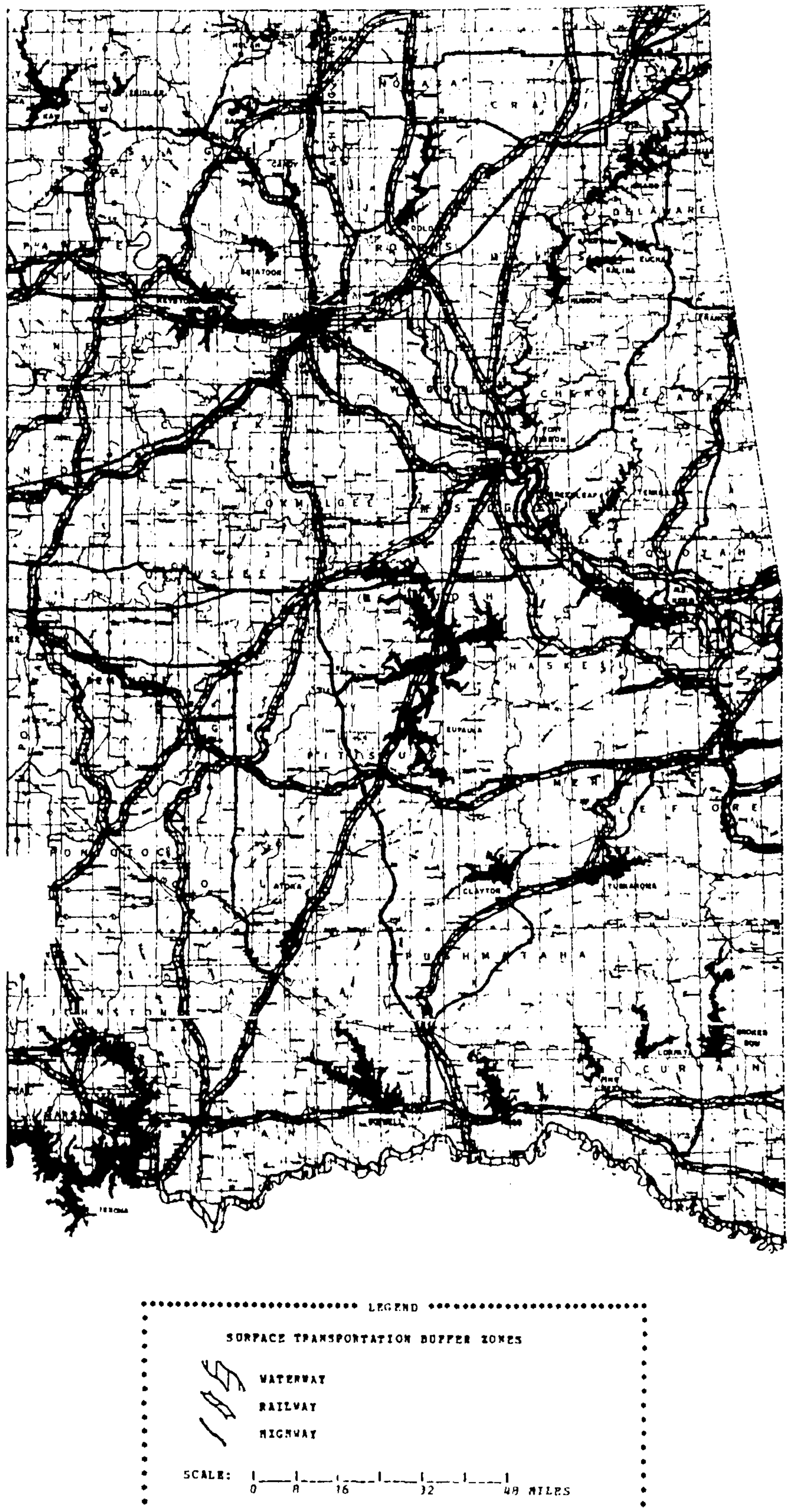


Figure 25. Surface Transportation Routes.

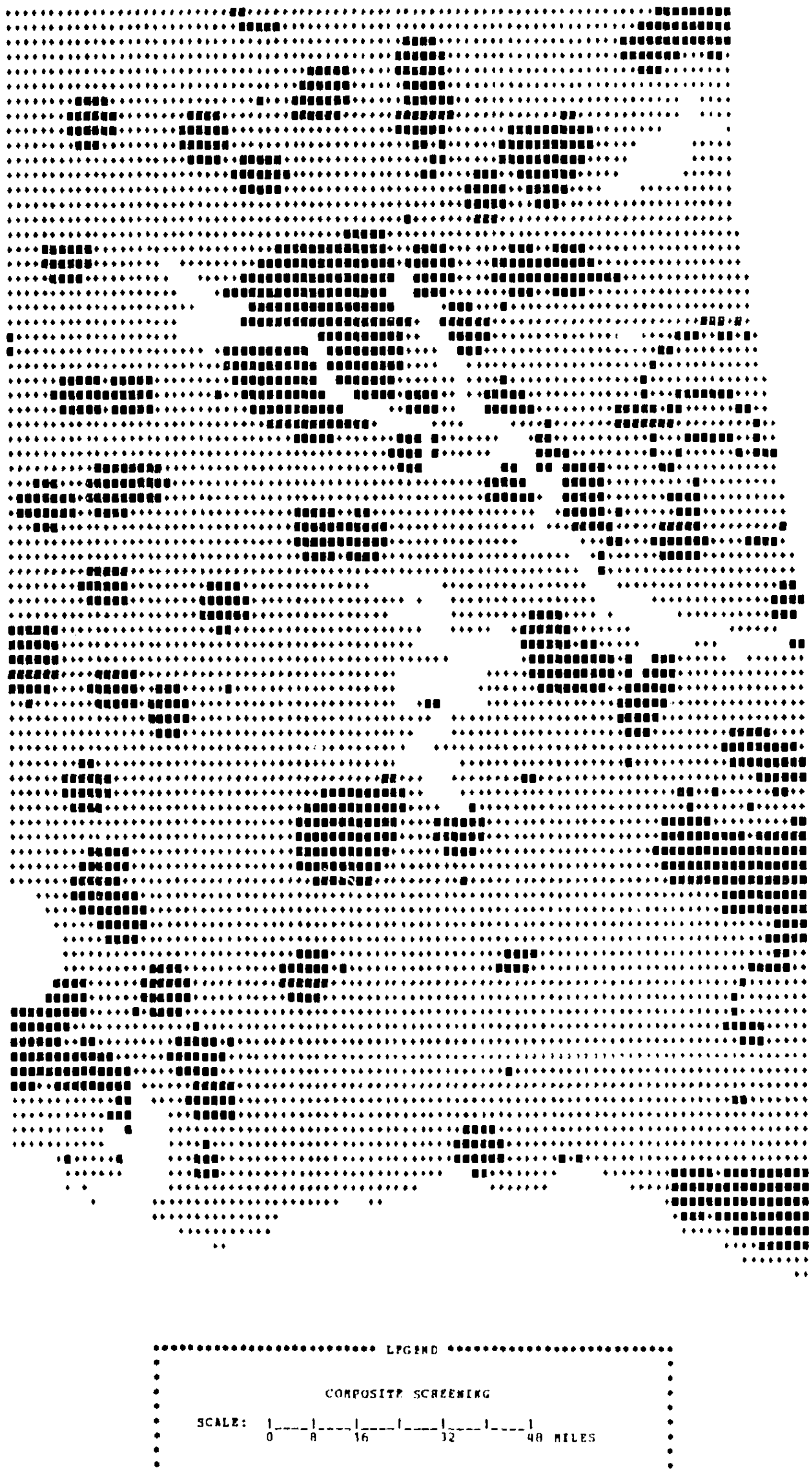


Figure 26. Composite Screening.

displaying functional requirements substantially different from those of the hypothetical model plant would change the acceptability/ exclusion criteria. For example, should a plant of smaller capacity than 7600 MWt be utilized in establishing the selection criteria the reduction in condenser cooling water requirements would open additional areas to investigation.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based upon the analysis of the selected functional/regulatory and environmental requirements of the hypothetical model nuclear power facility as defined and the corresponding natural resource base of the region of interest, the following conclusions regarding this application of acceptability/exclusion screening techniques to the identification of candidate siting areas have been reached:

(1) There are a large number of areas within the State of Oklahoma with diverse characteristics that are compatible with the siting criteria used in this study. Figure 26 indicates the candidate areas where there should be a high probability for finding specific suitable sites.

(2) The computer graphic technique of candidate area selection provides greater flexibility and quicker access to changing conditions than other overlay mapping techniques.

(3) While collection of the relevant data base is an extremely important part of power plant site selection at the reconnaissance level, the accuracy and availability of these data must be improved for

a more detailed examination of candidate sites. For example, presently available flood plain maps are at best fragmented, incomplete, and often outdated, leading to a situation which posed problems for a statewide survey.

(4) Many siting considerations were found to be time dependent. Specific criteria such as population density were subject to re-evaluation during the study as a result of ever-changing regulatory agency guidelines. While dynamic changes of this nature can also be expected to continue, they will not invalidate the results of this study but may require closer surveillance of potential plant/site combinations during formal review.

(5) While the study was directed at nuclear power plant siting only, the technique would be applicable to the identification of sites for large fossil-fuel plants, as well as other industrial activities.

6.2 Recommendations

As a result of the study and the conclusions noted above, a number of specific recommendations are made. Actions towards these recommendations might best be implemented by state or federal regulatory or planning agencies; or by the utility companies most directly concerned. No specific directions are given or intended.

(1) A statewide computerized spatial data base be assembled for existing environmental and socio-economic information. The Universal Transverse Mercator grid coordinate system is recommended for geographic referencing due to the fact that each UTM unit is a square

of constant size with coordinates expressed metrically. These coordinates are indicated on most U.S. Geological Survey maps.

(2) Studies be undertaken to determine the feasibility of reclamation of municipal and industrial waste water for evaporative cooling purposes. Further research should be undertaken to determine if significant quantities are available to supplement existing freshwater supplies.

(3) Reconnaissance-type studies be made of the potential capacity of all existing rivers and reservoirs of the state to provide cooling water for all types of steam-electric power plants in terms of maximum MWt supportable.

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APPENDIX A

SURFACE WATER RESOURCES

TABLE 9. STREAM LOW FLOW SUMMARY.[1]

River Basin	Station No.	Stream	Location	Average Flow (cfs)	Low Flow (cfs)	
					7 day/10 year	Historical 30 day
Arkansas	07-1525-00	Arkansas	Ralston	4,592		20.6
	1610-00[2]	Cimarron	Perkins	1,109		1.7
	1645-00	Arkansas	Tulsa	6,425	[3]	453
	1760-00	Verdigris	Claremore	3,523		16.9
	1915-00	Neosho	Chouteau	8,158	46.6	93.1
	1935-00	Neosho	Ft. Gibson	6,675	46.3	51
	1980-00	Illinois	Gore	1,506		7.7
	2450-00	Canadian	Whitefield	5,414	1.3	2.4
	2485-00	Poteau	Wister	1,130		0.1
	2505-50	Arkansas	Van Buren, Ark.	30,590	1,580	
Red	07-3160-00	Red	Gainesville, Tx.	2,737		79.8
	3310-00[2]	Washita	Durwood	1,365		0.1
	3316-00	Red	Denison Dam	4,749		554
	3355-00	Red	Auther City, Tx.	8,118	297	
	3370-00	Red	Index, Ark.	11,860	649	
	3385-00[2]	Little	Idabel	1,671		0.5

[1]Source: Mize, 1975.

[2]Unregulated natural flow.

[3]Insufficient records to establish 7 day/10 year low flow.

TABLE 10. MAJOR LAKES AND RESERVOIRS.[1]

Name	Stream	Surface Area (acres)	Conservation Storage (acre-feet)
Wash Hudson	Grand (Neosho) River	10,900	200,300
Tenkiller Ferry	Illinois River	12,650	641,000
Hugo	Kiamichi River	13,250	126,900
Fort Gibson	Grand (Neosho) River	19,100	365,200
Broken Bow	Mountain Fork River	14,200	918,000
Keystone	Arkansas/Cimarron	26,300	663,000
Robert S. Kerr	Arkansas River	42,000	493,600
Grand Lake o' the Cherokees	Grand (Neosho) River	46,500	1,672,000
Texoma	Red River	89,000	2,722,000
Eufaula	Canadian River	102,500	2,378,000

[1]Source: Oklahoma Water Resources Board, 1975:28-29.

APPENDIX B

HISTORICAL SEISMIC ACTIVITY

TABLE 11. MAJOR DAMAGING[1] EARTHQUAKES ORIGINATING AND FELT WITHIN OKLAHOMA.[2]

Year	Date	Time (CST)	Locality	Latitude (north)	Longitude (west)	Felt Area (miles^2)	Intensity (MM)
1918	Sep 10	10:30	El Reno	$35^\circ 30'$	98°	Local	V
1929	Dec 27	18:30	El Reno	$35^\circ 30'$	98°	8,000	VI
1933	Aug 19	13:30	El Reno	$35^\circ 30'$	98°	200	VI
1936	Mar 14	11:20	Southeast	$34^\circ 0'$	$95^\circ 12'$	900	V
1952	Apr 9	10:29[3]	El Reno	$35^\circ 24'$	$97^\circ 48'$	140,000	VII
	Apr 16	00:05	El Reno	$35^\circ 24'$	$97^\circ 48'$	.....	V
1953	Mar 17	07:12 08:25	Concho	$35^\circ 36'$	$97^\circ 48'$	.....	VI
1956	Feb 16	17:30	Edmond	$35^\circ 24'$	$97^\circ 18'$	.....	VI
	Apr 2	10:03	Southeast	$34^\circ 12'$	$95^\circ 24'$	.....	V
	Oct 30	04:36[3]	Northeast	$36^\circ 12'$	$95^\circ 54'$	3,700	VII
1959	Jun 15	06:45	Seminole, Pontotoc and Johnston counties				V
	Jun 17	04:27	Southeast	$34^\circ 30'$	$98^\circ 30'$	12,000	VI
1961	Jan 10	19:40	Southeast			.....	V
	Apr 27	01:30	Southeast	$35^\circ 0'$	95°	.....	V
1968	Oct 14	08:43[3]	Durant	$34^\circ 0'$	$96^\circ 48'$	Local	VI
1969	May 2	05:33	Eastern	$35^\circ 12'$	$96^\circ 18'$	13,000	V
1972	Mar 10	15:00	Oklahoma City Presbyterian Hospital				...

[1] MM Intensity V or greater
[2] Source: Coffman and Hake, 1973, 1974.
[3] Indicates time and location determined by instrumentation.

APPENDIX C

DEMOGRAPHIC PROJECTIONS

TABLE 12. POPULATION ESTIMATES AND SITE PROXIMITY RESTRICTIONS.

City	County	Area[1] (mi^2)	Year 2020[2] Population	Adjusted[3] Population	Density (persons/mi^2)	Radius of Uniform Density of 1000 people/mi^2
Ada		6.5	42,900		6,600	3.73 miles
	Pontotoc	714.	55,300	12,400	17	
Bartlesville		9.3	38,100		410	3.53 miles
	Washington	424.	49,900	11,800	28	
Broken Arrow		16.5	47,900		2,903	4.16 miles
	Wagoner	563.	67,200	19,300	119	
Claremore		7.2	70,670		9,815	4.83 miles
	Rogers	685.	95,900	25,230	37	
Coweta			18,110			2.47 miles
	Wagoner	563.	67,200	49,090	54	
Durant		3.5	19,200		5,486	2.50 miles
	Bryan	889.	36,000	16,800	19	
McAlester		6.5	29,300		4,508	3.07 miles
	Pittsburg	1341.	44,300	15,000	12	
Miami		7.4	25,900		3,500	2.91 miles
	Ottawa	464.	38,900	12,000	28	
Muskogee		22.5	83,100		3,693	5.21 miles
	Muskogee	818.	102,400	19,300	24	
Okmulgee		5.0	31,400		6,280	3.21 miles
	Okmulgee	700.	53,800	22,400	32	
Sand Springs		3.6	39,900		110,083	3.69 miles
	Creek	936.	89,200	49,300	95	
Sapulpa		5.9	28,800		4,881	3.13 miles
	Creek	936.	89,200	60,400	65	

(continued on next page)

TABLE 12 (continued)

City	County	Area[1] (mi^2)	Year 2020[2] Population	Adjusted[3] Population	Density (persons/mi^2)	Radius of Uniform Density of 1000 people/mi^2
Shawnee		32.5	89,000		2,738	5.42 miles
	Pottawatomie	794.	115,800	26,800	34	
Stillwater		17.3	83,400		4,821	5.25 miles
	Payne	694.	107,500	24,100	35	
Tahlequah		4.3	20,970[5]		4,877	2.61 miles
	Cherokee	756.	37,300	16,330	22	
Tulsa		171.9	602,400		3,504	15.79 miles
	Wagoner	563.	67,200	30,630	54	
Wagoner		4.3	36,570		8,505	3.51 miles
	Wagoner	563.	67,200	30,630	54	
Ft. Smith, Ark.		45.0	125,600[6]		2,791	6.55 miles
	Sequoyah	696.	46,500		67	

[1]U.S. Census of Population, 1970 Oklahoma PC (1)-B38.

[2]Oklahoma Employment Security Commission, 1974.

[3]Note: Adjusted population figures do not include the major population center of the specific county.

[4]$R = \sqrt{\dfrac{P}{\pi(1000 - D)}}$ where R = radius of area of uniform population density of 1000 people/mi^2;
P = projected year 2020 urban center population;
D = adjusted year 2020 population density of the county.

[5]Oklahoma Employment Security Commission, 1973.

[6]Estimate based on a regional population doubling time of approximately 40 years (EPA, 1974b:b-8).

APPENDIX D

SPECIALIZED LAND USES

TABLE 13. FEDERALLY ADMINISTERED AREAS.

Category	Name	Location (county)	Acreage	
			Land	Water
Nat'l Forest	Ouachita	LeFlore & McCurtain	240,361	286
Nat'l Recreation Area	Arbuckle	Murray	8,851	
Nat'l Park	Platt	Murray	901	11
Land Held in Trust	Camp Gruber	Muskogee & Cherokee	37,540	
Game and Wildlife Preserve	Tishomingo Nat'l Fish Hatchery		156	47
	Tishomingo Nat'l Wildlife Refuge		3,000	8,500

TABLE 14. STATE ADMINISTERED AREAS.[1]

Category	Name	Locale	Lake	Acreage	
				Land	Water
State Parks	Arrowhead	Canadian	Eufaula	2,459	102,500
	Beaver's Bend	Broken Bow	Broken Bow	5,135	14,240
	Fountainhead		Eufaula	3,401	102,500
	Greenleaf	Brags	Greenleaf	565	930
	Heavener Runestone	Heavener		50	
	Keystone	Lotsee	Keystone	715	26,300
	Locust Grove	Locust Grove		5	
	Osage Hills	Bartlesville		1,199	18
	Robber's Cave	Wilburton		8,246	189
	Rocky Ford	Tahlequah		37	
	Sequoyah	Blackgum	Ft. Gibson	2,875	19,100
	Talimena	Talihina		20	

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Table 14 (continued)

Category	Name	Locale	Lake	Acreage Land	Acreage Water
	Tenkiller	Gore	Tenkiller	1,188	12,500
	Texoma	Kingston	Texoma	1,882	93,080
	Walnut Creek	Prue	Keystone	1,429	26,300
	White Eagle	Hulah	Hulah	200	3,600
	Will Rogers	Oologah	Oologah	993	5,850
	Wister Lake	Wister	Wister	3,040	4,000
Recreational Areas	Adair	Stilwel		25	15
	Boggy Depot	Atoka		228	
	Choctaw	Boswell			
	Feyodi	Cleveland	Keystone	140	26,500
	Grand Lake:		Grand Lake		46,300
	Cherokee	Langley		42	
	Honey Creek	Grove		30	
	Twin Bridges	Fairland		63	
	Disney	Disney		20	
	Heyburn	Kellyville	Heyburn	438	1,070
	Okmulgee Lake	Okmulgee	Okmulgee	535	643
	Raymond Gary	Ft. Towson	Raymond Gary	60	390
	Salina	Salina		18	17,900
	Sallisaw #1	Sallisaw		90	227
	#2	Marble City			
	Sequoyah Bay	Okay	Ft. Gibson	303	19,100
	Snowdale	Pryor		15	46,300
	Spavinaw	Spavinaw		35	3,192
	Upper Spavinaw	Jay		51	3,192
Monuments, Museums, Memorials	Cherokee Courthouse	Gore			
	Chouteau Memorial	Salina			
	Fort Gibson Stockage	Fort Gibson		55	
	Murrell Home	Tahlequah		40	
	Pawnee Bill Museum	Pawnee		279	
	Saline Courthouse	Rose			

(continued on next page)

Table 14 (continued)

Category	Name	Locale	Acreage Land	Water
Wildlife Refuge Areas	Latimer County Refuge	Latimer	5,384	90
	Rogers County Game Refuge	Rogers	15	15
	Spavinaw Hills Refuge	Delaware	11,800	
	Oologah Game Management Area	Rogers Nowatta	27,150	5,850
	Okmulgee Game Management	Okmulgee	7,650	
	Improved Public Hunting Area	Wagoner	2,097	500
	Gruber Game Management Area	Muskogee	26,800	200
	Tahlequah Fish Hatchery	Cherokee	152	18
	Cherokee National Historical Society	Cherokee	44	
	Cherokee Game Management Hunting Area	Cherokee	32,000	
	Cookson Hills Game Refuge	Adair Cherokee	14,000	
	Burnt Cabin Game Management Area	Cherokee	1,950	
	Fort Gibson Game Management Area	Wagoner Cherokee	12,500	1,500
	Nanih Waiya	Pushmataha	109	131
	Ozzie Cobb	Pushmataha	225	117
	Pushmataha Refuge	Pushmataha	18,600	40
	Wister Public Hunting Areas and Waterfowl Refuge	LeFlore	16,096	1,200
	Latimer County Refuge	Latimer	5,404	
	Choctaw Game Management Area	LeFlore	184,000	2,000
	McCurtain Co. Game Preserve	McCurtain	15,250	10
	Pittsburg Co. Game Restoration - Bolen Hollow	Pittsburg	1,385	
	Scholler Lake	Choctaw	103	35
	Raymond Gary Lake	Choctaw	6,642	71
	Stringtown Management Area	Atoka	2,260	
	Blue River Game Management Area	Johnston	923	

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Table 14 (continued)

Category	Name	Locale	Acreage Land	Water
	Hickory Creek Game Management Area	Love	3,725	355
	Atoka Game Refuge	Atoka	6,400	
	Durant Fish Hatchery	Bryan	400	350
	Sportsman Lake	Seminole	1,522	355
	Stuart Lake	Hughes	60	
	Holdenville Fish Hatchery	Hughes	70	30
	Hulah Game Management Area	Osage	17,909	3,600

[1]Source: State of Oklahoma, 1972.

TABLE 15. WILD OR SCENIC RIVERS.[1]

Category	Name	Counties
Wild or Scenic Rivers	Illinois River	Cherokee, Adair & Delaware
	Flint Creek	Cherokee, Adair & Delaware
	Barren Fork Creek	Adair & Delaware
	Upper Mountain Fork	McCurtain & LeFlore
	Big Lee Creek	Sequoyah

[1]Source: OWRB, 1975b.

APPENDIX E

TRANSPORTATION ROUTES AND FACILITIES

TABLE 16. SURFACE TRANSPORTATION ROUTES.

Category	Name	Counties Bisected
Waterway	McClellan-Kerr Arkansas River Navigation System	Haskell, LeFlore, Muskogee, Rogers, Sequoyah, Tulsa
	Red River (potential)	Bryan, Choctaw, McCurtain
Highway	Interstate 40	Pottawatomie, Seminole, Okfuskee, Okmulgee, McIntosh, Muskogee, Sequoyah
	Interstate 44	Lincoln, Creek, Tulsa, Rogers, Mayes, Craig, Ottawa
	Indian Nations Turnpike	McIntosh, Pittsburg, Pushmataha, Choctaw
	Muskogee Turnpike	Tulsa, Wagoner, Muskogee
	Cimarron Turnpike	Payne, Pawnee
	U.S. 59	LeFlore, Sequoyah, Adair, Delaware, Ottawa, Craig
	U.S. 60	Osage, Washington, Nowata Craig, Delaware, Ottawa
	U.S. 62	Okmulgee, Muskogee, Wagoner, Adair
	U.S. 64	Pawnee, Tulsa, Wagoner, Muskogee, Sequoyah
	U.S. 69	Bryan, Atoka, Pittsburg, McIntosh, Muskogee, Wagoner, Mayes, Craig, Delaware, Ottawa
	U.S. 70	Marshall, Bryan, Choctaw, McCurtain
	U.S. 75	Bryan, Atoka, Coal, Hughes, Okfuskee, Okmulgee, Washington, Tulsa
	U.S. 169	Tulsa, Rogers, Nowata
	U.S. 266	Okmulgee, McIntosh, Muskogee

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Table 16 (continued)

Category	Name	Counties Bisected
	U. S. 270	Pottawatomie, Seminole, Hughes, Pittsburg, Latimer, LeFlore
	U.S. 271	Choctaw, Pushmataha, LeFlore
	State 10	Muskogee, Cherokee, Delaware, Ottawa, Craig, Nowata
	State 12	Johnston
Railway	Arkansas Western	LeFlore
	Atchison, Topeka & Santa Fe	Osage, Pawnee, Payne, Lincoln, Pottawatomie, Pontotoc, Washington, Tulsa
	Chicago Rock Island and Pacific	Pottawatomie, Seminole, Hughes, Pittsburg, Latimer, LeFlore
	Fort Smith and Van Buren	LeFlore, Haskell
	Kansas City Southern	LeFlore, Sequoyah, Adair
	Texas-Pacific	Osage, Tulsa, Wagoner, Muskogee, McIntosh, Haskell, LeFlore
	Missouri-Kansas-Texas	Bryan, Atoka, Pittsburg, McIntosh, Muskogee, Wagoner, Mayes, Craig, Tulsa, Nowata, Washington, Osage, Pawnee, Payne, Lincoln
	Missouri-Pacific	Nowata, Rogers, Wagoner, Muskogee, Sequoyah
	St. Louis-San Francisco	Marshall, Bryan, Choctaw, McCurtain, Johnston, Pontotoc, Seminole, Hughes, Okfuskee, Okmulgee, Creek, Lincoln, Tulsa, Pawnee, Rogers, Craig, Ottawa
	Tulsa Sapulpa Union	Tulsa, Creek

TABLE 17. COMMERCIAL AIR TRANSPORTATION FACILITIES.

Airport	Total Aircraft Operations/Year[1]	Location Latitude	Location Longitude	Minimum Site Approach Distance (miles)[2]
Tulsa Riverside	265,015	36°02'	96°00'	16.3
Wiley Post	204,133	35°32'	97°39'	14.3
Tulsa International	190,280	36°12'	95°53'	13.8
Will Rogers	150,231	35°34'	98°25'	12.3
Ardmore Municipal	61,297	34°18'	97°00'	10.0
Clinton-Sherman	28,912	35°20'	99°12'	7.6
Enid Woodring Municipal	26,618[3]	36°23'	97°47'	7.3

[1] Source: Federal Aviation Administration, 1974.
[2] See Section 3.7-4.
[3] Less than one full year of data available.

APPENDIX F

PUBLIC AGENCIES CONTACTED

TABLE 18. PUBLIC AGENCIES CONTACTED.

Level	Name	Branch
Federal	Department of the Interior	U.S. Geological Survey
	Energy Research and Development Administration	
	Environmental Protection Agency	Office of Radiation Programs
	Department of Commerce	National Oceanic and Atmospheric Administration
	Nuclear Regulatory Commission	
State	Oklahoma Archaelogical Survey	
	Oklahoma Biological Survey	
	Oklahoma Corporation Commission	
	Oklahoma Geological Survey	
	Oklahoma Industrial Development and Parks Department	
	Oklahoma Water Resources Board	
	Oklahoma Department of Wildlife Conservation	