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A Comparison Between Dispersed Nuclear Power Plants and a Nuclear Energy Center at a Hypothetical Site on Kentucky Lake, Tennessee

Vol. III. Environmental Considerations

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ENERGY DIVISION

A COMPARISON BETWEEN DISPERSED NUCLEAR POWER PLANTS AND A NUCLEAR ENERGY CENTER AT A HYPOTHETICAL SITE ON KENTUCKY LAKE, TENNESSEE

VOL. III. ENVIRONMENTAL CONSIDERATIONS

F. C. Fitzpatrick   O. Sisman
D. D. Gray   J. S. Suffern
J. R. Hyndman   P. A. Tyrrell
D. C. West

FEBRUARY 1976

This study was performed for the Nuclear Regulatory Commission in connection with the development of their Nuclear Energy Center Site Survey report to Congress.

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FOREWORD

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Section 207 of the Energy Reorganization Act of 1974 required the Nuclear Regulatory Commission to conduct a nuclear energy center site survey and report its findings to the Congress and the Council on Environmental Quality. The Survey included a general screening of the 48 contiguous States to identify large land areas that would be likely to contain sites potentially suitable for nuclear energy centers. It evaluated the technical and practical considerations involved in locating the production of electrical power at a nuclear energy center and compared these considerations with those involved in producing an equivalent amount of power at dispersed sites.

One of the techniques utilized in the Survey was an analysis of several "surrogate" sites. These specimen sites were selected to permit study of certain concepts and analysis of alternatives as they applied to a real, rather than hypothetical, location. Selection of a particular area for a surrogate site did not mean that it was a preferred or even well-suited site, but only that it represented particular site problems which were deemed worthy of study.

One of the surrogate sites selected for study was at Kentucky Lake, Tennessee. The Nuclear Regulatory Commission contracted with the Oak Ridge National Laboratory to undertake analysis of this site and to prepare reports on the various tasks when completed. This is one of a series of reports in the fulfillment of this assignment.

The complete report is composed of the following volumes:

- Vol. I. Summary
- Vol. II. Transmission of Power
- Vol. III. Environmental Considerations
- Vol. IV. A Site Selection Methodology

In analyzing the surrogate sites certain assumptions were made, one being that the technology used in the large NECs was the same as that in 4- and 10-unit plants. This caused certain effects, such as eutrophication and silting, to be much greater at a 40-unit plant than at a 4-unit plant. The reason for this sort of comparison is obvious: It was to compare all

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plants on the same basis so that problems related to size would show up. It should be equally obvious that if such problems did exist the applicant would have to install a more elaborate treatment system or change his mode of operation to conform with EPA regulation 40 CFR 423 and their relation to enforcement of water quality standards under Sections 303 and 304 of the Federal Water Pollution Control Act of 1972 (P.L. 92-500).

In the social impact section of this report some assumptions were also made, which may be at some variance with assumptions made in other NECSS documents. In most cases these variances do not detract from the major purpose of the report, which is to make comparisons between NECs and dispersed sites and not to make exact predictions. For example, 8.5 man-hr/KWe was used in this report, and others have assumed values up to 10.5. The manpower estimates for nonsupervisory labor may also be somewhat lower than reported in some other reports, but it is consistent for the different size plants. An operating staff of 350 persons was assumed for each 4-unit station. This value varies among plants, but some estimates are as high as 600. Finally, the influx of people into the area caused by the construction of a 40-unit NEC was based on workers directly associated with the NEC and their families. There will be a lot of peripheral construction and businesses, which will swell the number of new residents by a factor of 2 to 3 over the number employed directly by the NEC.

ABSTRACT

The thermal, ecological, and social impacts of a 40-reactor NEC are compared to impacts from four 10-reactor NECs and ten 4-reactor power plants. The comparison was made for surrogate sites in western Tennessee.

The surrogate site for the 40-reactor NEC is located on Kentucky Lake. A layout is postulated for ten clusters of four reactors each with 2.5-mile spacing between clusters. The plants use natural-draft cooling towers. A transmission system is proposed for delivering the power (48,000 MW) to five load centers. Comparable transmission systems are proposed for the 10-reactor NECs and the 4-reactor dispersed sites delivering power to the same load centers.

VOL. III. ENVIRONMENTAL CONSIDERATIONS

1. INTRODUCTION

1.1 General

The purpose of this environmental assessment is to (1) suggest a method for comparing the environmental impact of a nuclear energy center with that of dispersed sites supplying an equivalent amount of power to the same load centers and (2) to identify the areas in which more information is needed before impacts can be predicted or compared.

To develop and illustrate the method of comparison, surrogate sites have been selected for a large NEC, small NECs, and dispersed sites. The surrogate sites pass the basic criteria of water availability, low population density, and seismic stability, but they have not been studied in enough detail to determine their suitability as actual nuclear energy center sites. In particular, detailed engineering studies have not been made for the locations of the plants, cooling towers, roads, railroads, transmission line corridors, etc. Areas containing national parks, national forests, wildlife refuges, wild and scenic rivers (state and national), state forests, state parks, and Smithsonian-defined natural areas have been excluded. The "surrogate NEC sites" are hypothetical, as are most of the dispersed sites that have been selected for comparison. The geographical locations are real because this is the only way by which a realistic comparison can be made between the nuclear energy center concept and the present method of siting power plants.

The nuclear energy center would grow over a period of years, with one reactor being added perhaps every 9 to 12 months. We assume that the NEC first produces power in the late 1980s and is completed with all facilities operating in the year 2020. For the social and economic impacts, consideration of the changes that occur over this period of time will be necessary; however, for the ecological impacts, the NEC will be considered completely built (as a 40-unit NEC might look in the year 2020). In addition, all the areas that would have been disturbed during construction will be considered: dredged areas, construction buildings, laydown areas, new roads, railroads, pipelines, etc.

The impact of the transmission lines is an important part of the terrestrial ecological impact, and in this case also the assumption will be made that all the lines have been completed as they might appear in the year 2020. In this case, however, the entire transmission system will not be considered, but only the primary transmission routes that deliver the power to the load centers. The assumption has been made that further distribution would be approximately the same for NECs as for dispersed sites.

To compare a 40-reactor nuclear energy center with other siting modes, four surrogate 10-reactor nuclear energy centers and ten surrogate 4-reactor dispersed sites have also been selected. The environmental assessment will be made in the same manner for the dispersed sites as for the nuclear energy centers (again as the plants would look in the year 2020).

The possible impacts will be identified and methods suggested for how they might be measured and by what criteria they could be compared. Where possible, the impacts that can be generalized will be identified and the restrictions on generalization will be stated. Those effects that are essentially the same for NECs as for dispersed sites and therefore need no further consideration will be identified. The primary objective is to be able to compare the environmental impacts of nuclear energy centers with those from dispersed siting and to show what the major differences are.

1.2 Description of the Surrogate Sites

1.2.1 The Kentucky Lake 40-reactor surrogate

This surrogate NEC site is located on Kentucky Lake about 60 miles west of Nashville, Tennessee, and about 20 miles south of the Kentucky border. It is sparsely populated, rather hilly country.

The layout for the Kentucky Lake site is shown in Fig. 1. The center consists of ten units, each being a group of four reactors, four natural-draft cooling towers, and associated buildings and substation. (For study purposes, the 4-reactor units have been patterned after the

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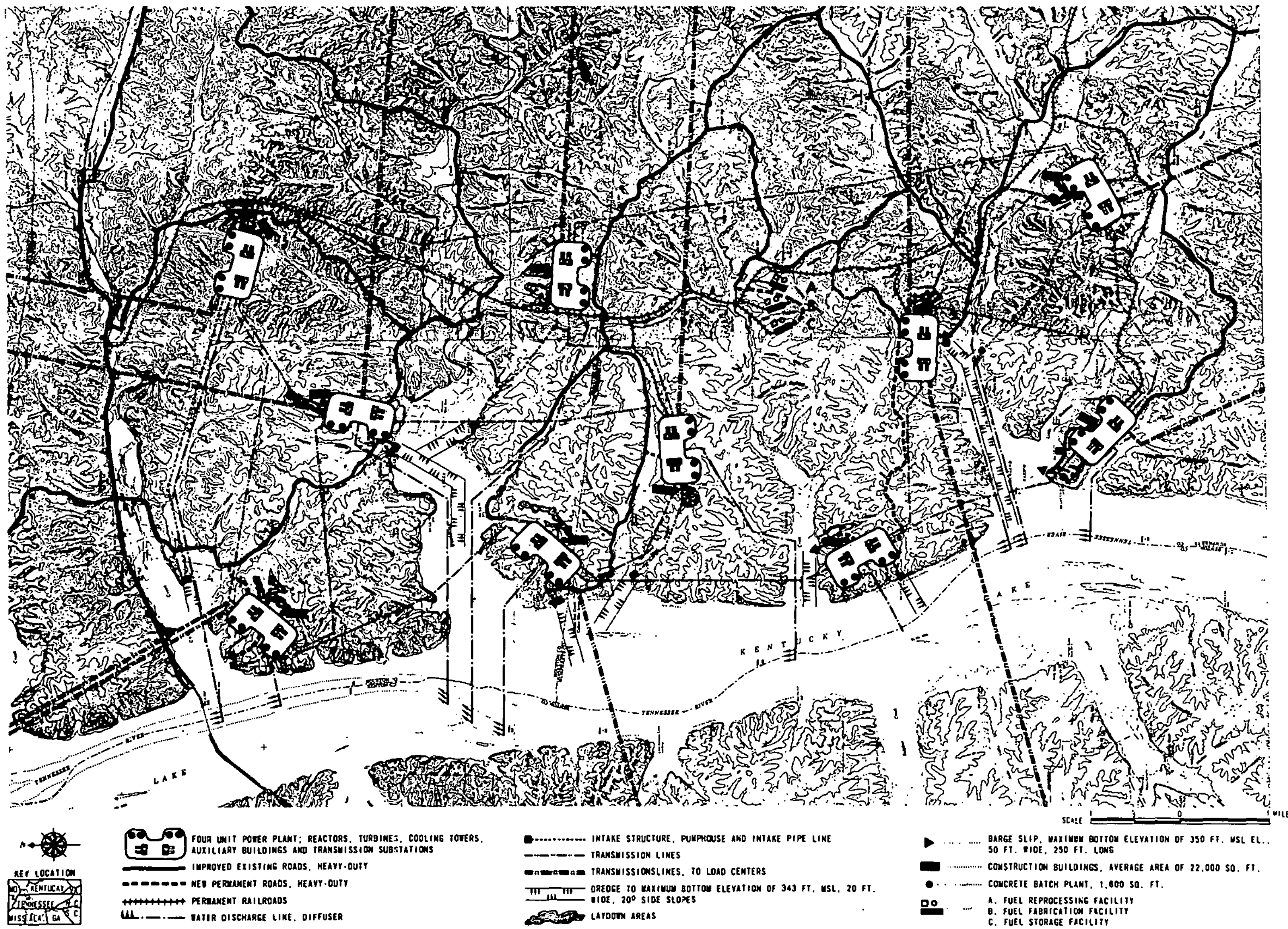

Fig. 1. Kentucky Lake 40-reactor surrogate.

proposed Hartsville Nuclear Plant.) The 4-reactor units are spaced approximately 2-1/2 miles apart. Those units that are on the lake have barge as well as road access, and the units that are not on the lake have both rail and road access. New and improved roads are shown in Fig. 1, as are railroads and transmission routes. The water intakes and discharges are on the lake. Areas where dredging will be necessary are indicated. An estimate has been made for the areas that would be occupied by construction buildings and material laydown areas during the construction period of each 4-unit group; those estimated areas are shown in Fig. 1. The site boundary is approximately at the edge of the drawing; the NEC occupies about 75 sq miles, about 1 acre/MWe.

A location is shown in Fig. 1 for fuel reprocessing, fabrication, and storage. Except for the small amount of additional land required for these facilities and for road and railroad access, presence of these facilities will be of little consequence to the assessment of thermal and nonradiological ecological impact and have mostly been ignored.

1.2.2 Dispersed sites and small energy centers

The surrogate dispersed sites that might substitute for the Kentucky Lake nuclear energy center are shown in Fig. 2. Each of the ten sites is assumed to contain a 4-unit nuclear power station exactly like one unit of the Kentucky Lake surrogate. They will serve the same load centers. These sites have been located in areas of adequate water availability and are relatively close to the load centers that they must serve.

The small nuclear energy centers will contain 10 reactors. A layout of four such sites that might substitute for the 40-unit Kentucky Lake surrogate is shown in Fig. 3. The small nuclear energy center has been assumed to be similar in all details, except size, to the large energy center.

Fuel reprocessing and fabrication to supply fuel elements for the dispersed sites and the small NECs could be located at one of these sites, but for the purposes of this analysis, the assumption has been made that none of the sites would contain fuel reprocessing and fabrication facilities. The present environmental assessment will not include impacts of these facilities for either the dispersed sites or the energy centers.

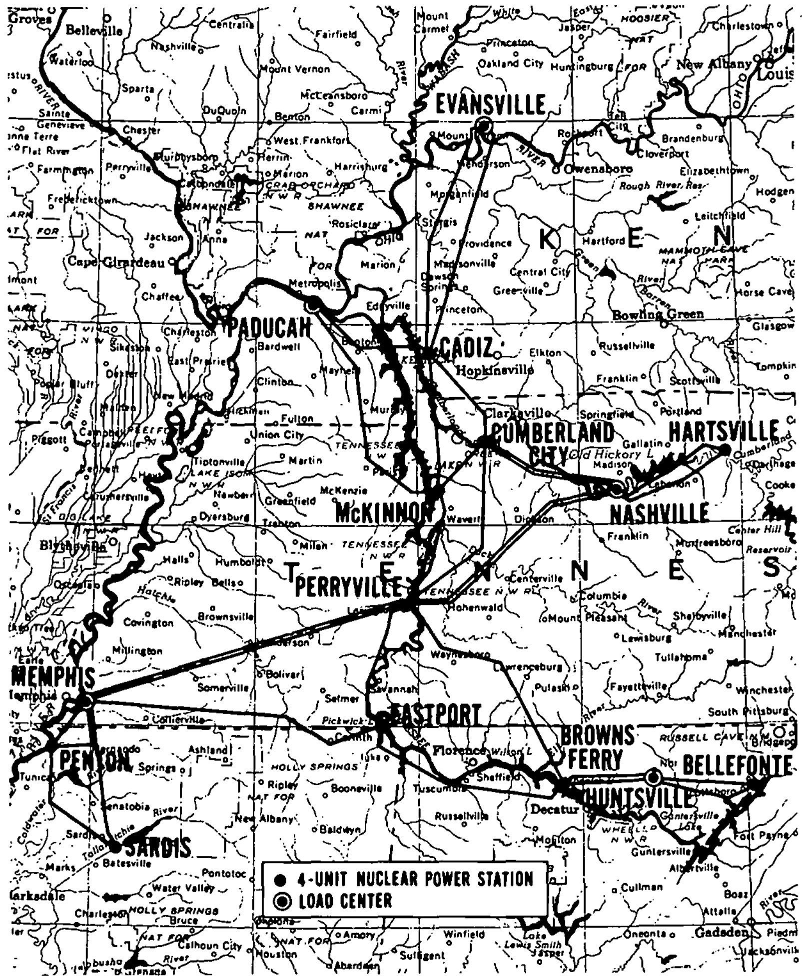

Fig. 2. Location of surrogate dispersed sites, load centers, and transmission line corridors.

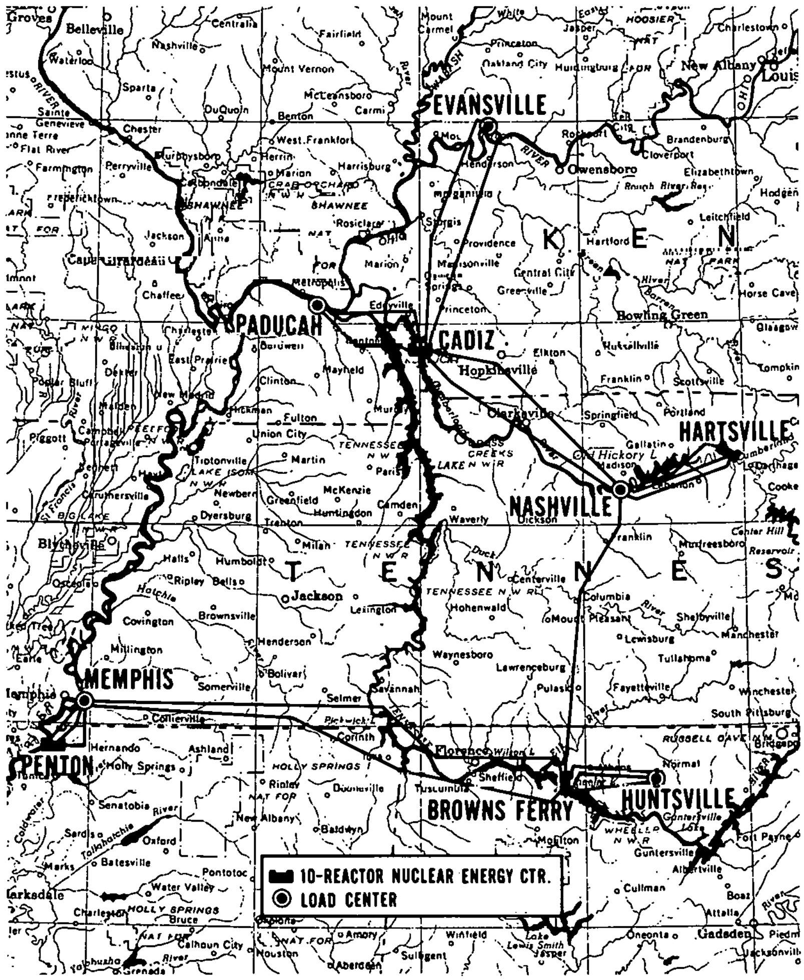

Fig. 3. Location of surrogate ten-reactor energy centers, load centers, and transmission line corridors.

1.2.3 Transmission corridors

For the purposes of the environmental assessment, transmission corridors have been selected for carrying the power to the load centers from the 40-unit site, the four 10-unit sites, and the ten 4-unit dispersed sites. The routes have been selected to avoid areas that would obviously not be good locations from an environmental standpoint, but they have not been engineered or screened in detail from an ecological standpoint.

The number and routing of the transmission line corridors are hypothetical just as the surrogate sites are hypothetical. The assumptions have been made that all transmission lines will be above ground and that all the lines to the load centers will be 765 kV. The very simplistic arrangement shown here is for ease in comparing the environmental effects. It shows no lines beyond the load centers. However, because the transmission lines and the transmission line corridors have been laid out in the same manner in each of the three arrangements (40-reactor, 10-reactor, and 4-reactor stations), the illustration of how the impact of transmission can be assessed is internally consistent and shows relative differences.

The load centers are the same for each of the three situations that have been evaluated. They are Nashville, Tennessee; Memphis, Tennessee; Huntsville, Alabama; Paducah, Kentucky; and Evansville, Indiana. The location of the surrogate sites and the transmission line corridors for the dispersed sites, the four 10-reactor surrogates, and the 40-reactor surrogate are shown in Figs. 2, 3, and 4, respectively. Some corridors carry double lines and some single lines, but there are at least two separate routes to each load center. For operational flexibility, each 4-reactor unit within the nuclear energy center is assumed to be connected to (but normally electrically isolated from) two other units by intermediate voltage lines. Similar flexibility is achieved with interstation corridors in the dispersed case.

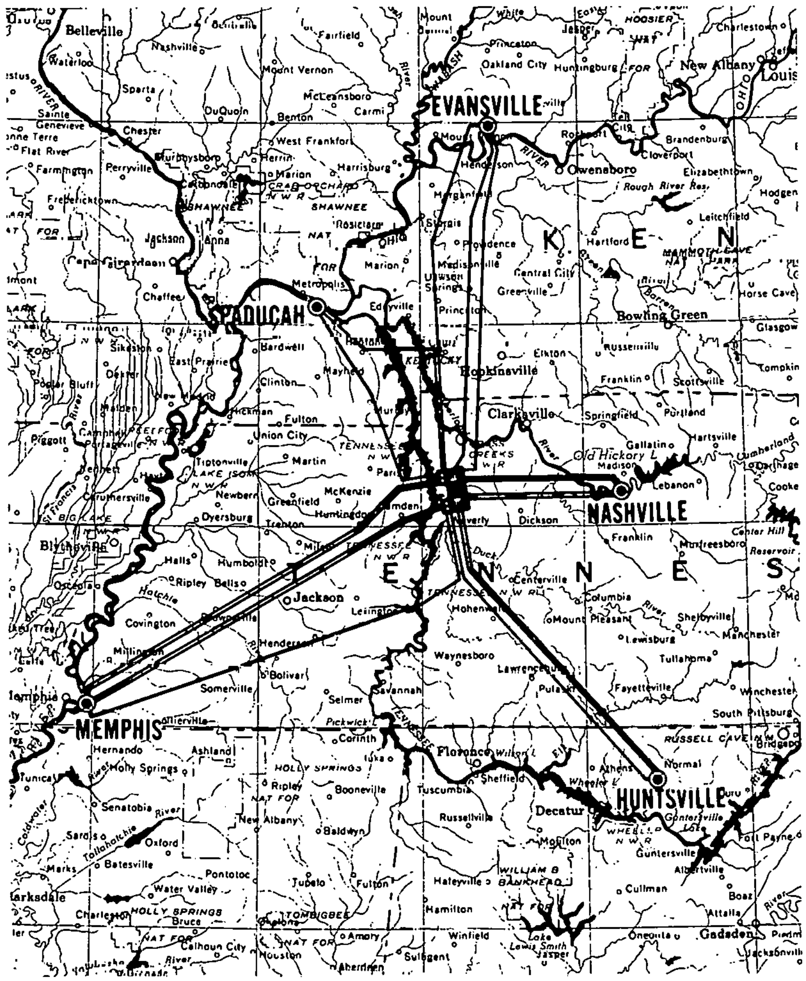

Fig. 4. Location of 40-reactor surrogate, load centers, and transmission line corridors.

1.3 Limitations of Present Assessment

The method of assessment described below presents a procedure that could be used in the ideal case in which all the necessary data were available and in which there were no time limitations. In the present study, very little data were available, and there was a severe time limitation. The study was, therefore, restricted to one surrogate dispersed site, one 10-reactor surrogate, and the 40-reactor surrogate site on Kentucky Lake near McKinnon, Tennessee.

The method of assessment developed herein is preliminary and, in some respects, simplistic. The essence of the evaluation is the comparison of concentrated vs dispersed impacts; that is, the kinds of effects expected (cooling tower drift, thermal plumes, erosion, etc.) are the same, but there are differences in scale. The effects of an NEC are concentrated in one place; those of dispersed sites, although of similar absolute magnitude, are scattered across a region.

At present, there are few conceptual or analytical tools available to deal with this sort of question in either aquatic or terrestrial systems. Given the absence of tools with which to evaluate differences between aggregated and dispersed impacts, the authors have compared some aspects of dispersed siting and NECs by using graphs of the summed dispersed effects and NEC effects. This technique is crude in the extreme; it ignores any qualitative differences that may result from aggregated-dispersed differences. At this point in time, however, it appears that this is the best available approach.

One objective of this study has been to delineate those areas in which information sufficient for decision-making is lacking. This has been done in Sect. 6, in which the authors have outlined those areas in which the greatest research development is needed.

It will become obvious to even the casual reader that the decision to build or not build NECs will be made in an information vacuum. Simply put, the science (and data) do not exist to answer many questions that have arisen so far, to say nothing of the unknowns that are bound to surface as time goes on. The goal of the authors has been to point out the known tradeoffs involved and delineate the areas needing further research.

For convenience, the 10-reactor surrogate that was evaluated was assumed to be located at the same site as the 40-reactor surrogate. The comparison was made by assuming that all four 10-reactor surrogates were identical except for the evaluation of the impact of the transmission system, for which the corridors and the four power stations were assumed to be located as shown in Fig. 3.

The 4-reactor surrogate for the dispersed case was assumed to be located at Hartsville, Tennessee, because more data were available for this site. All ten of the dispersed sites were assumed to be identical and located as shown in Fig. 2. The transmission corridor evaluation was made for the routing shown in Fig. 2.

The primary effects that are compared in the analysis include the dispersion of toxicants, areas of nutrient concentration due to blowdown, etc. These comparisons do not examine the implications of said effects on wildlife resources, recreational values, productivity, and other ecological values. The implications of impacts are discussed in some instances.

2. HEAT DISSIPATION

2.1 Proposed Heat Dissipation Systems — Capabilities and Generic Environmental Impacts

2.1.1 Once-through cooling

Once-through cooling has traditionally been the first choice of utilities because it is the simplest, most efficient, and usually the cheapest method of rejecting waste heat when sufficient water is available. Unfortunately, the environmental impacts can be severe. Consequently, the EPA[1] has forbidden the use of once-through cooling except where it can be shown to cause less environmental degradation than other methods that could be used.

In the operation of a once-through system, water is withdrawn from a natural water body, heated by passage through the condenser, and discharged to the water body. The severity of the impacts is related to the large flow rates required. To cool a single 1200-MWe reactor with a typical condenser temperature rise of 11°C (20°F) requires about 1800 cfs of water. Each phase of operation of a once-through system produces environmental impacts. The withdrawal of water causes impingement of fish and other large organisms on the intake filter screens. Injury or mortality of these organisms may result. Impingement problems are highly site-specific, but they can be minimized by careful placement and design of the intake system. Smaller organisms, such as ichthyoplankton and zooplankton, pass through the filter screens and suffer high mortality rates due to passage through the condenser. This entrainment problem may be reduced by judicious placement of intake, but there are no mechanical devices available to reduce entrainment. All other factors being equal, the severity of impingement and entrainment increases as the proportion of natural flow (past the intake) that is entrained increases. In general, serious impingement and entrainment problems are expected whenever more than 5% of the natural flow is withdrawn.

The largest river in the United States is the Mississippi. The smallest flow observed in the lower Mississippi from 1956 to 1970 was 120,000 cfs.[2] Therefore, about 6000 cfs could probably be safely used for once-through cooling. Because this flow is sufficient for only three

1200-MWe reactors, once-through cooling at inland sites appears to be unacceptable for 4-reactor dispersed power plants as well as for NECs. Coastal or offshore sites may be able to use once-through cooling, but careful site-specific consideration will be required.

The discharge of heated water may create thermal stresses on aquatic organisms. The fully mixed temperature rise of the Mississippi at low flow would be 0.67°C (1.2°F) for a 4-reactor dispersed power plant using a once-through system, 1.67°C (3°F) for a 10-reactor NEC, and 6.67°C (12°F) for a 40-reactor NEC. On the basis of temperature considerations alone, the use of once-through cooling at inland 40-reactor NECs can be ruled out. The acceptability of the temperature rises from dispersed power plants or 10-reactor NECs would have to be determined on a site-specific basis.

Land-use requirements for once-through systems are usually minimal, but the need to avoid entrainment of the discharged water may force wide separations between intake and discharge structures in an NEC. In some areas, the effects of shoreline construction can result in erosion difficulties.

There is no in-plant consumptive use of water due to once-through cooling, but some additional evaporation from the water body is to be expected. Generally, this evaporation is the least of any liquid cooling system — about 76 cfs for a 4-reactor power plant, 190 cfs for a 10-reactor NEC, and 760 cfs for a 40-reactor NEC. The heated water plume may act to increase or decrease fog, depending on local weather. In currently operating once-through systems, fog has not been a major problem.

The only noise associated with once-through cooling is that due to pumps. Because this can be effectively controlled by proper pumphouse design, noise should not be a problem for once-through cooling systems.

2.1.2 Cooling ponds

A cooling pond is an artificial water body that replaces the natural water body in once-through cooling. Water is withdrawn from the pond, heated by passage through the condenser, and discharged to the pond. Most heat is rejected to the atmosphere by convection, evaporation, and radiation. Because there is no indigenous population of aquatic organisms, problems of impingement, entrainment, and thermal stress may be eliminated. On the other hand, makeup and blowdown flows are sometimes needed to maintain tolerable salt concentrations.

Although the construction of an artificial cooling pond avoids many impacts to aquatic systems, it results in the total elimination of large terrestrial areas. The area required depends on climate and on plant design, but current experience suggests that one to two acres/MWt of waste heat are required.[3] Hence, the use of a cooling pond will double or quadruple the amount of land needed for an NEC. If simple extrapolation is valid, a 40-reactor NEC would require 150 to 300 sq miles. Although there are a number of man-made lakes of this size in the United States today, the magnitude of such an undertaking should not be underestimated. Moreover, size alone is not the entire story. Arrangement of intake and discharge locations so that the entire lake is used efficiently as a heat sink is necessary. For a 40-reactor NEC, this would be difficult.

A 10-reactor NEC would require 37.5 to 75 sq miles, whereas a 4-reactor dispersed power plant would need from 15 to 30 sq miles of cooling lake. Although the construction of such a lake would be a major undertaking, it would not be of extraordinary magnitude. Whether the benefits gained would balance the loss of terrestrial habitat must be addressed on a site-specific basis. However, if cooling lakes were to be used, dispersed siting would appear to be advantageous.

The presence of an artificial lake will inevitably result in additional fog. Although fog from existing cooling ponds has generally not been a source of concern, this may not be the case for the large ponds needed for NECs. In addition, significant effects on local weather, such as land-sea breezes, will be more prominent from larger lakes.

Noise would be similar to that from once-through systems and should cause no problems for NECs or dispersed plants.

Consumptive water use from an artificial cooling pond would probably exceed that from other evaporative cooling systems because natural evaporation as well as that induced by the thermal discharges must be charged to the plant. Seepage and influx due to rainfall must also be considered. There does not appear to be any difference in consumptive water use between NECs and dispersed power plants using cooling ponds.

2.1.3 Spray ponds and spray canals

To reduce the area required by cooling ponds, sprays are sometimes added to improve the transfer of heat to the atmosphere. Complete implementation of this strategy results in a spray canal in which nearly all heat transfer occurs as a result of the sprays. The function of the canal is merely to distribute the hot water to the sprays and to return the cooled water to the plant. The excellent heat dissipation afforded by sprays reduces land requirements to less than 0.05 acre/MWt waste heat, the exact value depending on climate. Because an NEC occupying one acre/MWe requires less than 10% of the area for a spray canal system, land use should not be an issue. Spray canals also impact the terrestrial environment by increased fogging, icing, and drift. At present, there are no reliable models and little reliable data from which to predict those impacts. The frequency of occurrence of additional fog is highly site-specific. Fog has generally been found to occur only during calm periods; hence, it is not usually expected to extend off site either for NECs or for dispersed power plants. Spray canals do generate vast quantities of drift, but the droplets are large and do not travel far from the canal. Concrete aprons extending 200 ft on either side of a canal are often provided to recapture as much of this drift as possible. The severity of the resulting salt deposition depends primarily on the TDS level of the circulating water. For a spray canal using freshwater makeup and operating with a circulating water TDS of 644 ppm, drift rates may reach 280 lb/acre-year 200 ft from the canal and fall to 28 lb/acre-year 500 ft away. Drift rates of this order may be acceptable environmentally. On the other hand, a saltwater spray canal operating with 50,000 ppm circulating water may produce 22,000 lb/acre-year 200 ft from the canal and 2200 lb/acre-year 500 ft away. Such high deposition rates will probably preclude use of saltwater spray canals. The frequency of icing will depend heavily on climate, but it should be a very localized phenomenon in any case.

The noise associated with spray canals is similar to rainfall and should not affect offsite areas. The aesthetic qualities of spray canals are not intrusive because the sprays seldom extend higher than about 20 ft.

Induced winds due to spray canals do occur, but they are generally disorganized and weak and should present no problem.

Consumptive water use is site-specific, but runs about the same as for evaporative towers — greater than for once-through cooling, but less than for cooling ponds. Typical consumptive use rates might be about 109 cfs for a 4-reactor dispersed site, 273 cfs for a 10-reactor NEC, and 1090 cfs for a 40-reactor NEC. The need to limit TDS buildup would require typical makeup rates of about 149 cfs for a 4-reactor dispersed power plant, 372 cfs for a 10-reactor NEC, and 1490 cfs for a 40-reactor NEC if use of fresh water is assumed. The 5% entrainment criterion would require minimum flow rates of 2976 cfs for a 4-reactor dispersed site, 7450 cfs for a 10-reactor NEC, and 29,760 cfs for a 40-reactor NEC if use of spray or evaporative tower cooling systems is assumed. There are a number of inland sites meeting the 5% entrainment criterion for 40-reactor NECs.

The impact of the blowdown plume is highly plant-, site-, and weather-dependent and cannot be adequately addressed in a generic sense, except to say that in many cases the impact of blowdown plumes will be acceptable.

Except for the increased water availability required to meet the 5% entrainment criterion, there does not seem to be any significant difference between NECs and dispersed power plants using spray canals.

2.1.4 Evaporative cooling towers

These towers are in wide use, and their popularity is expected to increase. Consequently, there are a number of types that may be suitable for NEC use: rectangular mechanical-draft, circular mechanical-draft, fan-assisted natural-draft, and natural-draft. Information concerning environmental impacts of circular mechanical-draft and fan-assisted natural-draft types is insufficient to speak with confidence; nevertheless, the impacts from these types are expected to be intermediate.

The land occupied by towers is small compared with the exclusion zone of a nuclear power plant. Even allowing for spacing to prevent recirculation, only about 0.01 acre/MWt waste heat is needed. This means that only about 2% of the area of an NEC would be needed for tower fields.

Mechanical-draft towers have heights of about 70 ft; fan-assisted towers are about 300 ft high, and natural-draft towers are around 500 ft high. Mechanical-draft towers would seldom be visible off site at either NECs or dispersed sites, but natural-draft towers may be visible for miles. The aesthetic impact of this visibility is highly subjective, but the net impact is probably minimized by NEC grouping.

The height of the towers also influences the ultimate plume rise and, hence, the impact of atmospheric effluents. The higher the plume rise, the more widely the effluents are dispersed, and the smaller the peak values at the ground. Conversely, higher plumes tend to maintain their identity and visibility for longer times. Evaporation rates are similar for all evaporative towers — about 30 cfs per 1200-MWe reactor. This water vapor emission may lead to the formation of a visible plume. The frequency of such condensation is highly weather- and site-dependent. In rectangular mechanical-draft towers, this plume often intersects the ground, resulting in ground fog. Up to 100 days of additional fog per year, 0.5 mile from the tower, may result from the towers of one reactor if the climate is unfavorable. Hence, climatic conditions may preclude the use of mechanical-draft towers due to fogging in some locations. On the other hand, there is evidence that natural-draft towers result in no additional ground level fog.[4] Icing due to fog will occur when fog is present and the temperature is below freezing. This phenomenon may cause problems if mechanical-draft towers are used. Conversely, the plume aloft is more often visible from natural-draft towers. The visible plume from one reactor tower may be overhead for 100 hr per year at a distance of 5 miles away from the tower.

Comparable drift rates can be obtained for all types of towers, but the height of discharge and buoyant plume rise influences the distribution of this material. The drift deposition and airborne concentration from mechanical-draft towers will be sharply peaked near the towers, whereas natural-draft towers will spread the material more widely. With freshwater makeup, maximum deposition can probably be held to less than 100 lb/acre-year for any type of evaporative tower. This level is usually acceptable. Deposition rates using saltwater makeup may be higher by a factor of 100, and the acceptability of any evaporative tower would need site-specific consideration. In regard to airborne salt concentrations, similar conclusions apply: With freshwater makeup there is probably no cause for concern, but salt water should be carefully studied.

Evaporative towers will result in additional precipitation, but quantification of this statement or discussion of other potential impacts on weather phenomena is not possible.

Consumptive water use will be similar for all evaporative towers, as will makeup and blowdown flows. Typical makeup rates might be 146 cfs for a 4-reactor dispersed site, 364 cfs for a 10-reactor NEC, and 1460 cfs for a 40-reactor NEC.

Noise is usually less for natural-draft towers, and this problem can sometimes be lessened by proper placement of towers on the site.

2.1.5 Dry cooling towers

Dry cooling towers discharge only hot air to the atmosphere. They eliminate totally the problems of visible plumes, fogging, icing, drift, makeup, blowdown, and consumptive water use. Dry towers require up to four times more land than evaporative towers, but the amount required is still only about 8% of the total NEC site area. Dry mechanical-draft towers may be up to 150 ft in height, but they should not have a major aesthetic impact. Dry natural-draft towers are about the same height as wet natural-draft towers (about 500 ft) and will be subject to the same aesthetic restrictions. Little data is available concerning noise from dry towers. Noise could be greater than that from wet towers because of the greater volume of air passing through the towers.

Because dry towers will process up to five times more air than wet towers, problems of vorticity concentration, if they exist, will be more severe for dry towers. Dry towers will probably tend to reduce local rainfall.

2.1.6 Wet-dry cooling towers

These towers reject part of their heat through wet cells and part through dry cells. Their drift, makeup, blowdown, and consumptive water use will be reduced in proportion to the percentage of heat rejected through the dry sections. Visible plume and fogging problems will be reduced in slightly greater percentages. The volume of air processed will be intermediate to wet and dry systems. In all other respects, they will have the same types of impacts as wet towers, but the magnitudes will be smaller. Consequently, an analysis for wet towers is a worst-case analysis for wet-dry towers.

2.1.7 Conclusions

Apparently, wet, dry, and wet-dry towers are all viable for NECs. Dry towers and wet-dry towers generally have smaller direct impacts than do wet towers; but they have the indirect effect of requiring larger reactors to achieve the same electrical output (because of reduced efficiency). The dry towers are much more expensive to build and operate than are the wet towers. Hence, they will probably be used only in unusual circumstances for which their particular qualities are essential. Among the wet towers, rectangular mechanical-draft and natural-draft towers have been used most extensively. Natural-draft towers are more efficient and generally have smaller fog and drift impacts. Rectangular mechanical-draft towers are less visible, have lower capital costs, and are more flexible in operation. The present trend is toward natural-draft towers for large installations because their advantages, particularly efficiency, seem to be most important. Hence, natural-draft towers are the most likely choice for NECs.

2.2 Comparative Environmental Impacts of Natural-Draft Cooling Towers at NECs and Dispersed Sites

As has been noted, many environmental effects due to cooling systems can be evaluated only on a site-specific basis. In this section, the 40-reactor and 10-reactor NECs are assumed to be located at the Kentucky Lake surrogate site, 60 miles west of Nashville, Tennessee. The typical

4-reactor dispersed site is Hartsville, Tennessee, about 40 miles northeast of Nashville. Weather conditions at both locations are assumed to be adequately represented by the weather records of Nashville. Both sites have sufficient water for evaporative cooling, but insufficient water for once-through cooling. Consequently, natural-draft cooling towers are the system selected for analysis.

The hypothetical cooling system is patterned after the system proposed at Hartsville.[5] For each reactor, there is a single hyperbolic natural-draft tower 460 ft high. Operating parameters of the assumed system are listed in Table 1. Each tower rejects 2374 MWt by evaporating 30 cfs of water and has a flow rate of 1002 cfs and a range of 20°C (36°F). Each tower operates at 5.7 cycles of concentration and has a drift fraction of 0.00001. The 4-reactor dispersed power plants have 4 cooling towers each, the 10-reactor NECs have 10 towers each, and the 40-reactor NEC has 40 towers. The consumptive water use of each tower is the same, regardless of how they are grouped. Hence, there is no difference in consumptive use of water between NECs and dispersed power plants if the same number of reactors is considered. Similarly, the amount of land required per tower does not depend on grouping.

Table 1. Assumed natural-draft cooling system parameters per reactor

Core thermal power, MWt	3579
Net electrical output, MWe	1205
Net heat rejection, MWt	2374
Range, °C (°F)	20 (36)
Circulating water flow rate, cfs	1002
Evaporation rate, cfs	30
Blowdown rate, cfs	6.4
Makeup rate, cfs	36.4
Drift fraction	0.00001
Cycles of concentration	5.7
Basin water TDS, ppm	644
Water/air mass flow ratio	1.125
Air exit velocity, fps	15
Tower height, ft	460

2.2.1 Chemical discharges

The water quality of Kentucky Lake at the surrogate NEC site[1] is shown in Table 2. It was determined that, if 5 ppm of a dispersant (polyacrylate polymer and aminomethylene phosphate) were added, 5.7 cycles of concentration could be used for the average condition without exceeding EPA or State water quality standards. The average conditions in the cooling tower blowdown would then be those shown for blowdown discharge in Table 2. These conditions were used for the heat dissipation and ecological evaluations that follow.

The blowdown chemicals listed in Table 2 include only chemicals that were already in the cooling water and were concentrated by evaporation in the cooling tower. The assumption has been made that if any chemicals are added to the blowdown from plant operations (e.g., chlorine, ozone, demineralizer regenerating solution, or others), the amounts discharged into the lake will meet EPA and State discharge standards.

For the 4-reactor surrogate, the water quality and chemical discharges assumed were those given in the Hartsville Environmental Impact Statement.

2.2.2 Atmospheric emissions

At full load each tower emits 1870 lb of water vapor and 0.6 lb of water droplets per second. These droplets, called drift, have the same composition as the tower basin water — 644 ppm of dissolved solids. Hence, each tower emits 12,680 lb of "salt" per year — chiefly sulfates and bicarbonates of calcium and magnesium.

The deposition of this material has been estimated using the Oak Ridge Fog and Drift Code (ORFAD).[6] This is a numerical model that calculates a plume trajectory every 3 hr by using weather data recorded from 1965 to 1975 at Nashville by the U.S. Weather Service as input. The tower operating parameters are listed in Table 1, and the drift droplet spectrum is presented in Table 3. ORFAD does not account for topographic variations. The most serious limitation of ORFAD in this application is the treatment of plume interaction. Each module is assumed to have four towers placed in a row 3600 ft long; the modules are separated by

Table 2. Water quality in Kentucky Lake and cooling tower blowdown

Parameter	Kentucky Lake[a] (ppm) Maximum	Minimum	Average	Average blowdown discharge[b] (ppm)
pH	8.3	7.0	7.6	9.0
Alkalinity as $CaCO_3$	73	44	52.5	299
Calcium (Ca)	29	15	18.9	108
Magnesium (Mg)	4.5	3.0	3.8	22
Sodium (Na)	11.4	1.8	6.0	34
Potassium (K)	4.4	0.6	2.0	11
Iron (Fe)	1.5	0.25	0.48	2.7
Manganese (Mn)	0.48	0.02	0.13	0.74
Ammonia (N)	0.50	<0.01	0.11	0.63
Nitrite (N)	0.03	<0.01	0.01	0.06
Nitrate (N)	0.86	0.01	0.37	2.1
Organic nitrogen (N)	1.5	0.15	0.54	3.1
Chloride (Cl)	22	5	12.1	69
Sulfate (SO_4)	20	7	12.2	70
Silica (SiO_2)	5.7	<0.1	2.1	12
Dissolved solids	180	70	113	644
Suspended solids	60	0	20	114
Soluble phosphate (PO_4)	0.29	0.02	0.14	0.80
Total phosphate (PO_4)	0.91	0.10	0.35	3.4

[a] Sampling station (TRM 91.0) located approximately 1 mile upstream from surrogate NEC; TVA data taken 1/24/68 through 12/10/68; parameters are from 29 to 34 samples taken throughout the year.

[b] Assuming 5 ppm of dispersant, but no acid, added; maximum cycles of concentration = 5.7; does not include chlorine, demineralizer, regenerating solution, or other plant chemical use that might be disposed of in the blowdown.

approximately 2.5 miles. The nature of the interaction that would occur among these plumes cannot be predicted, given the present state of the art. The calculations presented here assume that the four plumes from each module interact but that the different modules do not. The four-tower interaction is accounted for by an empirical correction of the empirically computed single-tower plume trajectory. Another related limitation has to do with the fact that ORFAD assumes that all the towers are located at the origin. Because the characteristic length of the Kentucky Lake 40-reactor NEC is about 10 miles, this is clearly a gross approximation, particularly for locations less than 10 miles from the center of the NEC. Assuming that all the towers are at one point yields a worst case in terms of peak values of salt deposition and airborne salt.

Table 3. Natural-draft tower drift particle size distribution used by staff

Mean diameter (μm)	Weight fraction
20	0.04
60	0.29
100	0.21
140	0.13
180	0.11
250	0.15
350	0.05
450	0.02

<u>Source</u>: F. M. Shofner et al., "Measurement and Interpretation of Drift Particle Characteristics," presented at Conference on Cooling Tower Environment — 1974, University of Maryland, March 4-6, 1974.

The maximum annual average salt deposition from the 40-reactor NEC is estimated to be 33.2 lb/acre-year one mile north of the origin. Although this is a worst-case calculation, a drift of this magnitude is negligible. The predicted annual average salt deposition distribution out to 16 miles from the 40-reactor NEC is presented in Fig. 5. Deposition rate estimates for 10-reactor NECs and for 4-reactor dispersed

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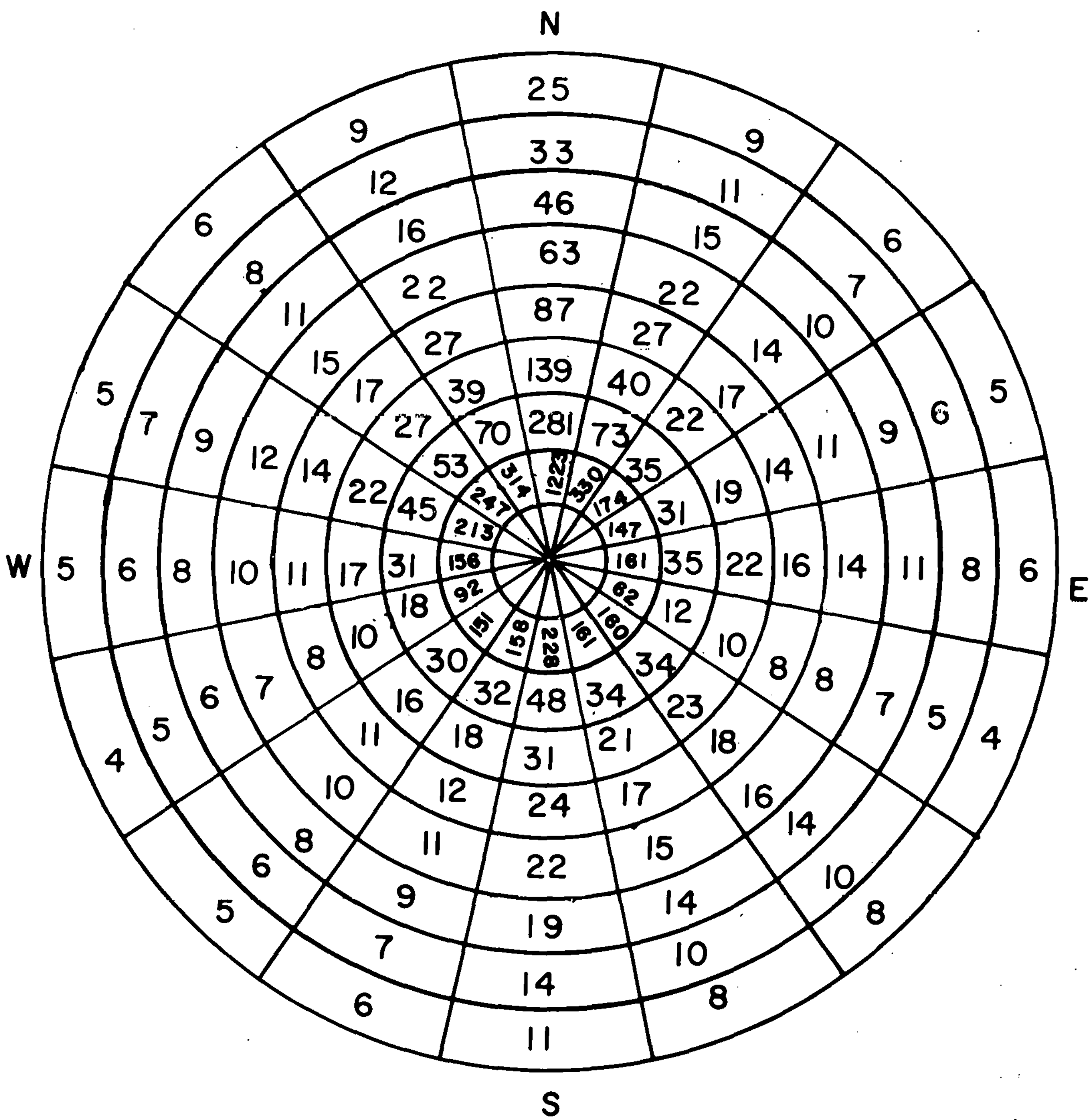

Fig. 5. Annual average salt deposition rates (mg/m^2-year) from 40 natural-draft towers at the origin. Values are for 2-mile intervals out to 16 miles. To convert values to lb/acre-year, multiply by 0.00893.

sites may be obtained by dividing by 4 and 10, respectively. No measurable impact from salt deposition is expected from any of these siting plans.

The maximum annual average airborne salt concentration is estimated to be 0.175 $\mu g/m^3$ one mile north of the origin for a 40-reactor NEC by using the assumptions detailed above. This is far below the Federal Secondary Ambient Air Quality Standard of 60 $\mu g/m^3$ and is not expected to have any measurable impact. Figure 6 shows the estimated annual average airborne salt concentration distribution out to 16 miles for a 40-reactor NEC. Airborne concentrations for 10-reactor NECs and 4-reactor dispersed sites may be obtained by dividing by 4 and 10, respectively. No measurable impact from airborne salt is expected from any of these siting plans.

Fog results when the concentration of water vapor is such that condensation occurs on nuclei suspended in the air. The relative humidity at which condensation occurs depends on the size spectrum, concentration, and chemical composition of the available nuclei. Because these factors are highly site-specific, this calculation has been based on the assumption that 100% relative humidity must exist for fog to occur. Given this criterion, ORFAD predicts that no additional fog at ground level will occur from the 40-reactor NEC because the efflux height for natural-draft towers is so great that the plume rarely reaches the ground. This result is supported by operating experience with natural-draft towers.[4] No fog is expected from any of the siting plans. For the present analysis, no attempt has been made to predict the frequency of visible plumes aloft.

When the temperature is below freezing, icing may occur from either drift droplet deposition or fog. In this case, only the first mechanism applies. Although no quantitative estimate has been made, no significant impacts from icing are expected from any of the siting plans.

No firm assessment of the potential meteorological consequences of NECs can be given. Some increase in precipitation down wind may result, and the potential for vorticity concentration exists. Nevertheless, any conclusions would be premature at this time.

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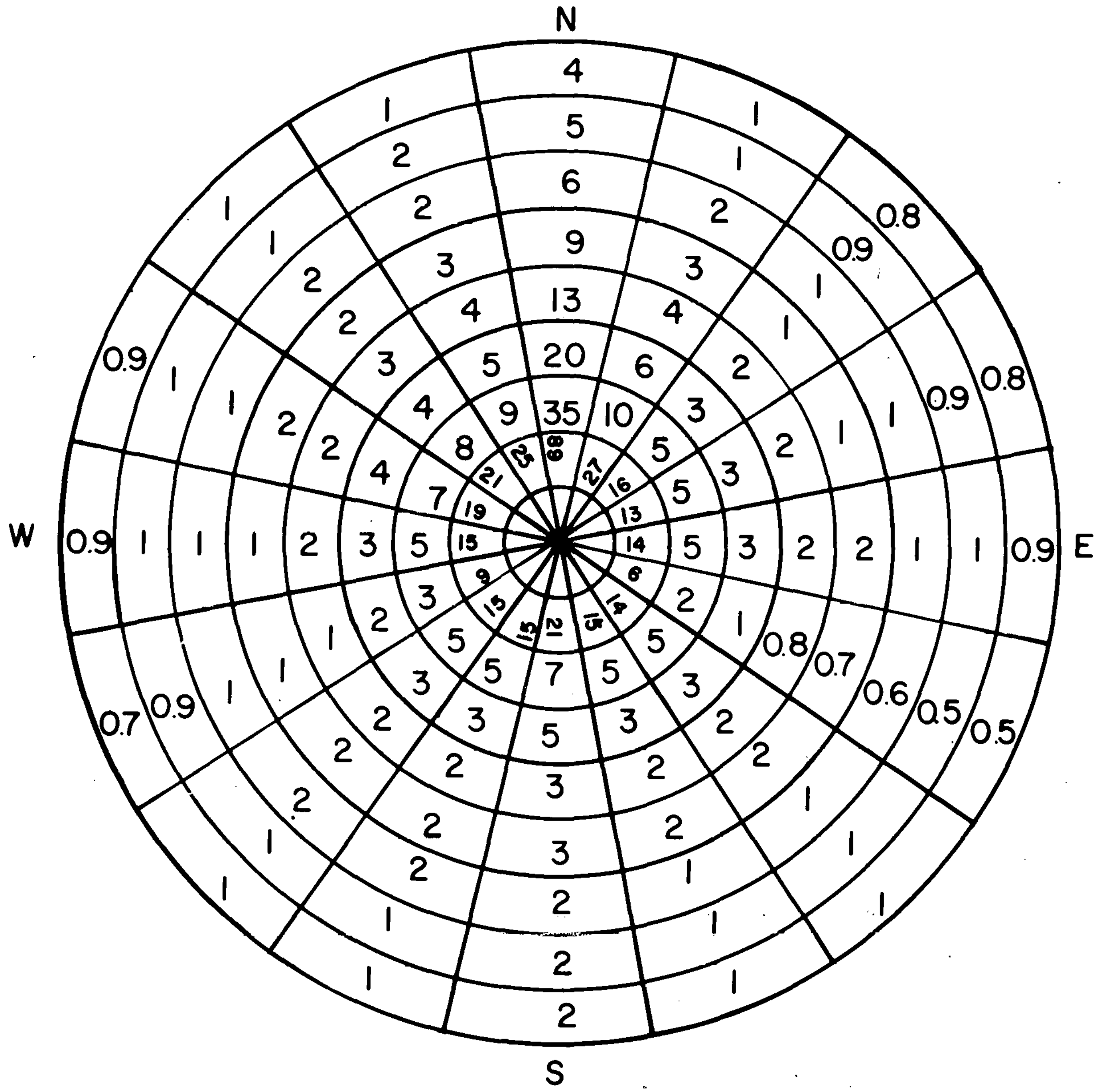

Fig. 6. Annual average airborne salt concentrations (pg/m^3) at tower base elevation from 40 natural-draft towers at the origin. Values are for 2-mile intervals out to 16 miles. To convert values to μg/m^3, divide by 1000.

2.2.3 Aquatic impacts

The mean annual flow rate past the Kentucky Lake Surrogate Site is 63,100 cfs. The month of lowest flow is September, during which a flow as low as 23,600 cfs can be expected once in twenty years. The total makeup rate for a 40-reactor NEC is 1460 cfs — about 6% of the twenty-year low monthly flow and 2% of the annual average flow. Hence, with careful placement and design of the intake structures, problems of impingement and entrainment should be tolerable for either 40-reactor or 10-reactor NECs at this site.

The mean annual flow in the Cumberland River past the Hartsville site is 17,000 cfs. The lowest monthly average flow to be expected once in 20 years is about 3125 cfs. The makeup rate of 146 cfs for a 4-reactor dispersed power plant is less than 5% of the twenty-year low monthly flow and less than 1% of the annual average. Therefore, with careful placement and design of the intake, entrainment and impingement should be acceptable for this 4-reactor plant. No quantitative comparison between NECs and dispersed sites can be made without detailed information about the distribution of biota in the respective water source.

Each 4-reactor module is assumed to discharge 25.6 cfs blowdown through two submerged ports. The ports have a diameter of 1.2 ft, face downstream, and are inclined 30° above the horizontal. The discharge velocity is 11 fps. At the Kentucky Lake site, the diffuser is assumed to be placed on the bottom of the navigation channel, a deepened region about 1000 ft wide and 50 ft deep.

Because the parameters of both the blowdown and the receiving water are subject to wide fluctuations, a comprehensive impact assessment is not possible. Instead, calculations are presented for unfavorable conditions that may occur during winter and summer seasons. After reviewing the available information concerning the hydrothermal state of Kentucky Lake[7] and the operating characteristics of the Hartsville reactors,[8] the parameters listed in Table 4 were selected as typical of pessimistic winter and summer conditions. No stratification was assumed in either season. Because the velocity of flow in the navigation channel is believed to vary widely, a number of cases were examined. The

Table 4. Parameters of ambient and blowdown water at Kentucky Lake surrogate

Season	Ambient water			Blowdown	
	Depth (ft)	Temperature (°C, °F)	TDS (ppm)	Temperature (°C, °F)	TDS (ppm)
Winter	50	4.5, 40	113	26.7, 80	644
Summer	50	30, 86	113	33.9, 93	644

Tennessee Valley Authority (TVA)[9] predicts navigation channel velocities of 0.5 fps during the summer, 1 fps during the winter, and 3.5 fps during the average yearly maximum flood near the surrogate site. Computations were performed for these velocities and for a stagnant lake. Blowdown plume predictions were made using the near-field, submerged buoyant jet model of Hirst.[10] This model assumed discharge to infinite ambient and, hence, overpredicts dilution. The results of the computations are presented in Table 5. The two plumes from each module do not merge. The maximum surface temperature rise is 1.7°C (2.5°F) for a stagnant lake in winter and 0.39°C (0.7°F) when the velocity is 0.5 fps in winter. During the summer the surface temperature rise in a stagnant lake is 0.28°C (0.5°F). More important from the ecological perspective are the small volumes of water at elevated temperatures.

Although the thermal impact of a single module does not appear to be significant, some considerations must be given to cumulative impact. The ten diffusers for the 40-reactor NEC are strung out over about eleven river miles. The smallest distance between diffusers is 1041 ft. To calculate the fully mixed temperature rise, the assumptions are made that no heat is lost to the atmosphere and that the heated water mixes fully with the 70-ft-wide water column moving over the ports. For a winter average flow of 1 fps and a discharge ΔT of 22.2°C (40°F), the fully mixed rise is 0.17°C (0.3°F) per diffuser. If the same 70-ft-wide water column passed over each diffuser, the fully mixed rise of that column would be 1.67°C (3°F) for a 40-reactor NEC. For a typical summer flow of 0.5 fps and a ΔT of 3.9°C (7°F), the fully mixed rise would be 0.06°C (0.1°F) per diffuser and 0.56°C (1°F) for ten modules. In spite

Table 5. Blowdown plume predictions for one module (four reactors) at Kentucky Lake

Case number	River velocity (ft/sec)	Surface centerline ΔT (°C, °F)	Surface centerline TDS (ppm)	Surface centerline dilution factor	Horizontal travel to surface (ft)	Travel time to surface (sec)	Surface half-width[a] (ft)	Total volume (ft^3) from two nozzles with ΔT greater than 6.6°C(11.8°F)	10.6°C(19°F)	14.6°C(26.2°F)
					Winter					
1	0	1.4, 2.5	147	15.6	55	32	9	166	50	20
2	0.5	0.4, 0.7	122	59	104	80	17	126	42	18
3	1.0	0.3, 0.5	119	89	183	123	16	104	38	16
4	3.5	0.1, 0.2	115	266	913	249	14	66	26	12
					Summer					
								1.1°C(2°F)	2.2°C(4°F)	3.3°C(6°F)
5	0	0.3, 0.5	149	14.8	74	47	11	186	30	6
6	0.5	0.08, 0.14	123	53	157	135	16	138	28	6
7	1.0	0.04, 0.08	119	89	322	230	16	114	26	6
8	3.5	0.03, 0.05	117	133	984	266	11	72	18	4

[a]Distance from centerline at which ΔT = 1/2 ΔT centerline.

of the highly conservative assumptions, the temperature rise in Kentucky Lake appears to be very modest.

River depth at Hartsville is less than 30 ft, and hydrothermal conditions are very complex. An accurate analysis would probably require physical modeling; but, as this was not practical, the Hirst model was used. Results of the analysis for the diffuser design mentioned above are presented in Table 6. Clearly, the impacts are relatively more severe at Hartsville than at Kentucky Lake, but since the diffuser has not been optimized, these are pessimistic values. If complete mixing with 2000 cfs is assumed, the fully mixed temperature rise would be about 0.28°C (0.5°F).

If no blowdown purification is assumed, each 4-reactor module at the Kentucky Lake site discharges about 1 lb/sec of dissolved solids — chiefly the same materials dissolved in the river before intake, but including chemicals added to the circulating water. As shown in Table 5, dilution factors of 15 or better are achieved by the Kentucky Lake plumes before surfacing. Under the conservative assumption of complete mixing with a 70-ft-wide water column, this will lead to a 46-ppm increase in TDS during the winter and a 92-ppm increase during the summer for a 40-reactor NEC at Kentucky Lake. A 10-reactor NEC would have increases of 11.5 ppm in winter and 23 ppm in summer.

The 4-reactor dispersed power plant at Hartsville achieves lower surface dilutions by a factor of 8.5 or better. The fully mixed increase in TDS at Hartsville is likely to be 8 ppm or less. The toxicity of these discharges depends on the exact nature of the added chemicals and on the distribution and type of aquatic organisms. In the unlikely event that significant harm occurs, blowdown purification could be used at either site.

2.2.4 Noise

Cooling towers, both forced- and natural-draft, generate and radiate noise when in operation. As the tower size and thermal capacity are increased, the accompanying noise radiation increases. As the generated noise is radiated away from the cooling tower, the resulting sound

Table 6. Blowdown plume predictions for one module (four reactors) at Hartsville site

Case number	River velocity (ft/sec)	Surface centerline ΔT (°C, °F)	Surface centerline TDS (ppm)	Surface centerline dilution factor	Horizontal travel to surface (ft)	Travel time to surface (sec)	Surface half-width[a] (ft)	Total volume (ft^3) from two nozzles with ΔT greater than		
								6.6°C(11.8°F)	10.6°C(19°F)	14.6°C(26.2°F)
					Winter					
1	0	2.6, 4.6	175	8.6	40	15	5.9	165	50	20
2	0.5	1.0, 1.9	138	21	58	28	9.3	125	42	18
3	1.0	0.67, 1.2	129	33	92	45	2.6	104	38	16
4	3.5	0.3, 0.5	119	89	400	104	8.9	65	26	12
					Summer					
								1.1°C(2°F)	2.2°C(4°F)	3.3°C(6°F)
5	0	0.44, 0.8	173	8.9	49	20	6.6	185	30	6
6	0.5	0.17, 0.3	138	21	77	42	9.5	133	28	6
7	1.0	0.11, 0.2	128	35	131	71	9.8	114	26	6
8	3.5	0.04, 0.07	119	89	688	183	9.3	72	18	4

[a]Distance from centerline at which ΔT = 1/2 ΔT centerline.

pressure levels at locations in the vicinity of the power plant will be affected by various features of the landscape and prevailing weather conditions. In addition, the presence of other cooling towers or structures will modify the noise pattern. A procedure has been developed for calculating the sound pressure levels in terms of both octave band levels and overall levels that can be expected at specified points in the vicinity of a nuclear power station that is served by natural-draft cooling towers.[11] Minor adjustments to the procedure would make it applicable to forced-draft tower installations. This procedure was then used to determine the noise levels at 4-reactor power stations, as well as those in and near the Kentucky Lake Surrogate Site containing 40 natural-draft cooling towers.

2.2.4.1 Attenuation of radiated sound. As the sound radiated by the cooling tower travels through the air, acoustic energy is extracted by viscous effects, heat transfer, and molecular absorption. Of these, molecular absorption is the predominant mechanism and is strongly dependent on the ambient temperature and relative humidity of the air. With the use of A.R.P. 866 data[12] on the dependence of this atmospheric absorption of sound energy on temperature and relative humidity, the attenuation in each octave band was subtracted from the corresponding spectral value of the radiated sound pressure level at the receiving point.

When the noise is being generated by an installation with more than one tower, many receiving points will be screened by one tower from another. If the noise level at the receiving point is reduced by 10 dB for the screened tower, the level due to both towers (assuming equal acoustic power for each tower) will be less than half a decibel higher than the level at that point due to the unshielded tower alone. Consequently, when visual line of sight between a receiving point and a tower occurred, the contribution of that tower to the noise level at that receiving point was taken to be negligible.

The variation of mean temperature and horizontal wind speed with height above the ground causes refraction of propagating sound waves. This is because these gradients cause the mean speed of sound to vary with height. The sound can be refracted upward away from the ground and cause an acoustical shadow zone when there is a strong negative temperature gradient or at points up wind from the source. The effect of a wind gradient is usually the more important of the two and will override the temperature gradient effect resulting in no shadow zone down wind. Wiener and Keast[13] have developed equations with which the location of the shadow zone, if one exists, can be approximated and with which the excess attenuation can be calculated at any distance from the source.

The excess attenuation of a propagating sound wave due to vegetation is considered in two parts: first, the attenuation due to shrubbery and thick grass and, second, the attenuation due to thick stands of trees. Analytical approximation of the corresponding attenuations are given in Beranek.[14] These equations give the excess attenuation for these two cases as a function of distance from the source and frequency of the sound wave. For broad band noise, the equations are applied to the sound pressure levels in each octave band using the octave band center frequency in the appropriate attenuation equation.

Each of the appropriate attenuations was made for each boundary point and cooling tower to obtain the octave band sound pressure levels at the boundary point at which the total noise level was being calculated. The total attenuated octave band and overall sound pressure level due to all towers was calculated at each boundary point by superimposing the level at that point calculated for each tower.

2.2.4.2 Application of noise prediction methodology to the Kentucky Lake NEC Surrogate Site. The noise prediction methodology was coded in FØRTRAN IV for numerical computation on the IBM System 360 Model 91 at the Oak Ridge National Laboratory and used to compute the predicted noise levels at various points at the Kentucky Lake Nuclear Energy Center Surrogate Site. First, the levels were computed at points around an arbitrarily chosen boundary of one of the 4-reactor groups as though it were operating as a single dispersed reactor installation. The methodology was then used to predict the noise levels at a series of points in the NEC Surrogate Site with ten of the 4-reactor units, making a total of

40 cooling towers. The points chosen were along a line, one end of which was near the center of the site, extending over 11 miles to the north.

In both cases, the elevations of the cooling tower bases and the points at which the noise levels were computed were assumed to be identical. Ecological surveys indicated that the site is covered with heavy stands of deciduous trees. Consequently, noise levels were computed to include both cases: when the trees are in full foliage and when they are bare.

In the absence of data concerning wind and temperature variations, the gradients of both were assumed to be negligible.

Acoustical screening was assumed whenever the line of sight between a particular cooling tower and computation point was obstructed by another cooling tower or an adjacent building.

The values of the various parameters used to calculate the acoustic power of each of the cooling towers are given below:

Cooling tower base radius, m	61
Distance from water culvert to pond, m	11.8
Packing depth below ring beam, m	0
Pond to packing height, m	8.96
Pond to ring beam height, m	8.96
Elevation of tower base, m	152
Cooling water flow rate, kg/sec	57,500

The corresponding acoustic power of each cooling tower using these data was computed to be 7.06 W. This acoustic power corresponds to an A-weighted* sound pressure level of 93.2 dB(A) at the run of each tower.

Results for a typical four-reactor site. The noise levels were computed at twenty points along the arbitrarily chosen boundary of the typical 4-reactor site. The site chosen was the 4-unit group farthest north and

*A sound filtering system having a characteristic that roughly matches the frequency response of the human ear for sound levels up to 55 dB. (Frequently used at higher levels.)

west at the Kentucky Lake NEC Surrogate Site, as designated in Fig. 7. The noise levels that were computed at these points are given in Table 7 for the cases when the trees are in full foliage and when the trees are bare.

As can be seen from Table 7, the noise levels vary from a minimum of 51 dB(A) at point number 12 to a maximum of 64 dB(A) at point number 18.

Results for Kentucky Lake NEC Surrogate Site. The noise levels were computed at twenty points along a line starting near the center of the Kentucky Lake Surrogate Site and extending due north 11.4 miles. The points along the line are 3/5 of a mile apart and are shown in Fig. 7. The computed noise levels are given in Table 8 for the cases of full tree foliage and bare trees.

The levels vary along this line from a minimum of 47 dB(A) at point 20 to a maximum of 66 dB(A) at point 1. The attenuating effect of a thick stand of trees over appreciable distances is evident in that the levels at sixteen of the measurement points is inaudible and very nearly so at the remaining points.

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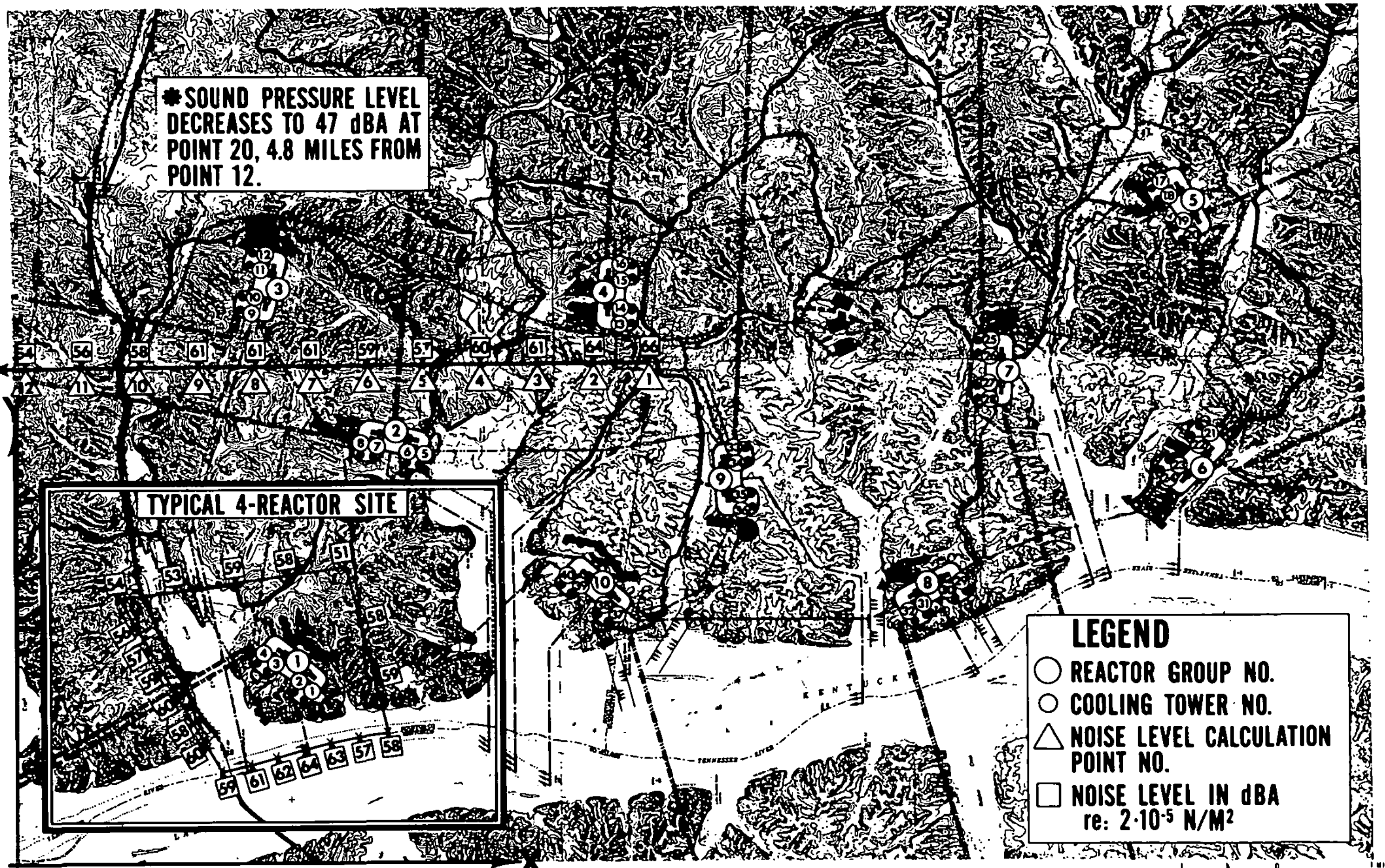


Fig. 7. Cooling tower noise at Kentucky Lake surrogate site.

Table 7. Computed sound pressure levels around a typical four-reactor site

Boundary point number	Sound pressure level[a] [dB(A)]	
	Trees in full foliage	Trees bare
1	59	59
2	60	60
3	58	58
4	60	60
5	59	59
6	57	57
7	56	56
8	54	54
9	53	53
10	59	59
11	57	58
12	0	51
13	52	58
14	5	59
15	58	58
16	57	57
17	63	63
18	64	64
19	62	62
20	61	61

[a] Re: 2×10^{-5} N/m^2.

Table 8. Computed sound pressure levels for Kentucky Lake NEC Surrogate Site

Noise computation point number	Sound pressure level[a] [dB(A)]	
	Trees in full foliage	Trees bare
1	8	66
2	7	64
3	0	61
4	0	60
5	0	57
6	0	59
7	0	61
8	6	61
9	5	61
10	0	58
11	0	56
12	0	54
13	0	52
14	0	51
15	0	50
16	0	49
17	0	49
18	0	49
19	0	48
20	0	47

[a]Re: 2×10^{-5} N/m^2.

3. TERRESTRIAL ECOLOGY

In the following sections, a discussion is presented for comparing the ecological impacts of a nuclear energy center with those of dispersed sites of equivalent power generation if all the desired data were available. Following each part of the general discussion are some analyses for the Kentucky Lake Surrogate Site and its dispersed site counterparts as discussed in Sect. 1. The analyses that were done were those for which some data were available or could be inferred and those that could be done within the time constraints imposed. In some sections the analysis is purely descriptive, but in others some conclusions could be drawn. A much more detailed analysis would be expected when evaluating a real site.

3.1 Site and Transmission Corridor Description

To ascertain the amount of ecological impact of construction and operation of NECs and dispersed nuclear power plants, as complete a biological and ecological investigation as practicable should be performed for areas that may be disturbed. The analysis would describe the flora and fauna of the site and the surrounding areas. A description would be made of each known taxon considered endangered and/or threatened, and its known distribution would be mapped; the study would include, when possible, species that migrate through the area or that use it for breeding habitat. A discussion of past or current biological studies relating to the proposed construction in the region should be reviewed and interpreted.

The description of the transmission line corridors would be similar to the site description. However, special effort should be made to point out and evaluate any dissection of the ranges and/or habitats of sensitive populations of fauna or interference with bird migration routes.

3.1.1 Soils and physical features

The nearness of unique geologic features that could be disturbed would be ascertained from geologic maps and associated data. These features may include caves and caverns that could be affected by erosion and possibly could be an important habitat for endangered or threatened species.

A description of the soils according to suitability classes within the sites should be made; this can usually be done from county soil survey maps or Soil Conservation Service (SCS) information. However, in some cases these maps do not exist. Where this is the case, an effort should be made to produce a soil survey map from which suitability classes can be determined. These maps can be invaluable for evaluating erosion potential from such factors as soil type (texture) and soil phase (slope-erosion) within a prospective construction area.

A description would be made of the soil suitability classes within the proposed transmission line corridors and should be a description comparable to the site evaluation.

Surrogate Analysis

Descriptions of soils and their associated erosion potentials have not been included in the surrogate comparison of NECs and dispersed sites because of time and resource constraints. This information and descriptions of unique physical features would be expected to be included in a later, more detailed site-specific study.

3.1.2 Land use

A regional description of land use would be made with specific consideration given the proposed sites. Special emphasis would be given the agronomic impact of construction and operation of NECs and dispersed siting.

Surrogate Analysis

By using values from the Hartsville Generating Station Draft Environmental Statement, some estimates can be made of actual land requirements for both NECs and dispersed sites. The restricted area (i.e., the construction site and buffer zone needed for the operation and maintenance of the generating hardware) will be about 2000 acres for each individual 4-unit station.

If no restrictions on land use outside the station area are assumed, 20,000 acres will be required for the large NEC, 5000 acres for the small NEC (i.e., 2.5 four-reactor facilities), and 2000 acres for each of the single 4-reactor dispersed sites. Except for transmission lines, the area between the individual facilities at the large and small NECs should not be significantly disturbed or removed from current land use practices.

The present land use within the region of the Kentucky Lake 40-unit surrogate NEC is primarily forest cover. Very little farming occurs within the boundary of any of the proposed reactor sites.

No historic places are recognized by the National Register in either of the counties containing the surrogate site. A different situation of land use can be seen within the area of the 4-unit Hartsville plant. This area is currently about 90% farmland. Although pasture and hay are the crops grown on the majority of the farmland, tobacco, corn, and soybeans also occupy a significant portion of the farmed land. The National Register of Historic Places recognizes one historic place within 10 miles of the proposed site.

The transmission line facilities for the 40-reactor NEC require approximately 54,694 acres (2055 miles x 225 ft) of land. The 4-reactor surrogate sites require 49,791 acres (1826 miles x 225 ft), and the 10-reactor NECs require approximately 33,184 acres of land (1217 miles x 225 ft). Of these totals, 39, 57, and 51% of the respective amounts are forested.

3.1.3 Ecological communities

Maps (existing or produced) that show the distribution of plant and animal communities within the vicinity of the generation stations should be used for locating unique or sensitive habitats. However, for the surrogate comparison, maps and other important documentation were not available.

3.1.3.1 Plants. As complete an inventory of known vascular and nonvascular plants as practicable would be made in any area of suspected effect from the proposed site(s). A more specific (large-scale) map and description, including habitat requirements of important species[15] would be produced for any known or suspected endangered or threatened taxa. The Smithsonian list of endangered and threatened plants would be consulted for this effort.

Surrogate Analysis

The proposed site of the Kentucky Lake NEC is located within the Mississippi Plateau section of the Western Mesophytic Forest Region. Essentially all of the intended sites are currently covered by forests typical of the region. The topography is generally hilly and supports various mixtures of oaks and hickories. A white oak-hickory forest type usually dominates the slopes, whereas the ridge tops predominately support an open-canopy forest of hickories and chestnut, black, post, and blackjack oaks. This forest type generally contains a fairly well developed shrub and/or understory strata. The ravine communities of the region contain a more mesic species composition of beech, yellow poplar, sugar maple, and white oak.

The 4-unit surrogate site is located within the Western Mesophytic Forest Region — more specifically, the northern portion of the Nashville Basin. The natural forest vegetation of this region consists of trees typical of the Cedar Glade community: red cedar, post oak, shagbark hickory, redbud, and winged elm. However, on the proposed site, about 90% of the forest vegetation has been replaced with various agronomic activities, as discussed in Sect. 3.1.2.

At present, no endangered or threatened plant taxa are known to be located within the Kentucky Lake NEC area. However, one species (*Silphium intergrifolium* var. *gattingeri*) has been reported just north of the proposed site in the Land Between the Lakes recreation area. Special attention should be given to examining likely habitats (dry grassland type of vegetation) where this species could occur.

On the 4-unit surrogate site, 257 plant species have been identified. Of these, one species, *Onosmodium molle*, is considered by local botanists to be endangered or threatened.

Vegetation on the transmission line rights-of-way for the surrogate cases has not been characterized for this analysis. A variety of forest types — oak-hickory, mixed mesophytic and pine — as well as other plant communities are expected to be traversed by lines. Whether any endangered or threatened plant taxa are located in the surrogate rights-of-way or adjacent areas is not known. This site-specific information should be available for a detailed comparison of routing and surrogate comparisons, but it requires the application of aerial photography and extensive field work, which are beyond the scope and resources of this study.

3.1.3.2 Animals. A list of known terrestrial animals (mammals, birds, reptiles, and amphibians) would be made. This list would include resident and migratory individuals and/or populations. A more specific map and description of habitat requirements should be produced for important species[15] and any endangered or threatened taxon.

Surrogate Analysis

Common faunal components of the Southeastern region encompassing the NEC and dispersed surrogate sites and transmission facilities include about 241 avian species, of which approximately 104 are known to be breeding species and 43 are known to be migratory. These include over 25 game species, 11 species of hawks and vultures, 4 species of owls, 7 species of woodpeckers, and about 84 species of the perching birds such as sparrows and warblers. Mammalian species are represented by the opossum, three species of shrews, the eastern mole, nine species of bats, the eastern cottontail, and four rodents (woodchuck, squirrels, mice, chipmunk). The bobcat, striped skunk, weasel, mink, raccoon, gray and red fox, and white-tailed deer are other mammalian species that are typical of this region.

The surrogate region contains several heavily used waterfowl migration corridors.[16] Over 12 million ducks use the Mississippi Flyway each fall en route to wintering grounds. Several wintering areas are close or adjacent to surrogate sites.

Approximately ten threatened or endangered species may occur in some part of the surrogate region. They are the American alligator, Southern bald eagle, Mississippi sandhill crane, American peregrine falcon, American osprey, Golden eagle, red-cockaded woodpecker, Bachman's warbler, Indiana bat, and Eastern cougar. Field studies are necessary for confirmation of the presence or probable absence of these species on specific sites.

The presence or absence of particular animals on any particular site will be highly dependent on the particular plant communities that are present and their suitability as habitats for specific fauna.

3.1.3.3 Sensitive habitat components. Potential sites for NECs would be examined for sensitive habitat components. These are generally defined as breeding areas, areas that are used during animal migrations, and components that are required for completion of some part of the life cycle of a particular plant or animal species. Efforts would be undertaken to determine, through onsite surveys, contact with knowledgeable agencies, and pertinent literature searches, whether any sensitive habitat components are present on or adjacent to sites and transmission line rights-of-way.

The following criteria should limit the scope of this determination. Only species that are commercially or recreationally valuable, threatened or endangered, critical to the structure and function of the ecological system, or biological indicators of radionuclides in the environment or those that affect the well-being of some important species within the former categories would be considered in the determination of the presence of sensitive habitat components.[15] The physical extent of examination would include the area within the proposed boundaries and the extent of any ecological community containing a sensitive habitat component that extends outside the boundary.

Surrogate Analysis

Descriptions of sensitive habitat components are not available for the surrogate comparison due to time and resource constraints. As far as is known at this time, no proposed or recognized natural areas are located within or adjacent to the surrogate sites and rights-of-way. Several wildlife refuges are located near or adjacent to the surrogate sites. Additional information on these habitats should be collected for any future proposed comparisons.

3.2 Effects on Terrestrial Ecology

Construction and operation of nuclear power facilities will cause ecological disturbances of varying degrees. The areas of effect would be considered to be those containing habitat alterations that are caused by clearing, excavation and filling activities associated with construction, and the operational impacts due to the heat dissipation system and transmission facilities. Habitat alterations would be detected by means of appropriate remote sensing and field techniques to yield population, community, and regional data for pre- and post-construction periods.

3.2.1 Construction effects

Disturbances due to construction will range from complete destruction of all plants and some animals at the actual sites of construction to relatively mild perturbations of the biota and physical features of surrounding areas. Habitat losses due to changes in physical features and losses of vegetation due to clearing, erosion, and herbicidal contamination can result in altered ecological community structure. The physical area of habitat affected will be delineated by the extent of disturbance to the natural edaphic features and the extent of permanent alteration of vegetation from natural conditions. The area of toxicant effects will be the areas around each toxicant source in which detection of toxicants in or on organisms can be measured and in which the level of toxicants is above levels typical of preconstruction conditions.

3.2.1.1 Effects on soils and physical features. Soils and physical features will be affected by construction through clearing, excavation, and filling activities. Soil profiles will be completely destroyed in some areas. Drainage patterns will be altered through changes in the natural topography due to earth moving, and some erosion will occur resulting in soil losses.

The extent of disturbance to soils and physical features due to construction will depend on the topography and the types of soils present as well as the amounts and types of fill and removed material involved. Factors to be considered are the total acreage affected, the acreage with slopes of 20% or greater, the erosion potential of the soils present, the degree of disturbance of natural drainage patterns, the amounts of excavated material and fill, the method of vegetative clearing used (mechanical or herbicidal), and the vegetative cover type that becomes established after construction.

The spatial extent of disturbance will be considered to be the extent of measurable habitat alteration due to construction activities. Erosion would be measured by using appropriate field measurements or literature values of the amount of expected suspended solids in the runoff. Erosion must be limited, according to EPA standards, to 50 mg/liter suspended solids in the runoff. Erosion is not likely to be a problem if proper control procedures are followed. Alterations in natural features would be quantified by approximations of the amounts of material (rock, soil) disturbed and/or moved through cutting and filling activities. Ratios would be calculated for each type of material and activity and should yield some measure of the magnitude of alteration of physical features. Areas in which the soil profile is destroyed and measurable soil losses have occurred can also be estimated and compared for each case.

Surrogate Analysis

Clearing, grubbing, and excavating required for the reactor site preparation will result in soil loss from erosion of considerable magnitude. By using the Kentucky Lake site as an example, a soil loss equation[17] was used to calculate the amount of soil lost during the construction of an NEC. The equation,

$A = RKLSCP$,

where

A = tons of soil lost per acre per year,

R = a constant derived from rainfall amount and seasonal distribution,

K = erodibility constant of a given soil,

L = slope length in feet,

S = slope steepness in percent,

C = cropping management,

P = conservation practice,

was developed specifically for Tennessee soils. The values for R, K, C, and P are taken directly from the literature; the values for L and S are estimated, and the appropriate soil loss ratio derived from these two parameters is taken from Jent et al.[17] The value given these two parameters (with all other variables held constant) can be a source of significant variation in the calculated soil loss values.

For example, if the average slope length and steepness are estimated to be 200 ft and 20%, respectively, 567 tons of soil will be lost per acre per year. This value, assuming a 1940-acre site and 25% addition for laydown area, represents a total loss of 1,374,975 tons of soil loss per year per site. Converted to a vertical measurement in terms of soil depth (2250 tons of soil per acre-foot[18]), this is equivalent to 3 in. of soil loss per year. However, if the values for L and S are assumed to be 100 ft and 6%, respectively, then the loss is reduced to 0.03 ft of soil loss per year per site, corresponding to a loss of 66.15 tons/acre per year.

Because of a lack of data, no analysis was made of the surrogate 10-reactor NECs or dispersed sites.

3.2.1.2 Effects on land use. The extent to which construction interferes with or inhibits specific land use practices would be estimated through field observation and relevant literature. Areas of effect would include not only the immediate areas of construction but outlying areas as well. Construction effects can impact surrounding areas through the production of erosion, noise, dust, and smoke as well as the destruction of valued visual horizons. The amounts of each type of inhibited or prohibited land use due to construction activities would be estimated and compared for each surrogate case. Where prohibition of land use results in economic losses (agricultural and wood products), these costs will also be estimated and compared.

Surrogate Analysis

In the immediate area of site preparation, preconstruction land use practices will cease. In adjacent areas, disturbances to land use practices are expected to be minimal or temporary in most cases. At the Kentucky Lake NEC, some public lake accesses and at least one boat dock are close enough to the reactors to be affected by the construction activities. The transmission grid that connects each of the 4-reactor units with three other units is likely to interrupt some farming activity during construction. However, the extent of this disturbance should be insignificant to present land use if proper routing techniques are used for the lines. The disruption of land use practices is expected to be of equal magnitude for each of the surrogate cases due to the similar land requirements.

Land use for the surrogate transmission line rights-of-way analysis has been divided into forested and nonforested categories. This does not allow discrimination of specific construction impacts. More acreage is involved during the construction than during the operation of rights-of-way; thus, compatible land uses are more limited during construction. In general, the largest impact results from vegetation removal and damage due to the presence and operation of heavy equipment. The impact of transmission line construction would be expected to be related to the specific practices employed during construction and specific site characteristics. A rough index of adverse impact is the amount of forested land to be cleared because the clearing of all tall trees is usually required for rights-of-way. Using this index, the following ratios were obtained for each case:

Ratio	Forested acreage
40-reactor NEC/40-reactor NEC	1.00
10-reactor NEC/40-reactor NEC	0.81
Dispersed (4-reactor) sites/40-reactor NEC	1.35

The ratios for the surrogate sites used in this analysis indicate that the least construction impact would be expected for the 10-reactor NEC case, and the most for the 4-reactor site case. Transmission line acreage requirements as well as acreage of forested land are dependent on the specific configurations of load centers and sites; thus, the surrogate comparison should be viewed as only one of a number of possible configurations.

3.2.1.3 Effects on ecological communities. Plants. The expected effects on plants due to construction activities associated with NECs, dispersed sites, and transmission facilities are reduced vigor and/or mortality due to clearing activities resulting in alteration or destruction of the ecological communities present.

The areas affected will be those habitats altered or destroyed directly or indirectly through clearing or filling activities. Areas affected by herbicide use that are not included in areas of habitat alteration due to clearing and earth moving will be those areas in which an effect due to herbicides can be detected. Changes in community structure, which may occur due to construction, can result in changes in productivity. The number of plant species that will be affected by construction activities would be estimated from field inspection and vegetative maps. The amount of land removed from production due to construction and losses of projected productivity calculated for agricultural and forest lands and, wherever literature values are available, for other plant communities would also be estimated. The number of acres of each type of plant community to be cleared would be calculated through field observations and/or extrapolation from topographic maps or aerial photos. The approximate number of acres of plant communities that are affected by herbicides and erosion damage would be estimated from field observations of similar cases and relevant literature. Wherever possible, the area encompassing any energetic or reproductive requirements that are adversely affected, resulting in the collapse of important community components,[15] would be estimated through field observations and relevant literature. The proportion of the total and breeding population affected and the known distribution of the species would be considered for each case and compared directly.

Surrogate Analysis

Surrogate site construction effects on natural plant communities are highly dependent on specific site conditions. Data (i.e., floristic list, timber cruise, etc.) necessary for an effective evaluation of construction at the Kentucky Lake NEC site were not available.

At present, the Hartsville site is primarily devoted to farming activities; little natural vegetation (forest) exists on the proposed site. Therefore, the effect of construction will essentially be the removal of the acreage from agricultural productivity.

The surrogate transmission line comparison was based on rough estimates of forested acreages on rights-of-way. Losses due to clearing are greatly dependent on the construction practices employed and the specific productivities of the forested areas. This information was not available for the present analysis. If equivalent technologies are assumed and if forested acreage alone is considered, the transmission facilities of the 10-reactor case would have the smallest impact of the surrogate cases examined because it has the least amount of right-of-way.

Animals. The observable impacts on fauna due to construction activities will be reduced population size due to mortality and/or reduced reproductive rates. These effects are due to direct damages through construction activities such as clearing and indirect effects due to habitat losses and the toxic effects of herbicides.

Areas of effect would be considered to be those areas of alteration of habitats containing reduced populations of important species due to construction. Species that use these habitats for only a short period (e.g., migrating waterfowl) would be included in this consideration.

Wherever possible, populations of animals adversely affected by herbicide use would be included as an adverse effect.

The comparison between the NEC and dispersed siting cases would be based primarily on the number of important species affected and the extent to which the species' breeding populations are numerically reduced. These would be estimated by using the areas of effect (above) in concert with field observations and/or examination of pertinent literature. A quantification of faunal effects would be made by constructing the ratio of

$$\frac{\text{NEC: } \Sigma \text{ (Species affected) (\% Reduction of breeding deme)}}{\Sigma \text{ dispersed sites: } \Sigma \text{ (Species affected) (\% Reduction of breeding deme)}}$$

In addition, the disturbance of a rare species' habitat, even if the animal uses the proposed construction site and immediate area for only a portion of its life cycle or part of the year, would be noted in view of the mandate of the *Endangered Species Conservation Act of 1973.*[19]

Surrogate Analysis

Construction effects on animals cannot be quantified for the surrogate comparison due to the lack of specific data on the surrogate sites and on the construction practices employed. Onsite preparation can be expected to cause losses of most of the fauna in the immediate areas of construction, and noise will cause disturbances to fauna in surrounding areas. The types of habitats present after construction will determine the long-term effects on animal populations.

Floristic manipulation on rights-of-way can result in a more diverse fauna than that which existed formerly, or it can result in reduced diversity. Rights-of-way with diverse flora (forbs and shrubs) can support more species of animals due to the variety of habitats available. Many game species prefer edge habitat, which rights-of-way can provide if proper vegetative management practices are used. Animals that require mature forest habitat will be adversely affected due to tree removals.

Wildlife usage of variously treated rights-of-way (unsprayed, broadcast sprayed, or basal sprayed) seems to involve species-specific responses. In a series of studies, deer, grouse, and rabbits were found to be much more numerous on unsprayed corridors, whereas squirrels and turkeys were more numerous on sprayed corridors.[20]

Several possible effects of herbicides on fauna need further investigation if they are to be related to changes in community structure: modified toxicity and/or palatability of treated flora to fauna, teratogenic effects in fauna, effects on insects, and possible synergism with insecticides resulting in predator-prey imbalances.

Sensitive habitat components. Sensitive habitat components that can be affected during construction through habitat destruction or alteration are breeding areas, areas used during animal migrations, and components required for completion of some part of the life cycle of a particular plant or animal species.

Areas of effect will be the same as those delineated in the plant and animal sections. Areas containing sensitive habitat components would be segregated from the total "areas of effect," and a separate comparison produced. The number of acres of each type of sensitive habitat for plant species adversely affected would be estimated and compared with the regional (or U.S.) availability of this type of habitat. For each faunal species, the expected percentage reduction in the breeding population due to the destruction of a sensitive habitat component would be estimated and compared with the known distribution and abundance for the region (or United States). Field observation, remote sensing, aerial photos, topographic maps, and relevant literature would be used for estimating these values. Direct comparisons of these values would be made for each case, as would be done for effects on plants and animals.

	Σ dispersed	Σ 10-reactor NECs	40-NEC
Acres of each type of sensitive habitat destroyed			
% Regional reduction of each type of sensitive habitat			
% Reduction in breeding deme for each important species			

Surrogate Analysis

Descriptions of sensitive habitat components were not available for the surrogate comparison.

3.2.2 Operational effects

The primary terrestrial disturbances due to operation of nuclear power plants will be effects due to the heat dissipation system and transmission facilities. The heat dissipation system causes weather, toxicant, and habitat effects on and in terrestrial ecosystems. Toxicant effects, including electrical effects and habitat effects are the major areas of impacts due to the operation of transmission facilities.

3.2.2.1 Heat dissipation system. The primary terrestrial disturbance related to the operation of nuclear power plants is the potential impact of the heat dissipation system. Perturbations to the environment can generally be classified into one of the following categories: (1) heat, (2) moisture, and (3) drift (i.e., toxicants). Each of these source parameters is a characteristic associated with the operation of evaporative cooling towers. Because the three general categories represent releases to the atmosphere from a single source and the effects of heat and moisture are interrelated, the means for detection will be discussed simultaneously for (1) and (2), and separately for (3).

Heat and moisture. Because increased heat and moisture released into the atmosphere potentially cause a modification of living conditions for the biota, the overall effect of these additions to the ecosystem can be classified as contributions to weather modification. The ecological consequences of weather modification caused by power generation will depend upon the nature, duration, and extent of the modifications. The factors expected to affect the terrestrial biota are changes in precipitation, cloudiness, temperature, storm activity, and wind velocity and direction. The extent and duration of some of the changes can be predicted. Estimates of local fogging, icing, and increased cloudiness, made in Sect. 2 of this report, will define the affected areas for both NECs and dispersed sites. Comparison between the NEC and dispersed sites would be done by ratio comparison.

Predictions of larger-scale modifications are less exact, and the amplitude of natural variations in climate is such that changes caused by power generation may be difficult to discern. Several major atmospheric impacts could be better predicted with the aid of more research. These are the formation of "heat islands," increased precipitation, storm genesis or other changes in basic circulation patterns, and vortex formation due to waste heat rejection. The ecological effects associated with large-scale changes in weather would be estimated to the extent possible given the state of our knowledge, and comparisons would be drawn between the NEC and dispersed siting where possible.

Surrogate Analysis

An estimated 2 billion lb of air containing about 22 million lb of water vapor will be released from the 40 cooling towers of the Kentucky Lake NEC.[4] Depending on air temperature, humidity, and wind speed, the released vapor could produce a number of effects. As of yet, the exact behavior of the water condensate from 40 cooling towers, located relatively close together, is essentially unknown. However, on the basis of data from large-scale heat dissipation studies, adverse effects are probable.

Toxicants. Atmospheric transport of toxicants depends on meteorological conditions at the time of release, environmental conditions around the source, position of the source in relation to surrounding physical features, the physical and chemical properties of the toxicant, and its concentration at the point of release.

Transport of the toxicant can occur by other vectors after deposition from the atmosphere. The degree and kind of secondary transport will depend on location and physical characteristics in which the toxicant is deposited.

In view of the above statements, a unique situation of toxicant transport can be expected for each point-source release. To define the areal extent of toxicant transport, physical, meteorological, and ecological conditions must be evaluated at each site.

The initial extent of the affected area will be considered as the distance from the point source in all directions that toxicants would be measured at above accepted standards. This areal extent would be estimated using the drift analysis in Sect. 2. The "any detection" criterion should be initially followed because of the unknown long-term effects of many transportable toxicants. Comparison of the area of toxicant effects would be done by using a ratio comparison of the concentration due to the 40-reactor NEC and the concentrations due to the 4- and 10-reactor NECs.

Wherever background levels are known, a comparison with these would also be made. This will provide a preliminary comparative estimate of the affected area. A more refined estimate of the affected area would be established by examining the impacts of each of the toxicants when such information exists. The area of ecological effects can be established only by examining the biological impacts of each of the toxicants.

Surrogate Analysis

Drift analyses for the surrogate NECs and the dispersed sites are presented in Sect. 2 of this report. The model used was adjusted to reflect the plume rise resulting from a four-tower cluster, but it combines the drift from all clusters within an NEC. Maximum deposition is predicted 1 mile north of the towers. The amount of drift predicted for each case is: 40-reactor NEC, 33.2 lb/acre^{-1} year^{-1}; 10-reactor NEC, 8.3 lb/acre^{-1} year^{-1}; 4-reactor dispersed site, 3.32 lb/acre^{-1} year^{-1}. These amounts, which are not expected to cause vegetation damage,[21] are higher than those which would be found using the spacing proposed for the Kentucky Lake 40-reactor NEC. With 2.5 miles between four-tower clusters, none of the 0- to 2-mile circles of maximum deposition around each cluster overlap outside the site boundaries. At some places within the NEC, as many as four of the 0- to 2-mile circles overlap.

The maximum deposition expected at any location within the NEC was calculated by assuming that a point that was within 2 miles of four 4-reactor clusters was also within 4 miles of the other six 4-reactor clusters. With maximum deposition rates within 2 miles of 3.3 $lb/acre^{-1}$ $year^{-1}$, and within 2 to 4 miles of 1.1 $lb/acre^{-1}$ $year^{-1}$ for each cluster, such a point would receive a total deposition of 19.8 $lb/acre^{-1}$ $year^{-1}$. Outside the NEC boundaries, a point within 2 miles of one cluster and within 4 miles of all other clusters, would receive a total deposition of 13.2 $lb/acre^{-1}$ $year^{-1}$.

The maximum predicted airborne concentrations of salt 1 mile south of the towers are: 40-reactor NEC, 0.176 $\mu g/m^3$; one of the 10-reactor NEC sites, 0.4 $\mu g/m^3$; and one of the 4-reactor dispersed sites, 0.02 $\mu g/m^3$. These concentrations are not expected to cause vegetational damage.[22,23] No comparison of the area of toxicant effects has been made, because this amount of salt drift is not expected to cause adverse effects in any of the surrogate cases considered.

3.2.2.2 Transmission facilities. The major areas of impact due to the operation of transmission facilities are toxicant effects, including electrical effects and habitat alteration effects. Toxicant effects are due to herbicide use in the maintenance of rights-of-way, ozone production that is believed to be associated with coronal discharges of high-voltage transmission lines, and electrical effects such as low-level electrical fields and induced voltages present under high-voltage transmission lines. In this comparison, the assumption has been made that 765-kV lines will be used.

The effects of herbicides on the biota have been discussed in the sections under construction effects and will be assumed to be similar or less in magnitude because maintenance practices are similar to initial construction practices. Comparison of impacts would be accomplished in a similar manner as for the construction effects, but the chronic input would be considered whenever possible. Corona discharge is determined by conductor surface potential gradients, which in turn are dependent upon design parameters of the transmission system selected. Field studies have been conducted to measure increases in ambient ozone levels near energized 765-kV lines, but have been deficient in one or more areas of procedure, analysis, or interpretation.[24,25] Tests conducted for the Greenwood facility[26] for two 765-kV lines under the worst possible weather conditions at the edge of the right-of-way estimated an ozone concentration of 6.5 ppb for an 8-hr period. The National Primary Air Quality Standard for oxidants, as issued by the EPA, is 80 ppb by volume maximum arithmetic mean for a 1-hr concentration, not to be exceeded more than once per hour (Appendix D of 42 CFR 410). With proper design, ozone production could be minimized to levels below which vegetational damage is known to occur.[27,28] Because duration of exposure, age, temperature, relative humidity, vigor, presence of other pollutants, and light intensity, among other factors, all affect the response of a particular species to ozone,[29] a meaningful quantification and comparison of this effect is not possible at this time. Field tests should be conducted at facilities to determine ambient levels of ozone present under the transmission lines, along with the appropriate monitoring of any large concentrations of ozone-sensitive species for damages.

The electric field associated with an energized 765-kV transmission line will induce voltages in conducting objects within the field. If the object is well-grounded, the resulting potential between the object and the ground will be near zero. However, if the object is insulated from the ground, significant voltages may be induced and a potential shock hazard created. The magnitude of the charge, and therefore the severity of the shock, will be related to parameters associated with the transmission line design: line voltage, size and dimensions of the object, proximity of the object to the line, and degree of insulation of the object from the ground. Shocks can be prevented through careful grounding of conductors and of objects under the lines. It will be assumed that any effects due to shock hazards are roughly proportional to transmission line acreage and will be compared in this way:

$$\frac{\text{Acres of transmission line corridors: } \Sigma \text{ Dispersed sites}}{\text{Acres of transmission line corridors: NEC}} .$$

Habitat effects due to the operation of transmission facilities include changes in the community structure in rights-of-way and faunal disturbances due to noise and other sensory effects. These effects can be caused by toxicants, erosion, public usage, and the sound of operating lines. For example, there is some evidence that transmission facilities crossing wetland areas, which have waterfowl populations, cause behavioral modifications that apparently result in the absence of birds from an area within one-fourth mile from the line. The swaying of the lines in the wind, their reflective properties, and the humming of the lines are believed to be the contributing causes of the game birds' abnormal behavior.[30] Habitat alterations resulting from changes in community structure (e.g., forest to pasture) would be quantified for each case and compared:

$$\frac{\text{Acres of transmission line corridors forested: } \Sigma \text{ Dispersed sites}}{\text{Acres of transmission line corridors forested: NEC}} .$$

Quantification and comparison will be similar for other cases.

Surrogate Analysis

Land-use practices can, in most cases, continue after transmission facility construction. Vegetation management aims and practices will determine the possible land uses in rights-of-way. Most agricultural crops can continue, whereas forestry is usually limited to low-growing species. Losses of wood products, correlatable with acreage, occur throughout the lifetime of the rights-of-way. Structures cannot be built in rights-of-way, thus limiting some types of land uses.

Effects due to herbicide use, shock hazards, and habitat alterations are correlatable with right-of-way acreages. These effects were estimated by comparing the acreage requirements for forested and nonforested right-of-way land. Other types of data (such as changes in the availability of plant species that serve as wildlife food, cover, and nesting materials) should be produced for a meaningful comparison of future cases, as they are not necessarily correlated with right-of-way acreage and cannot be estimated from the table shown below.

A ratio of the acreages of these two broad categories of land types required for rights-of-way is shown below for the Kentucky Lake Surrogate Site and its counterpart:

Transmission line acreage ratios	Land type		
	Forested	Nonforested	Total
40-reactor NEC/40-reactor NEC	1.00	1.00	1.00
10-reactor NEC/40-reactor NEC	0.81	0.48	0.61
Dispersed (4-reactor) site/ 40-reactor NEC	1.35	0.63	0.91

The comparison shows that the effects correlated with acreage are least for the 10-reactor NEC case. Total acreages for the three cases reveal that the 10-reactor NEC requires the least acreage, and the 40-reactor NEC the most.

Breaking the acreage into forested and nonforested categories shows that the use of forested land is least in the 10-reactor NEC case, and greatest in the dispersed-site cases. The use of nonforested land is again least in the 10-reactor NEC case, and greatest in the 40-reactor case. The use of forested vs nonforested acreage is an artifact of regional land-use patterns and the particular configuration of load centers and sites, and values can be expected to vary widely between regions and design alternatives.

3.3 Summary Comparison

On the basis of analyses made in this report, the following comparisons of land requirements and of heat dissipation systems can be made for the 40-reactor NEC, the 10-reactor NEC, and dispersed siting.

3.3.1 Land requirements

Total land requirements for the different siting arrangements do not differ; however, land requirements for transmission line rights-of-way do, as shown in Table 9. As can be seen in the ratio comparison, the rights-of-way land-use requirements are least for the 10-reactor NEC option and greatest for the 40-reactor NEC option; the 40-reactor NEC requires 21,509 more acres than does the 10-reactor strategy, and 4902 more acres than does the dispersed-site case.

Table 9. Land requirements for transmission line rights of way

Acreage requirements	40-reactor NEC	Σ 4-reactors	Σ 10-reactors
Forested acreage required			
Site	20,000	20,000	2,000
Transmission facilities	21,156	28,565	17,060
Total (forested)	41,156	48,565	19,060
Nonforested acreage required			
Site	0	0	18,000
Transmission facilities	33,538	21,226	16,124
Total (nonforested)	33,538	21,226	34,124
Total acreage requirements	74,694	69,791	53,184
Transmission line acreage ratios			
System considered 40-reactor NEC			
Forested	1.00	0.81	1.35
Nonforested	1.00	0.48	0.63
Total	1.00	0.61	0.91

The amount of soil loss associated with construction will be much (35–305X) greater at the NEC site than the total expected from the small NECs or dispersed sites. This large difference is primarily a function of topographic relief, which is substantial at the NEC site.

Construction and operation of the different arrangements will result in spatial and temporal differences in impact on the disturbed areas. In the case of the large NEC, the construction disturbance will continue over a period of about 40 years. In the dispersed- or small-NEC cases, the construction effects will be relatively short-termed (6 to 14 years), and the impacts will be distributed over a wider area. The ecological difference of these arrangements at the regional scale cannot yet be fully evaluated. However, the ecosystem's ability to compensate for disturbance will likely be greatest in the dispersed-site case, for which the spatial and temporal extent of impacts is least.

3.3.2 Heat dissipation

The most significant and obvious difference among the siting arrangements is likely to be in the release of moisture to the atmosphere. If a substantial fraction of the released vapor from the cooling towers precipitates within a state-sized area, then a change in the plant communities could be detected. Studies of weather modification associated with urban heat release of the same order of magnitude as the 40-reactor NEC have shown an increase in storm activity down wind. This effect, coupled with the release of water vapor from the cooling towers of the 40-reactor NEC, makes a noticeable increase in precipitation quite likely. According to existing documentation, the dispersed-siting arrangement will not significantly increase moisture condensation in the area of the power plants. In any specific comparison such as this, regional land-use patterns, ecological characteristics of specific sites, and the configuration of load centers and sites will determine which siting strategy (40-reactor NEC, 10-reactor NECs, or dispersed siting) will have the least impact.

4. AQUATIC ECOLOGY

In the following sections, a general discussion for comparing the ecological impacts of a nuclear energy center with those of dispersed sites of equivalent power generation is presented if all the desired data are available. Following each part of the general discussion are some analyses for the Kentucky Lake Surrogate Site and its dispersed-site counterparts, as discussed in Sect. 1. The analyses that were done were those for which some data were available or could be inferred and those that could be done within the time constraints imposed. In some sections the analysis is purely descriptive, whereas in others, some conclusions could be drawn. A much more detailed analysis would be expected when evaluating a real site.

4.1 The Physical Environment

The physical, chemical, and hydrological characteristics of the surface- and groundwaters on and adjacent to the site that may be affected by construction or operation would be described. These descriptions will be based on data from state and Federal agencies where possible. When necessary, field studies should be carried out.

4.1.1 Water quality

Water quality descriptions of the NEC and dispersed sites should include seasonal ranges and averages of temperature, dissolved oxygen, pH, trace metals, nitrate, phosphate, and dissolved and suspended solids. Existing sources of pollution, when known, would be described. As above, existing data would be used where possible. In cases where no data exist, field studies will be necessary.

Surrogate Analysis

The water quality information used in this report was taken from data collected and published by TVA.[7] The samples used to approximate conditions at the surrogate NEC site were taken at river mile 91, about one mile upstream of the site. The range of values found is indicated by the yearly average, minimum, and maximum values shown in Table 10. A more complete chemical analysis is given in Sect. 2.2.1, Table 1.

Table 10. Water quality data for surrogate NEC site

	Maximum	Minimum	Average
Temperature, °C	29.6	5.0	18.6
Dissolved oxygen, mg/liter	13.8	3.5	9.3
pH	8.3	7.0	7.6
Turbidity, JTU	65	7	22
Total hardness ($CaCO_3$), mg/liter	89	50	62.8
Solids, mg/liter			
Dissolved	180	70	113
Total	240	90	134
Phosphate, mg/liter			
Soluble	0.29	0.02	0.14
Total	0.91	0.10	0.35
Nitrogen, mg/liter			
Organic	1.5	0.15	0.54
NH_3	0.50	0.01	0.11
NO_2	0.03	0.01	0.014
NO_3	0.86	0.01	0.38

The water is soft to moderately hard. It should be capable of supporting moderate to good freshwater fisheries and is satisfactory for most industrial and municipal uses. Thermal stratification was observed only in midsummer and in the downstream portions of the reservoir.

Environmental statements done for nuclear plants at various locations on the Tennessee River System indicate that water quality will vary somewhat between the surrogate sites, depending on land use and economic development. Analysis for specific sites was not made for this report.

4.1.2 Hydrologic characteristics

The hydrologic characteristics described for all water bodies that may be affected by construction or operation of NECs and dispersed generating stations will include flow rates, frequency and magnitude of floods, water elevations, currents, the effects of existing or planned control structures, and, where applicable, tides, wave actions, and flushing times. Seasonal fluctuations would be described by means of average, minimum, and maximum monthly values. The drainage pattern of the site and significant tributaries above and below the site would be described. Existing and projected consumptive water uses above and below the site would be listed.

Surrogate Analysis

Kentucky Lake is formed by the impoundment of the Tennessee River by Kentucky Dam. The lake extends from the dam 183.4 miles up stream to Pickwick Dam. The water is about 75 ft deep at the dam; the water surface covers about 250 sq miles. Flow through Kentucky Lake is regulated for flood control and power generation. For the twenty-one years between 1945 and 1966, the mean flow at Kentucky Dam was 68,040 cfs. The 7-day, 10-year low fow is 14,500 cfs. The TVA[7] describes the normal yearly variation in the lake as follows:

> The reservoir is held near full-pool level, elevation 359.0 from May 1 through mid-June and is then gradually drawn down to elevation 354.0 by December 1. Between this low-level stage and the top of the gates at elevation 375.0, the maximum storage space for flood control is available. As the threat of winter floods gradually passes, the reservoir is allowed to refill during April to full-pool level.

The cycle is varied to accommodate floods, or the threat of floods, as they appear.

The Kentucky Lake NEC site extends approximately from river mile 80 to river mile 90. In this section, the lake varies in width from 1.7 to 2.9 miles. A barge channel approximately 1000 ft wide and 50 ft deep runs through the lake. The depth of the overbank area varies from 0 to 26 ft, averaging about 10 ft.

The Hartsville site, assumed to be typical of the ten dispersed sites, is on Oak Hickory Reservoir on the Cumberland River. The general hydrologic regime is the same as that of the NEC site — a deep channel with shallow overbank and cove areas. Flows are managed in a similar manner as for the NEC site as a part of the basin flood control and power generation programs.

4.2 Community Structure

The aquatic community structure is definable from two related viewpoints: (1) spatio-temporal — species and their distributions — and (2) trophic — the energetic relationships among species. One is implied in the other; both should be examined to more accurately predict impacts.

4.2.1 Spatio-temporal

Migration patterns of species would be described. This includes circadian, circannian, and breeding migrations of fish and zooplankton. Breeding and nursery areas of fish species should be located. Habitat locations for fish species would be described and located relative to intake and discharge structures. Representative and important species would be listed and discussed. These are species that are (1) important to the local economy, (2) key components in the local community, and (3) rare and endangered species, which, because they have very specific requirements, are sensitive to perturbation. The above information would be generated by an extensive field study and literature search.

Surrogate Analysis

The aquatic community at the surrogate site is largely determined by hydrologic regime, described in Sect. 4.1.2. The community structure described for the Kentucky Lake NEC site is drawn largely from a TVA document.[7] Kentucky Lake is a deep (about 50 ft) channel averaging about 1000 ft in width, with wide overbank areas averaging about 10 ft in depth and many shallow coves.

The TVA studies indicate that algal productivity peaks in June, July, and August and that diatoms dominate the algal association. There are occasional blue-green algal blooms (usually the genus *Merismopedia*). The most common green alga is *Chlorella*.

Zooplankton densities peak in July; the association is dominated by rotifers. Other, more detailed studies on TVA reservoirs with similar morphometry and hydrologic regimes have shown a much higher (10-1000X) concentration of zooplankton in the shallow overbank and cove areas than that found in the channel. This implies that the overbank areas (1) may behave much like lakes and (2) may be water masses quite distinct from the channels.

The fish association is known largely from cove fish poisoning studies. The actual dynamics of the fish community are not well understood in that the open overbank and channel areas have not been studied thoroughly to date. Fish species found in cove studies were as follows:

Species of fish	Percentage of total numbers
Gizzard shad	43
Bluegill	26
Threadfin shad	15
Forage fish	4
Drum	3
Largemouth bass	9

There is evidence that catfish, carp, drum, and other fish inhabit the channel areas, but the sizes and distributions of the populations are unknown.

The community description for the dispersed sites is drawn largely from the Hartsville Draft Environmental Statement.[5] River flow at the Hartsville site is controlled. The morphometry of the impoundment is similar to Kentucky Lake — a deep (about 30 ft) channel, with shallow overbank areas and coves.

Algae are present in two basic associations: attached (periphyton) and free-floating (phytoplankton). Both associations are dominated by diatoms, with occasional high numbers of dinoflagellates (genus *Peridinium*). Green algae also constitute a measurable fraction of the group. Algal density is one to two orders of magnitude (10-100X) less than that found in other TVA reservoirs; this is thought to be a result of the short water retention time, absence of thermal stratification, and higher turbidity that characterize the site location. Rooted aquatic vegetation is not an important part of the plant community.

The zooplankton association is dominated by the rotifiers *Synchaeta, Polyarthra,* and *Asplanchna*, with the crustacean *Bosmina* present in substantial numbers.

The benthos, or bottom community, is dominated by Chironomid larvae, the clam *Corbicula*, and Tubificid worms.

Fish censusing, done largely by cove rotenoning, showed gizzard shad, carp, and bluegills most common, with crappie, sauger, buffalo, and drum also present. Walleye and catfish were taken in open-overbank gill netting and electrofishing samples and may be an important part of the fish association.

Larval fish were found to be 3 to 5 times as dense along shore as in the midchannel and about 10 times as dense in a tributary cove. Evidently, the overbank and cove areas are spawning and nursery grounds for the fish association.

Community description is necessary to predict the biological effects of various impacts. For this analysis, community description is too general for detailed assessment. However, some conclusions can be drawn: For example, for both NEC and dispersed sites, intakes and discharges should be placed in midchannel to minimize the entrainment and impingement of young fish; further, channel flow would appear to be somewhat discrete from overbank flow, and discharge water would be most quickly diluted by midchannel placement of diffusers.

4.2.2 Trophic structure

The trophic structure of the aquatic community would be examined by food-chain relationships and by estimation of biomass, turnover time, and production rates of species. Coupling this information with species' sensitivity to the various construction and operation effects will allow prediction of community impacts. The trophic analysis would be based on extensive literature review and field studies. This sort of an analysis amounts to a mapping of community energy flow over time, a type of work that has not, to date, been incorporated into decision-making processes. Modeling of energy flow and distribution in aquatic communities is in its infancy; this part of the community description is expected to be a major research effort. It will prove extremely worthwhile, however, as it allows the examination of environmental impact as perturbations of energy flow. This approach is likely to be the next step in sophistication of assessment impact, in that it allows development of a numerical index of impact.

Due to time constraints and lack of data, no trophic analysis was made.

4.3 Construction Effects

Construction activities that may alter or destroy aquatic habitats, including channelization, stabilization, and piping of streams, dredging of lakes and streams, and draining and filling of wetlands, should be examined at each site. Sedimentation, a secondary effect that accompanies almost all construction in or near water bodies, is considered separately.

4.3.1 Habitat alterations

Aquatic habitat alterations that may accompany construction include the elimination of habitats, the reduction of breeding and nursery areas, and the interruption of migration routes. To measure the amount of habitat destruction caused by construction of a power-generating facility, knowledge of the locations and lengths of channel alterations, the locations and sizes of dredged areas, and the locations and sizes of drained or filled wetlands would be necessary. To determine the effects of habitat destruction on population and community structure, one must know the population dynamics and habitat requirements of the organisms living in, breeding in, or migrating through the areas.

Comparing habitat alterations of NECs and dispersed sites can be meaningful in specific cases, but not in a generic sense. The amount of habitat alteration at an NEC can be compared with that at dispersed sites on an areal basis for each habitat type (e.g., comparing the number of acres of lake bottom dredged, the number of acres of wetlands filled, etc.). However, these areas will be specific to the design requirements at each individual site rather than to any inherent differences between requirements for NEC construction and dispersed site construction as currently conceived. Moreover, unless all sites are on similar water bodies, the ecological importance of the habitat alterations will not depend solely on the area involved, but on the resultant effects on the populations of species that use the area during some part of their life cycle and on the importance of those species either to man or to the ecological community. Individual investigations of a population's requirements in a specific area will be necessary to determine such population effects.

Clearly, the magnitude of the ecological effect of the larger area of disturbance at an NEC site compared with the effects of the same type of disturbance over several smaller areas depends on the nature of the areas disturbed rather than their size. When specific areas are to be compared, the first determination will be whether any species important to man (e.g., commerical species, officially listed rare and endangered species, sport species), to the life cycle of such important species, or to the structure and function of the ecosystem exist in the area. If such species are found, the studies required to determine whether the destruction of habitat that will occur will affect their population may be extensive, but they are necessary if comparisons are to be made. If such information is obtained for the same species under the different construction patterns being compared, the results can be compared numerically. Otherwise, discussion of the possible significance of the results without direct numerical comparisons will be necessary.

Surrogate Analysis

The types of direct aquatic habitat alterations caused by construction will be similar for large and small energy centers and dispersed siting. The main cause will be the dredging necessary for the installation of intake and discharge structures and barge slips. All site designs call for dredging in both main channel and overbank areas.

The 40-unit NEC occupies about 11 miles of Kentucky Lake shoreline, containing five coves where creeks enter the lake. The site layout, as currently conceived, calls for each cove to be dredged for two to five installations of intake lines, discharge lines, or barge slips. All ten discharge lines extend from the shore to the main channel. The 10-unit NEC occupies 2.5 miles of shoreline, containing one cove, which will contain two discharge lines and a barge slip. The three discharge lines will extend to the main channel. The 4-unit dispersed site involves no coves. The intake and discharge lines both extend to the main channel.

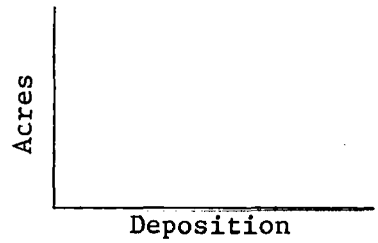
The dredging, and the resulting turbidity and sedimentation, will be similar in all cases, but the size of the 40-unit NEC and the length of its construction period may cause some differences in the ecological effects. The individual units within the NECs will be constructed sequentially; the coves will be subject to repeated, prolonged disturbances that will interrupt and delay reestablishment of populations, especially benthic populations that have been destroyed by sedimentation. No information is currently available on Kentucky Lake populations other than for fish and plankton; however, the reservoir is not expected to contain species that will be permanently affected by construction-related habitat alterations other than in the immediate vicinity of the construction.

4.3.2 Sedimentation

Sedimentation will occur as a result of transmission line construction, site preparation, and dredging operations around intakes and discharges. There will be a gradation in effect, with the greatest sediment load and mean particle size near its origin and the load decreasing with increasing distance from the origin. The ecological effects on increased sedimentation will be a function of intensity and species susceptibility. When the rate of deposition is great (near the source), localized destruction of the bottom community, along with the removal of fish with low tolerance to turbid water, can be expected. As the concentration of sediment decreases with distance, effects will consist of changes in plant distributions due to shading and nutrient loading. There may be chemical as well as physical effects from dredging (i.e., dredging of organic-rich sediments with a high BOD may produce anaerobic conditions over a large area for some period, and some sediments may contain toxic materials).

Sedimentation rates vary strongly with soil type, sedimentation control programs at the construction site, and precipitation and hydrologic patterns. Sedimentation rate estimates would be calculated for each area, they would assume good sedimentation control practices, and they would be analyzed using the far-field thermal plume model. This approach is conservative, in that it does not account for the sinking rate of suspended solids and does not consider differential sinking rates of sediment particles of varying size, but it is the best that can be done at present.

Comparison between NECs and dispersed siting would be done by graphing:



By displaying the summed effect of dispersed siting deposition on the same set of axes as the NEC-related deposition, any fundamental differences in sediment-load distribution would be obvious.

Surrogate Analysis

The sedimentation analysis done on the Kentucky Lake Surrogate Site is based on the estimates of soil erosion developed in Sect. 3.2.1.1. In that section, two estimates were developed, one assuming a slope of 6% and a slope length of 100 ft, and the second assuming a slope of 20% and a slope length of 200 ft. Given the extreme relief of the surrogate site, the 20%, 200-ft case is probably a closer approximation of conditions during construction. Use of these figures as a basis for sedimentation analysis is conservative, in that road, railroad, onsite transmission line, and fuel cycle construction and dredging have been ignored.

The analytical method used for this surrogate analysis is less sophisticated than that described in the preceding subsection, a fact necessitated by time constraints. The method used was:

a. The total number of acres contributing sediment to each cove was calculated by using USGS contour maps with the hypothetical generating stations superimposed. Sediment was assumed to run off with the contours.

b. The entire sediment load was assumed to be deposited in the receiving cove.

c. Deposition was assumed to be uniform throughout the cove.

d. Deposition was calculated for both the 6%-slope, 100-ft case and the 20%-slope, 200-ft case, on a monthly, yearly, and total (2 years) basis.

The results of these analyses are shown in Table 11; values have been rounded off where appropriate.

These data indicate that sedimentation will vary from cove to cove, the lightest deposition estimate being on the order of 0.44 cm per month (5.3 cm per year) and the heaviest being 68 cm per month (8.1 m per year). These sedimentation rates are substantial enough to cause major disruptions of the plant and animal associations in the coves. The disruptive effect of the sedimentation will be felt over 11 river miles. Typical of the kinds of changes resulting from the sediment loading are mortality of bottom-dwelling organisms and the failure of spawning efforts of fish. A full analysis of this problem should include examination of turbidity increases caused by site runoff; such an analysis has not been made for this surrogate case.

On a local scale, there is no doubt that this impact will be significant; the coves, known to harbor concentrations of fishes and zooplankton, will receive sediment at rates sufficient to actually fill some coves completely, removing the habitat permanently. Others will receive less sediment and return to an altered, but habitable, condition after construction (and its consequent sediment runoff) have ceased. Any sport fishing currently going on in these areas will be severely disrupted.

In the absence of site-specific data for the dispersed sites, the sedimentation data for the proposed Hartsville nuclear plant has been extrapolated to provide hypothetical data for the dispersed sites.

In the Hartsville Draft Environmental Statement, calculations based on data and methodology supplied by the Tennessee Soil Conservation Service indicated that some 1500 tons of soil would be displaced per year for six years as a result of construction activity for a 4-unit site. By the assumption that all displaced soil ends up in receiving water bodies, 9000 tons of sediment would be deposited at each site, and a total of 90,000 tons may be expected as a result of construction of all (10) the dispersed sites. By the assumption that each 4-unit site is

Table 11. Sedimentation analysis for Kentucky Lake Surrogate Site

Cove	Area (km^2)	Sediment (cm)					
		6%, 100-ft slope			20%, 200-ft slope		
		Per month	Per year	Per 2 years	Per month	Per year	Per 2 years
Hoop Pole Branch	0.052	8	9	192	68	816	1632
Richland Creek	3.393	0.48	5.76	11.52	4	48	96
Turkey Creek	0.984	1.3	15.6	31.2	11.3	135.6	271.2
Greenbrier Creek	0.207	3.15	37.8	75.6	27	325	650
Whiteoak Creek	4.973	0.44	5.3	10.6	3.8	45.6	91.2
Cane Creek	2.046	0.8	9.6	19.2	4.1	49.2	98.4

constructed according to the Hartsville schedule, sedimentation would be spread over six years at each site along about 1.5 miles of impoundment.

By using the same assumptions of soil displacement and sedimentation as for dispersed sites, the following estimate was made for sedimentation associated with the construction of 10-reactor NECs:

9000 tons/4-reactor site x 2.5 = 22,500 tons of sediment/site .

This sediment would be deposited over an interval of about 12 years and along some 2.6 miles of impoundment. Total sedimentation from the four 10-reactor NECs would be 90,000 tons and would be concentrated at the sites shown in Fig. 3 over a total interval of some 40 years if one assumes some overlap in construction.

The total sediment deposition from the 40-reactor NEC would be spread over an interval of some 40 years. In the analysis of this case, sedimentation was assumed to last for 2 years at each 4-reactor cluster, estimated to be the minimum amount of time necessary to grade the sites in that terrain. Given these assumptions, the total sediment load is calculated to be between 3.2 and 27.5 million tons, that is, between 35 and 305 times the total estimated for the ten dispersed sites. These data are summarized in Table 12.

Table 12. Comparison of sedimentation effects for surrogate sites

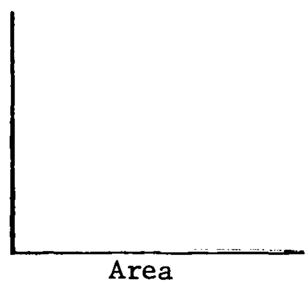
	Total sedimentation (tons)	Sediment/ site (tons)	Time of sedimentation/ site (years)	Scale of site (miles)
4-reactor x 10	90,000	9,000	6	1.5
10-reactor x 4	90,000	22,500	12	2.6
Kentucky Lake 40-reactor NEC	3.2×10^6 to 27×10^6	1.6×10^5 to 7.4×10^6	44	11

To arrive at an accurate comparative analysis of NEC vs dispersed-site effects, the sort of analysis done for the 40-reactor NEC should be done for each 10-reactor NEC and dispersed site because sedimentation is so much a function of geography and topographic relief. The relief at the 40-reactor NEC site is substantial; consequently, the sedimentation there is much greater than the total estimated for the dispersed sites. A central question here, as with many other aspects of the environmental comparison between NECs and dispersed siting, is whether aggregated (as with the NEC) impacts are of greater or less biological significance than dispersed impacts. At present, the science of ecology has not developed to the point that this question can be dealt with.

4.3.3 Chemical

Changes in water chemistry are expected as a result of construction. The concentrations of dissolved solids will change as a result of altered runoff rates, vegetative cover, and drainage patterns. The direction and magnitude of these changes would be estimated per unit area for each site (i.e., the NEC and each dispersed site) and scaled according to site size. Estimated change would be based upon SCS and USGS data on runoff water quality. Comparison between NECs and dispersed sites would be made with the use of a ratio:

$$\frac{\text{Concentration TDS: NEC}}{\text{Concentration TDS: Dispersed sites}}$$



No surrogate analysis of construction-related water chemistry changes has been made.

4.4 Operation Effects

4.4.1 Intake

Power plant intakes have considerable potential to cause significant aquatic environmental impacts. The spatial extent of intake effects is physically defined by the alterations in near-field current patterns. In actuality, the area affected by intake considerations is much greater, in that entrainment and impingement can affect fish populations, thereby affecting a much greater area. This area is difficult to define, but it should be considered as the region within which statistically significant changes in populations are expected. To evaluate these effects accurately, one must have a great deal of site-specific data, assessing cropping potential for fish species and estimating the impact on populations. This information should include population size estimates, breeding sites, migration patterns, and behavioral descriptions. Most of this information will have to be collected in field studies at each site, but some will be available in the literature. To the extent that this type of information is available, a comparison can be made by assuming that there will be shifts in community structure as far as intake effects are reflected in populations. A calculation of

$$\frac{\text{Area affected, NEC}}{\text{Area affected, } \Sigma \text{ dispersed siting}}$$

will provide an estimate of the relative impacts of the two systems. This mechanism will not discriminate that case in which a relatively small area is affected but a species population is eliminated.

No surrogate analysis of intake effects has been made.

4.4.2 Flow alteration

Flow alterations may result from the intake and discharge of cooling water, contour modifications from construction, and changed onsite runoff patterns. Changes in the vicinity of cooling water intake and discharge structures and around stormwater drainage systems may include currents, eddies, and flow reversals. Consumptive water use will reduce flows down stream of the plants. The upstream and downstream extent of all changes will be determined by local topography and flow conditions and by structure design.

Flow alterations affect the population and community structures of aquatic organisms by altering and destroying aquatic habitats. The extent and importance of the effects will be site-specific; they will depend on the type of water body involved, the exact locations and effects of intake and discharge structures, and the habitat requirements of the existing populations in the affected areas.

The magnitude of the flow-related impacts caused by energy centers and dispersed siting would be compared in a manner similar to the habitat alteration impacts (Sect. 4.3.1). If representative or important species[31] could be chosen for the area, they would be studied further and their habitat requirements compared with the anticipated changes in volume of flow, current patterns, velocities, and bottom sediment types. The possible significance of any alterations of feeding grounds, spawning areas, and migration routes would be discussed for each case.

Surrogate Analysis

Both the 40- and 10-unit energy centers and the surrogate dispersed site being considered in this study are located on impounded rivers. The reservoirs used as water sources are controlled for power generation and flood control, and these objectives, rather than the natural seasonal variations, determine their flow patterns. In Kentucky Lake, this results in the highest flows occurring in the summer and fall months, the times of lowest natural flows.

The mean flow at Kentucky Dam, the controlling structure for the Kentucky Lake section of the Tennessee River, is 68,040 cfs, and the 7-day, 10-year low flow is 14,500 cfs. In an artificially controlled flow of such magnitude, the consumption of 1200 cfs by a fully operational 40-unit energy center would not be expected to cause noticeable ecological effects. However, because the amount of water consumed is directly proportional to the number of units operating, the size of an energy center that can be sited on a given water body without causing serious adverse effects will be determined by the available flow. Local effects such as current alterations and flow reversals at intake and discharge structures will be site-specific and are not expected to differ in kind for energy centers and dispersed siting.

4.4.3 Thermal plume

The ecological effects of heated water discharges depend on the physical characteristics of the resulting thermal plume. The plume characteristics, in turn, depend on the hydrology of the receiving water body and the volume, velocity, and temperature of the discharge. The areas of plumes, and the temperature ranges within them, will vary seasonally, but they will be predictable for expected combinations of flow rates and ambient temperatures. The biological effects of thermal plumes occur as effects on individual organisms and become effects on population and community structure. Individual effects may be realized as thermal deaths, increased susceptibility to disease, and physiological changes such as interference with spawning, changed metabolic rates, and hatching out of phase with food organisms. Population and community changes are the result of individual changes, including those that result from habitat impairments such as elimination of spawning areas.

A comparison of the NEC and dispersed site thermal effects would begin with a consideration of the physical characteristics of the expected plumes. The plume sizes, shapes, and temperature ranges would be computed at average, minimum, and maximum flow rates for summer and winter conditions to determine whether the NEC creates a larger total rise in temperature than any dispersed site and whether the portions of the NEC plume within different temperature ranges are larger or smaller than the combined dispersed site plumes of the same temperature ranges.

The biological effects of the plumes will be site-specific and will depend on the requirements of the particular species found at each plume's location. At each site, the temperature range of the plume would be compared with the optimum temperatures and the tolerance ranges of the aquatic species in the areas. The shapes of the plumes would be examined to determine whether passage would be impeded. Impingement of the plume on sensitive habitat components (i.e., breeding areas, feeding grounds) would be examined. Unless the same species is affected in several areas, these results will not be amenable to direct numerical comparisons. Their possible significance, however, would be discussed.

Surrogate Analysis

In the conceptual designs of the 10- and 40-unit NECs and of the 4-unit dispersed sites, each 4-reactor group shares a single discharge structure. In all cases, the structure is assumed to be a two-port diffuser with the ports 70 ft apart. The spatial arrangement of the ten diffusers of the larger NEC can be seen in Fig. 1. The 10-unit NEC has three diffusers, two serving 4 units each and one serving 2 units. For this comparison, the three upstream diffusers of the larger NEC can be used to illustrate the 10-reactor case although the plumes have been calculated as if for 12 reactors. Each 4-unit dispersed site has a single diffuser.

All diffusers at the Kentucky Lake site discharge at the bottom of the main channel, and only main channel flow is considered in the thermal calculations. Because the channel is uniform in width and depth along the surrogate site, the individual diffusers create plumes with identical shapes under each given set of flow conditions. The temperatures vary, because the heat from the fully mixed plume of each diffuser raises the ambient temperature at downstream diffusers. A detailed description of the methods and assumptions used in the thermal plume calculations can be found in Sect. 2.

The patterns of the near-field summer and winter thermal plumes are shown in Fig. 8. In each case, temperatures are highest at the diffuser, but drop as the heated water becomes mixed with the river water. After the plume reaches the surface, it is assumed to mix completely with a column of water the width of the diffuser (70 ft) and the height of the channel (50 ft). No consideration is given to further mixing in the 1000-ft-wide channel or to heat loss to the atmosphere. In actuality, both will occur and further reduce the water temperatures.

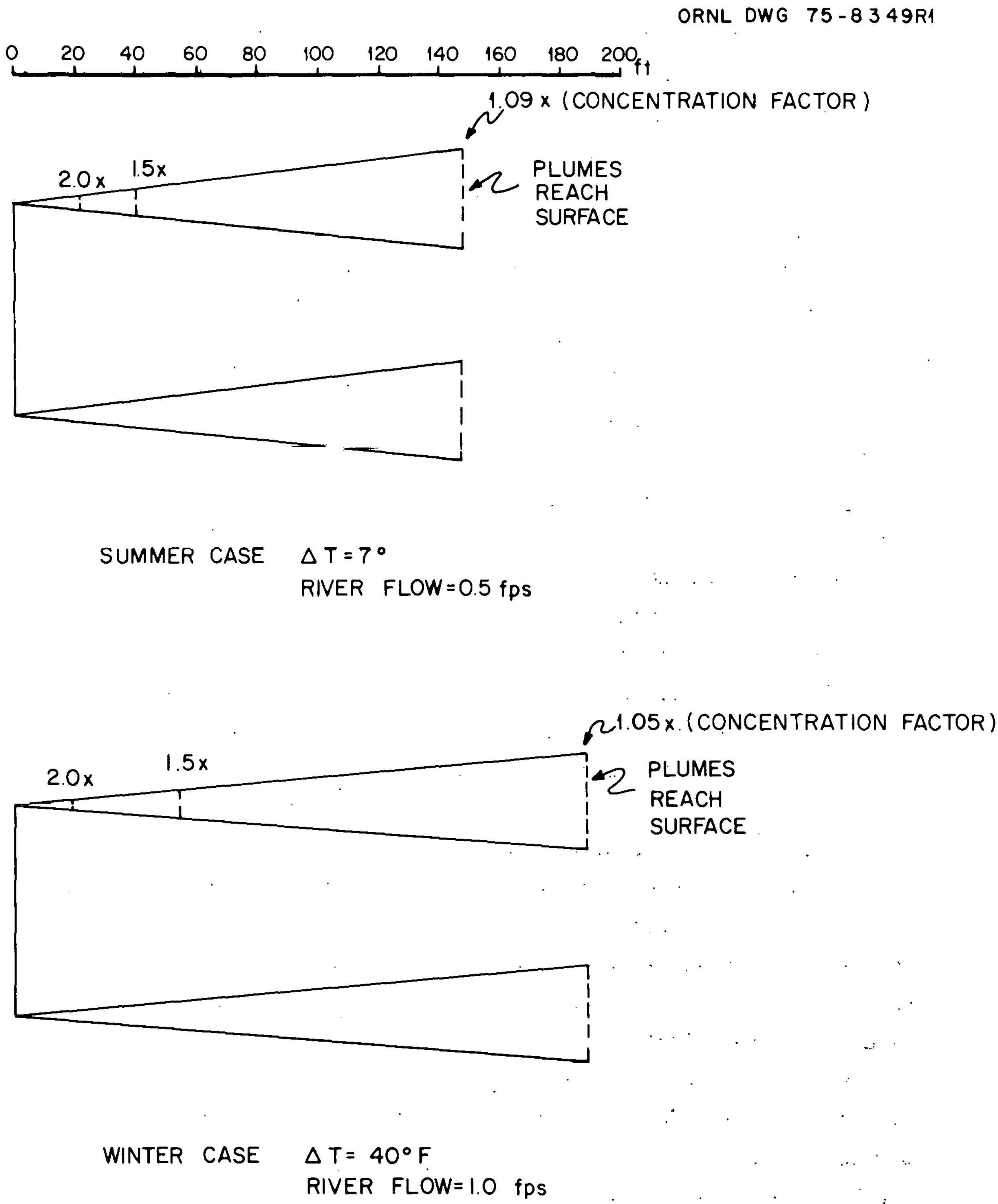


Fig. 8. Near-field dispersion analysis, winter case, ΔT = 40°F, river flow - 1.0 fps.

In the summer case, an ambient temperature of 30°C (86°F) is used, and the discharge temperature is 34°C (93°F). The plume reaches the surface in 147 ft, and the fully mixed increase in temperature caused by each diffuser is 0.056°C (0.1°F). When all ten plumes have become fully mixed, the total temperature increase is 0.56°C (1.0°F). The ambient temperature used in the winter case is 4.4°C (40°F), and the discharge temperature is 26.7°C (80°F). The plume reaches the surface in 188 ft, and the fully mixed increase for each diffuser is 0.17°C (0.3°F). Ten diffusers cause a fully mixed increase of 1.67°C (3°F).

The smaller, 10-unit NEC has identical plumes and identical increases for each plume. However, because there are only three diffusers, the total fully mixed temperature rise is 0.14°C (0.25°F) in the summer and 0.42°C (0.75°F) in the winter. The single diffuser of a 4-unit site would cause fully mixed summer and winter increases of 0.056°C (0.1°F) and 0.17°C (0.3°F), respectively.

The maximum plume temperature of 34°C (93°F) is high enough to be lethal to many organisms. However, the plumes are quickly diluted and affect only one-tenth of the channel width and thus should not cause much direct mortality in the channel of Kentucky Lake. Sublethal elevations in temperature can cause behavioral anomalies and secondarily increase mortality by increasing susceptibility to predation. However, these effects should not differ in the near-field plumes of NECs and dispersed sites. Cold shock can occur if, during a period of low ambient temperature, heat dissipation ceases due to station shutdown. This event is unlikely in all cases considered in this analysis because each diffuser is used by several reactors. That all of a station's reactors will be down at one time is improbable; thus, the heated plume will be a relatively permanent feature.

One obvious difference between NEC and dispersed-site thermal effects is in the far-field warming. As can be seen in Fig. 9, far-field warming on the order of 1.67°C (3°F) in winter and 0.56°C (1°F) in summer can be expected for a water column 50 ft deep and 70 ft wide. These effects should not increase mortality. In fact, the increased temperatures possibly will interact with nutrient concentration effects to increase productivity over a fairly extensive reach of river.

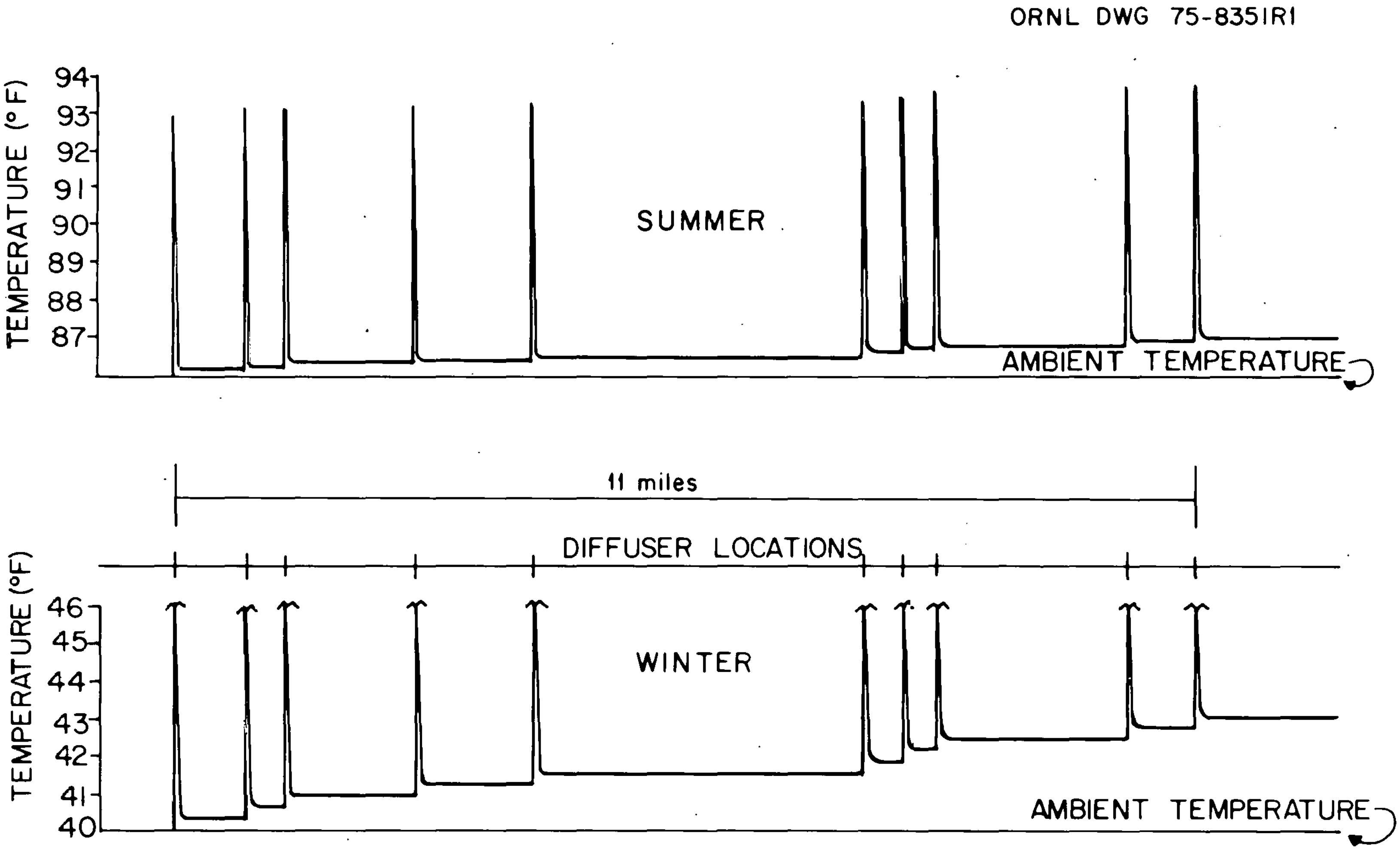
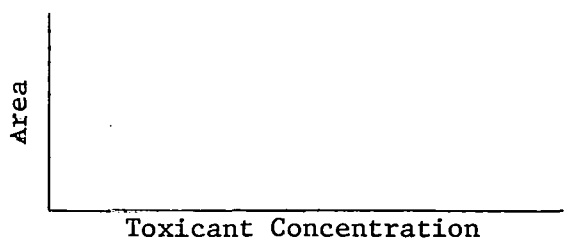


Fig. 9. Thermal plume, interaction, 40-reactor NEC.

4.4.4 Transport of toxicants

Toxicants discharged from power plants can originate from onsite chemical use (biocide use and chemical wastes from various processes such as demineralizer regeneration, etc.) and from the concentration by evaporative cooling of ambient levels of dissolved solids. Because toxicity is a concentration-duration phenomenon, the effect will be greatest at the point of discharge and become progressively less with increasing distance. Of course, this scenario is complicated by the fact that some species are more sensitive to toxicants than others. The area of primary effect would be determined by using literature values for short- and long-term toxicity in concert with a chemical dispersion analysis. The area of secondary effect will be much more difficult to define in that it will be a function of biological pathways that are, in many instances, poorly understood. Toxicity would be compared using the same method as was explained in the sedimentation section in construction effects. A graph would be made of



As with other comparisons of this sort, synergistic effects would probably be overlooked. Where synergistic effects are known to occur, they would be treated separately.

Surrogate Analysis

Because no design assumptions have been made regarding biocide use, no surrogate analysis was attempted for toxicant transport.

4.4.5 Eutrophication

Eutrophication of water bodies will result from the addition and concentration of nutrients by evaporative cooling and other plant processes. As with toxicants, the effect will be greatest at the point of discharge, becoming less with distance. The affected area would be defined as that within which the increase in concentration of nutrients is measurable. Comparison between NECs and dispersed sites would be done in the same manner as for toxicants, that is, plotting nutrient concentration against area for NECs and dispersed sites.

Surrogate Analysis

The eutrophication, or enrichment, of receiving water bodies will occur as a result of nutrient concentration by closed-cycle cooling systems. On the basis of data from planned and operating power plants, closed-cycle cooling has been assumed for the NEC and dispersed sites, which will concentrate dissolved materials by a factor of 5.7. Other assumptions basic to this analysis are (1) use of two-port diffusers, angled at 30° above the horizontal, with a spacing between ports of 70 ft and (2) "typical" reservoir cases for summer [ambient temperatures of 30°C (86°F) and river flow rate of 0.5 fps] and winter [ambient temperature of 4.4°C (40°F) and river flow rate of 1 fps]. These summer and winter cases are based on TVA data for Kentucky Lake, the surrogate NEC site.

Near-field dispersion analyses, based on calculations done in Sect. 2, are shown for summer and winter cases in Fig. 8. These analyses would be typical for each diffuser of the NECs as well as the diffuser for a dispersed site. Within 190 ft, the discharge plume has been diluted to about 10% above ambient. This process is calculated to take 105 sec in the winter case and 115 sec in the summer case. For a single diffuser (dispersed site), then, eutrophication is not anticipated to be of great magnitude.

For the NECs, plume interaction must be considered. Preliminary calculations, based on the following assumptions, have been made:

(1) No heat dissipated to the atmosphere.

(2) Mixing confined to the body of water passing directly over the diffuser.

(3) 70-ft port spacing.

The thermal profiles for winter and summer cases for the 40-reactor NEC are shown in Fig. 9, which shows an elevation in temperature, downstream of the last diffuser, of 1.67°C (3°F) in the winter case and 0.56°C (1°F) in the summer case. These temperature elevations correspond to a concentration factor of 1.35 in winter and 1.67 in summer. This seemingly anomalous result is caused by the operating characteristics of the cooling towers, which cause a 22°C (40°F) change in temperature in winter and a 4°C (7°F) change in summer, whereas the concentration factor remains the same at 5.7. Preliminary calculations indicate that the elevated levels of nutrients will be detectable for about 20 miles.

This level of interaction for the 10-reactor NEC can be examined by looking at the interaction between the first two plumes of the 40-reactor case and adding half the increase for a 4-unit diffuser to approximate the discharge from 10 reactors (see Fig. 10). This analysis yields a downstream change in temperature of 0.4°C (0.75°F) in winter, corresponding to an increase in far-field concentration by a factor of 1.09, and a change in temperature of 0.14°C (0.25°F) in summer, corresponding to a concentration factor of 1.17. These elevated levels of nutrients should decay to near ambient in about 5 miles.

Although the calculations done in this analysis are crude and involve conservative assumptions (e.g., mixing only with the water passing directly over the diffuser), some qualitative conclusions can be drawn concerning eutrophication. Fully mixed cooling system discharge water downstream of the last diffuser could contain nutrients concentrated to 1.67 times their ambient levels. This will cause changes in productivity and species distribution unless all nutrients needed by all species present are in excess, an extremely unlikely situation. Algal blooms and changes in species distributions, commonly recognized effects of eutrophication, will probably occur. The effect of a 40-reactor NEC will be evident for many miles; the effect of a 10-reactor

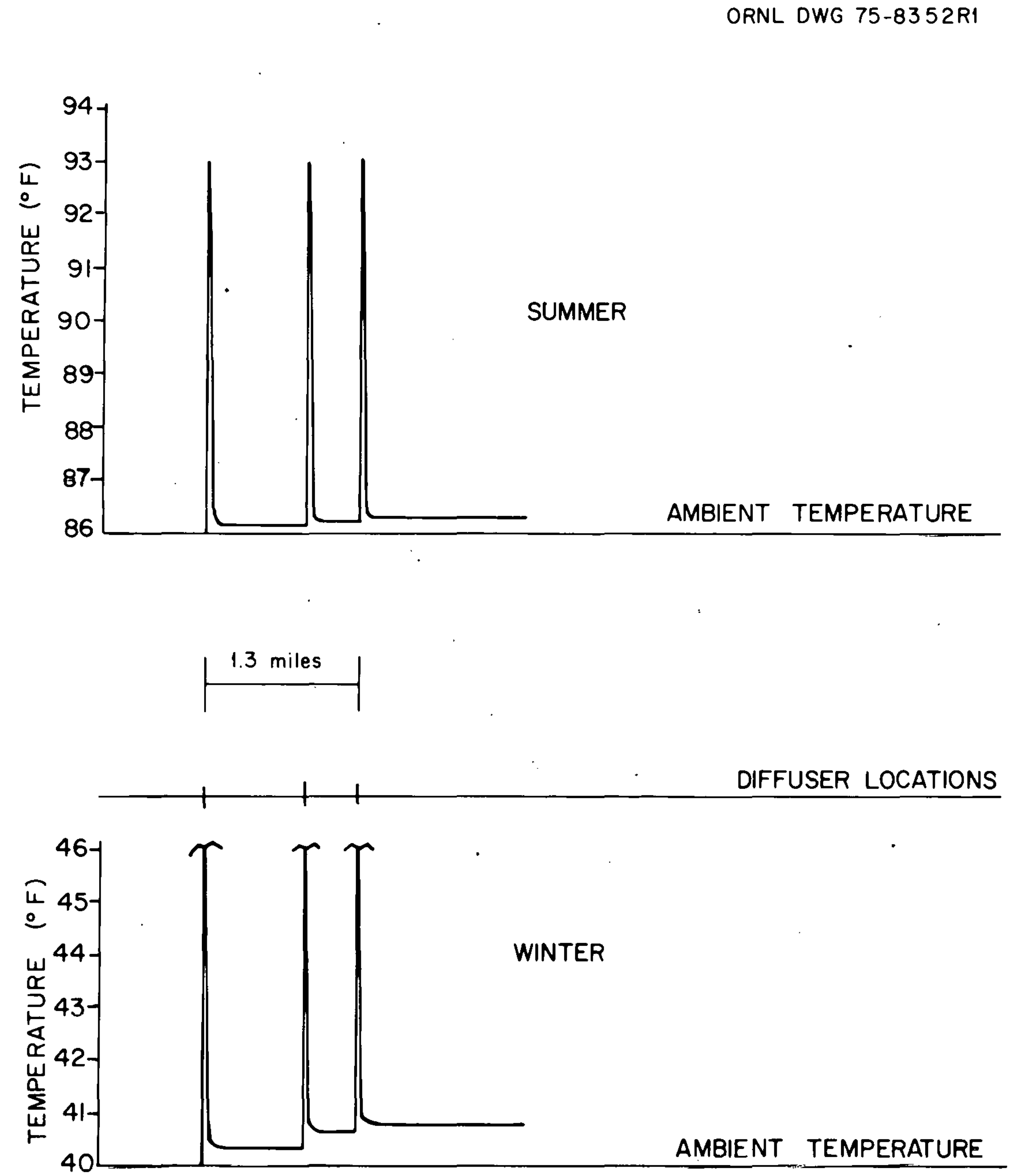


Fig. 10. Thermal plume, interaction, 10-reactor NEC.

NEC will be proportionately less. The effect of a dispersed (4-reactor) site probably will not be noticeable.

4.5 Extrapolation of Local Effects to Regional Ecosystems

The preceding discussion has treated the different environmental impacts of power plant construction and operation separately and has asked for each one, "What is the difference between the effect of one large energy center and that of an equivalent number of smaller ones?" The summary comparisons have then emphasized the areas where differences in size and type of effect may be found. They do not attempt to compare the effects of different spatial arrangements of similar impacts. Such a comparison is beyond the scope of this document and current analytical techniques; however, that comparison is necessary to begin to answer the very basic question with which the study began, "Is it better, from an ecological standpoint, to concentrate environmental impacts or to spread them over a larger area?" That question and the related one, "How much impact can an ecosystem absorb before unacceptable changes occur?" have prompted current regional studies. Complete answers may be available some time in the future; some aspects can be addressed more quickly.

One immediate approach is to use existing environmental quality criteria as the best available definitions of "acceptable" impacts. These criteria can be used to explore the capacity of specific regions to absorb the impacts they describe. For example, establishment of water comsumption criteria will make possible the determination of whether a watershed can support more generating capacity in a dispersed or a concentrated pattern. Water quality can be examined in a similar manner. Air quality standards are also available, although defining an appropriate region may be more difficult. Because there are no standards for terrestrial impacts, other approaches will be necessary there.

4.6 Summary Comparison

From the limited analysis made for this report, the following conclusions were drawn. (A much more thorough study would be anticipated for future evaluations.)

4.6.1 Eutrophication

The eutrophication of receiving waters may be extensive with the 40-reactor NEC. Preliminary estimates indicate substantial changes in nutrient levels extending over as much as 20 river miles, with concomitant biological effects such as algal blooms quite probable. The effect due to a 10-reactor NEC may be obvious for as much as 5 miles; there should be no obvious eutrophication effect from dispersed sites.

4.6.2 Sedimentation

The sedimentation associated with construction of the Kentucky Lake 40-reactor NEC is much greater than that of the 10-reactor NECs or dispersed siting. The sedimentation associated with the NEC probably will cause more persistent floral and faunal changes, with accompanying greater secondary effects. A longer time will be required for reestablishment of "normal" community structure upon cessation of sedimentation than would be the case with dispersed siting.

4.6.3 Habitat alteration

The size of the area affected by the larger NEC may cause delays in reestablishment of communities compared with the recovery times of the dispersed sites, when that recovery is dependent upon migration from adjacent areas and when there is repeated or prolonged disturbance in one section of an NEC because of construction in adjacent sections.

4.6.4 Flow alteration

Ecologically sound siting criteria for water use will minimize the impact of both NECs and dispersed sites. When such criteria are applied, the greatest difference between NECs and a dispersed site configuration will be the limited number of sites available for the NECs compared with the smaller units.

4.6.5 Thermal effects

Far-field warming associated with the NEC discharges likely will interact with increased nutrient levels to increase productivity over substantial areas. No such effect is anticipated for dispersed sites.

5. SOCIAL AND ECONOMIC ASPECTS

The probable social and related economic aspects of meeting electric power needs by means of nuclear energy centers, wherein large blocks of generating capacity are located at single suitable sites, must be considered in relation to those aspects attendant to the present practice of dispersed siting of power generating units. For this purpose, an attempt was made to envision and classify possible social and economic impacts resulting from the construction and operation of a 40-unit power-only nuclear energy center (NEC) and a 4-unit nuclear power station. To assess the possible effects of these impacts on the local area, two types of sites were considered. These are (1) sites within commuting distance (one-hour drive) of an already established urban center (urban region) and (2) sites in initially sparsely populated regions.

The most concentrated and relatively severe initial economic and social impacts of any large construction project occur in the immediate environs of the construction site. Although distinguishing between the interrelated economic and social impacts causing the cumulative effects experienced by people living near the site is difficult, the economic impacts can be broadly categorized as including effects on the local economy, governmental services, and finances, whereas the social impacts include effects on human activity patterns, health, safety, recreation, and aesthetics.

The data needed to predict possible impacts of a planned construction project and to assess the severity of resulting effects on the local area are site-specific. These data include information relative to existing area demographic and social conditions; land use and land-use management; physical and economic resources with particular respect to available housing, services, public institutions, and access or transportation modes; governing bodies with respect to the broader legal and regulatory mandates under which they function and the prevalent attitudes of these bodies relative to their functions; types of recreation enjoyed and facilities available; and aesthetics in general. Not the least of these considerations is the attitude of the local population relative to the construction project proposed for their area and its possible effects on their lifestyle.

Despite the absence of site-specific information, some generalizations can be made about the possible impacts of large construction projects in the two types of regions selected for this assessment. The possible physical and economic impacts resulting from the construction and operation of both a 40-unit NEC and a 4-unit nuclear power station are envisioned as (1) the initial impact resulting from acquisition of the land required for the project; (2) provision of housing and services for the influx of construction workers and permanent operating personnel and their families; (3) the impact of the construction activity itself; (4) additions to local income resulting from direct expenditures on construction materials and employment; and (5) possible increased revenue from local property taxes.

Although two types of regions were postulated to consider the relative magnitude of possible impacts, both the NEC and the 4-unit station were assumed to be constructed in an essentially rural area. In general, people who live in rural counties and communities are long-term residents who live there because they like it, not because they are forced to stay there for employment or other reasons. The factors entering into this preference include the residents' satisfaction with the rural, uncrowded atmosphere of their surroundings, the present condition of their homes and neighborhoods, the friendliness of the people, and community closeness.[32] The people with such value judgments as these are the ones that will experience the greatest social impact from a large construction project in their area.

5.1 Acquisition of Land

The initial physical impact resulting from construction of either an NEC or a 4-unit station is the acquisition of land required for the project. An estimated maximum of 48,000 acres of land would be required for the 40-unit NEC, whereas an average of about 2000 acres would be required for the 4-unit station. Although the exact impact would be site-specific, one could safely assume that the acquisition of a 75-sq-mile tract would displace a larger number of people than the acquisition of 31.25 miles[33] in average 3.125-sq-mile tracts at 10 dispersed sites. However, the 75-sq-mile value currently estimated for the NEC is an arbitrary maximum value and could come down.

5.2 Provision of Housing and Services

The second major impact on a rural area is foreseen as the influx of workers with the attendant demand for housing and services. To envision the magnitude of this impact, approximations of the work force required during the peak of construction activity were made for both a 40-unit NEC and a typical 4-unit station at a dispersed site. The number of permanent operating personnel remaining at the site after completion of the construction phase was also estimated for both types of projects. In the following discussions of the number of people that will be added to the community, only the workers and their families will be considered. In reality there will be a large number of support personnel, who are not working directly on the project but who could increase the influx of people by a factor of two or three.

5.2.1 NEC

Construction of an NEC would progress over a period of several decades, depending on regional power needs with each generating unit being placed in commercial operation upon completion of its testing. This would necessitate the presence of a semipermanent conctruction force as well as permanent operating personnel at the NEC site during the construction phase of the project.

Assumptions relative to unit construction duration and startup intervals were made to determine the possible length of time required for completion of an NEC comprised of 40 light-water-reactor units, each with a generating capacity of 1200 MWe. The resulting uninterrupted construction periods were then used to postulate a possible range of workers that could be required during the peak of construction activity. Further assumptions were made to estimate the area population increase that might result from construction and operation of an NEC in an urban region and in a sparsely populated region.

5.2.1.1 Construction duration and work force requirements. Based on a construction period of five years for each unit and uninterrupted unit construction startup intervals, completion of the 40-unit NEC would take about 35 years with a 9-month unit startup interval. Approximately 44 years would be needed to complete the NEC at a startup interval of 12 months, and about 64 years would be required for a startup interval of 18 months. The number of workers (laborers, craftsmen, supervisors) required at the peak of construction activity is estimated at about 6650, 5050, and 3350 for unit construction startup intervals of 9, 12, and 18 months, respectively.

The construction labor requirements are expected to peak during the third or fourth year of NEC construction activity and to remain relatively stable for the following 25 to 55 years, depending on the unit construction startup interval, declining thereafter through completion of the initial construction phase. However, the construction phase of an NEC may be an ongoing activity with earlier units, as they reach the end of their useful operating lifetime, being retired and replaced with new units.

The initial construction startup intervals and craft labor requirements are illustrated in Figs. 11 through 13. The requirements are based on the craft labor distribution for a single unit given in Table 8 of WASH-1334[33] adjusted to 8.5 man-hr/kWe for a 1200-MWe unit. No allowance was made for potential reductions in labor requirements that might result from improved manpower and equipment use and increased efficiency through the development and implementation of standardized construction techniques and stabilization of the labor force. Such a reduction in the required labor force has been postulated to possibly amount to 10 to 15% over that required for a single-unit installation at a dispersed site.[34]

Nor does the number of required craftsmen include construction management personnel, engineers, surveyors, inspectors, and site security and safety personnel. These onsite nonmanual workers typically number about 15 to 20% of the manual craft workers.[33] Thus, the total construction work force required during the peak of NEC construction activity could range from about 3900 to 8000 employees, depending upon the percentage of nonmanual workers and the unit construction startup interval. Specific data for this range are given in Table 13.

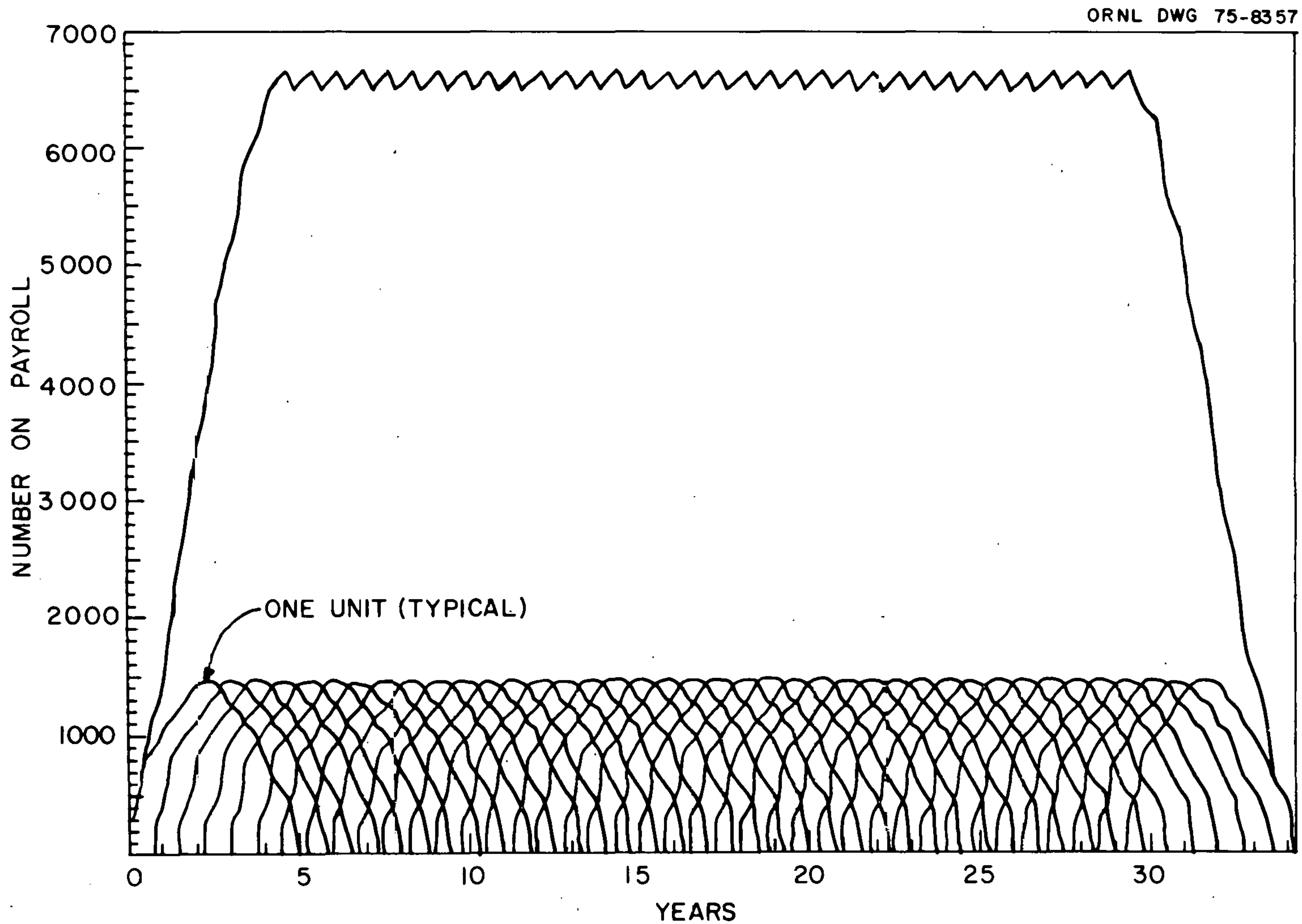


Fig. 11. Craft labor for power plant construction at an energy center — forty 1200-MW(e) units at 9-month intervals.

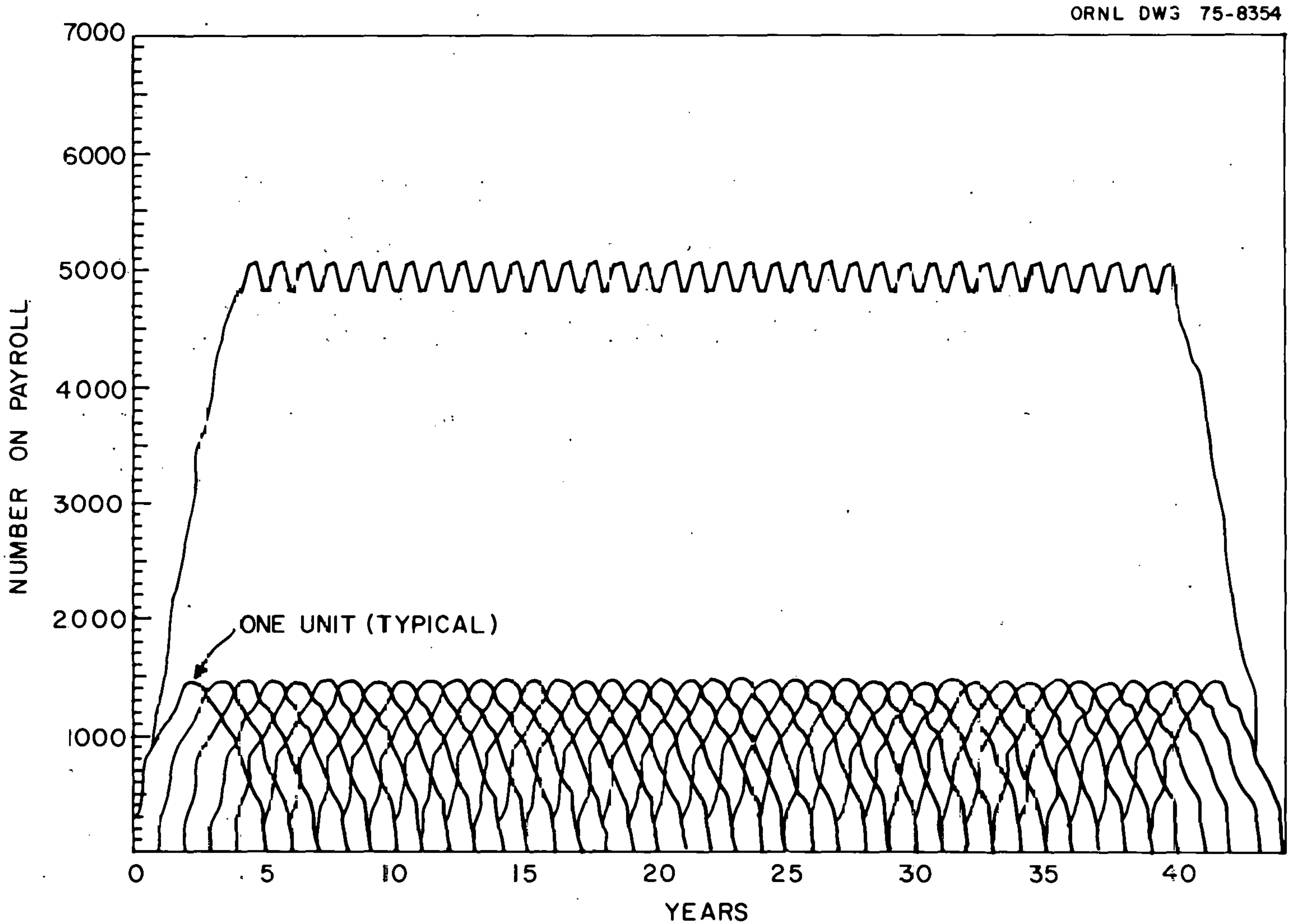


Fig. 12. Craft labor for power plant construction at an energy center — forty 1200-MW(e) units at 12-month intervals.

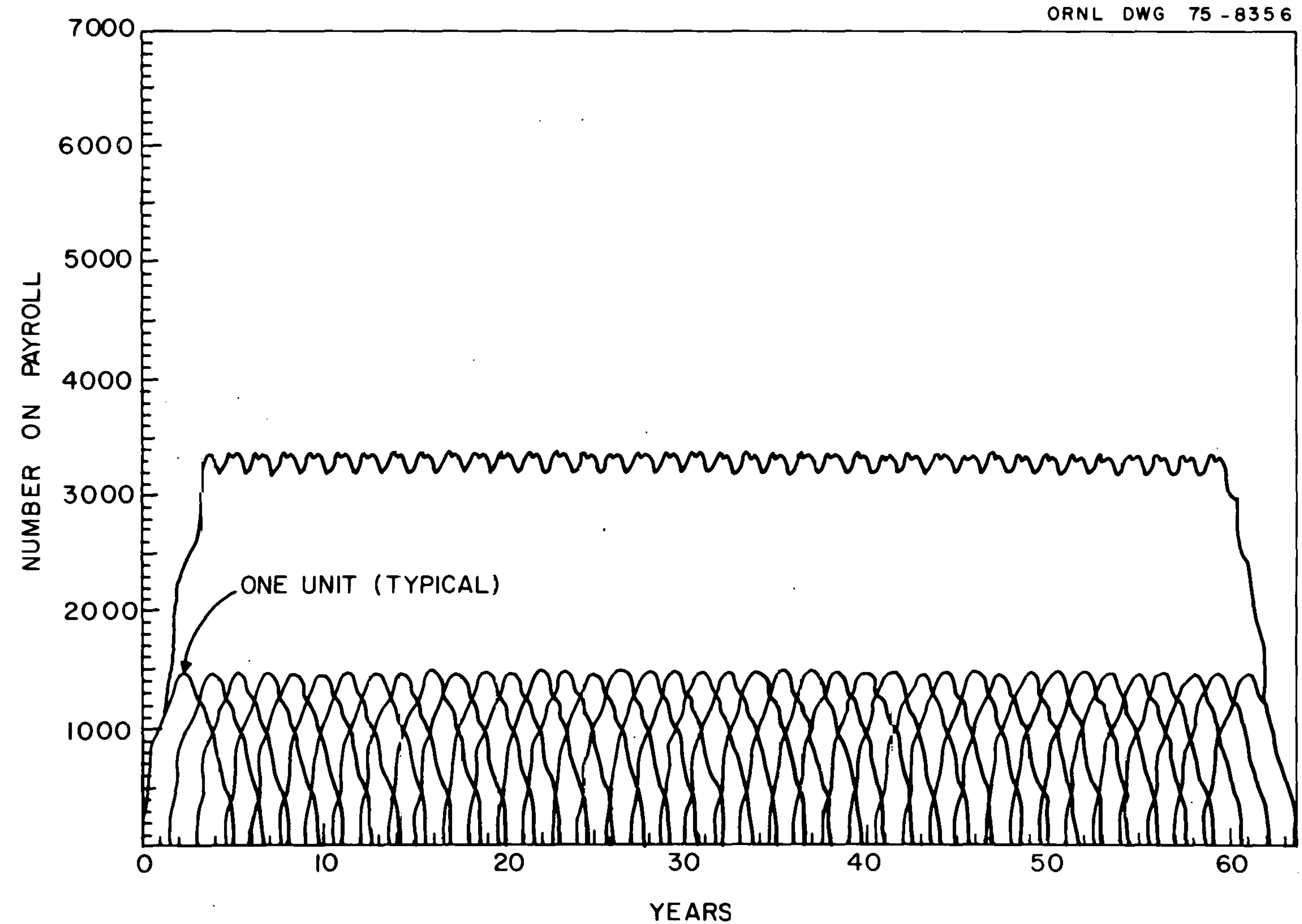


Fig. 13. Craft labor for power plant construction at an energy center — forty 1200-MW(e) units at 18-month intervals.

Table 13. Estimated work force requirements during peak of construction activity for a 40-unit NEC

	Unit construction startup interval		
	9 months	12 months	18 months
Duration of construction			
Activity, years	35	44	64
Peak, years	25	35	55
Construction craftsmen	6650	5050	3350
Nonmanual workers			
15% of manual force	998	758	503
20% of manual force	1330	1010	670
Total number of workers			
15% nonmanual	7648	5808	3853
20% nonmanual	7980	6060	4020

In addition to these semipermanent construction workers, the permanent operating personnel will increase the total number of workers present at the NEC site. Approximately 350 people are expected to be required for operation of each group of 4-reactor units, giving an ultimate total of about 3500 permanent operating employees.

5.2.1.2 Area population increase. The initial population increase in the immediate environs of the NEC will depend in large part on the demographic makeup of the region and the existing labor market. Although these factors are site-specific, assumptions relative to possible population increases were made for hypothetical types of sites.

Urban region. If the NEC is located in a rural area that is within reasonable commuting distance (one hour's drive) of a major urban center, from 40 to 75% of the work force required for construction of the NEC is expected to be drawn from the local labor market. The remaining 25 to 60% of the work force is expected to move into the urban region, probably around the fringes of the urban area closest to the NEC. At least 70% of the 975 to 4800 workers moving into the area are expected to be married and to bring their families with them. If the population of each of these families is the same as for the nation as a whole in 1972, each family will be comprised of 3.1 persons.[35] Thus, during the peak of construction activity, the population in the urban region could be increased by 2410 to 11,900 people, not counting support personnel and their families.

It is envisioned that, as the influx of construction workers and their families continued, existing housing, services, and schools in the urban locale would soon be overtaxed and new construction would become necessary. The location of this new construction would depend largely on the distance of the urban locale from the NEC site. If the urban area is some distance from the site in terms of daily commuting times, the rather permanent nature of the job could induce most workers to relocate in planned communities closer to the construction site. However, the pattern of urban expansion and random community growth would be determined by site-specific conditions such as the financial resources of the area and the prevalent attitudes of local governing bodies with respect to growth.

Sparsely populated region. If the NEC is located in a rural, sparsely populated area that is not within reasonable commuting distance of a major urban center, only 5 to 15% of the work force required for construction of the NEC is expected to be drawn from the local labor market. The major portion of the work force, 85 to 95%, is expected to move into the area. If 70% of these 3315 to 7600 workers bring their families and if each family coming into the area is comprised of 3.1 persons, the population in the area during the peak of NEC construction activity could be increased by 8200 to 18,800 people, not counting support personnel and their families.

Housing and services would be needed for 2320 to 5320 additional families and from 994 to 2280 additional unmarried individuals, and educational facilities would be needed to accommodate 2320 to 5320 additional students if each new family contained one school-age child. In addition to the semipermanent workers, an increasing number of permanent operating personnel and their families would have to be accommodated in the area. Application of the previously used assumptions relative to population statistics[35] to the permanent operating staff yields an estimated permanent area population increase of about 8645 people at the end of the NEC initial construction phase, including possibly 2450 families, 1050 individuals, and 2450 school-age children. Provision of needed facilities for such a large number of workers would undoubtedly result in the emergence of a new community.

If this new community is a "developed" one, extensive prior planning will be necessary. Construction of housing and services for the NEC work force will bring additional construction workers into the area for this purpose, and if NEC and housing construction proceed simultaneously, additional provisions will have to be made for the transient construction workers. At some period before the original 40-unit NEC nears completion, some additional planning will be necessary to maintain a stable community if remodeling of older plants will not employ all of the construction force.

5.2.2 Four-unit station

Estimations are presented in the following paragraphs relative to the time required to complete construction of a nuclear power station comprised of four light-water-reactor units, each with a generating capacity of 1200 MWe; the number of workers required during the peak of construction activity; the number of permanent operating personnel required; and possible population increases resulting from construction and operation of this station in an urban region and in a sparsely populated region.

5.2.2.1 Construction duration and work force requirements. Construction of a 4-unit nuclear power generation station, in which one unit comes on line every 12 months, is expected to take place over an 8-year period. The number of workers (including nonmanual) employed during the peak of construction activity is projected to be from 5300 to 5600, and this peak is expected to occur about 3-1/2 years after work has begun and to last approximately one year. However, at least

4400 workers are anticipated to be employed from near the end of the second year of construction through the fifth year, a period of about three years. The permanent operating staff for the 4-unit station is expected to number about 350 people.[4]

5.2.2.2 Area population increase. The population increase in the immediate environs of the construction site is expected to depend largely on the demographic makeup of the region and the existing labor market. In the absence of specific site data, assumptions relative to possible population increases were made for the same two types of sites used in the NEC assessment.

Urban region. If the 4-unit station is constructed in a rural area that is within reasonable commuting distance of a major urban center, from 40 to 90% of the construction work force is expected to be drawn from the local labor market. Because of the temporary nature of the construction job, it is anticipated that fewer of the work force will elect to move into the immediate area of the site. However, the range of possible movers will be 10 to 60%.

Application of these percentages to the minimum number of 4000 workers required for about three years during the height of construction activity yields a possible range of movers numbering from 400 to 2400. Applying the same assumption as was used for the NEC, the population increase in the area over this three-year period would range from approximately 1000 to 6000 people. Housing and services would be required for 300 to 1500 additional families and 100 to 800 additional individuals, and area schools would have to accommodate 200 to 1500 additional students. The number of transient workers coming into the area at the peak of construction activity would increase these numbers by about 20%.

The major portion of the workers required for construction of a 4-unit station would be expected to be supplied by the local labor market in most major urban regions, and most of these workers would be expected to commute to the job site on a daily or weekly basis. The housing and services required to accommodate the transient workers and their families moving into the region would then be on the low side of the postulated ranges just discussed. Accommodation of the estimated 350 permanent operating employees and their families upon completion of the construction phase of the project should pose no significant hardship on a major urban region.

Sparsely populated region. If the 4-unit station is constructed in a rural area that is not within reasonable commuting distance of a major urban center, only 5 to 25% of the work force is anticipated to be drawn from the local labor market. Thus, from 75 to 95% of the workers will move into the area, and the impact of the influx of this number of transient workers on the local area could be significant. From 3000 to 3800 transient workers could be expected to remain in the area for about three years during the height of construction activity. The population increase could range from 7000 to 9000 people. Temporary housing and services would be needed for 2000 to 2500 families and 1000 to 1300 individuals. The number of transient workers coming into the area is expected to peak at about 20% above these values. Upon completion of the construction phase of the project, about 350 operating personnel and their families will remain in the area.

5.2.3 Possible effects on local area

The sudden population growth in a rural area surrounding a project site not within commuting distance of a major urban center would undoubtedly impose a severe strain on the physical, financial, and organizational resources of that area unless new resources are developed through prior planning. There will be increased demands on housing and related services, educational and health-care facilities, protective services, and social services. These demands will disrupt the small-town character of a rural area. Along with changes in land-use 5atterns and housing shortages, the effects experienced by local area residents could include crowding and congestion of local schools, shopping area, roads, and recreation areas, with a possible attendant increase in crime.

Although relatively temporary, these effects experienced by local residents as a result of construction of a 4-unit station in a sparsely populated region could be partially alleviated through proper planning to accommodate the expected influx of construction workers. The development of a new community and attendant public services and facilities to accommodate NEC workers would alleviate the crowding effects experienced by a majority of the local residents and lead to the least disruption of their lifestyle. There would still probably be crowding of local recreation areas and some possible traffic congestion.

Construction of a 4-unit station in an urban region would lessen the magnitude of the impact on housing and services in the area immediately surrounding the project site. Superficially, it would appear that locating an NEC within commuting distance of an already established urban center would also lessen the magnitude of this impact, thereby reducing the overall cost of constructing the NEC. The initial population increase resulting from the influx of NEC workers would rely, to the maximum extent possible, on existing housing, services, and social amenities, whereas locating an NEC in a sparsely populated region would entail the accompanying construction of houses, sewer and water lines, roads, schools, and health care facilities needed to accommodate the semipermanent and permanent employees and their families.

The large variation in the number of people employed and the number of families to be housed is primarily a result of the rate of reactor additions and, to a lesser degree, of the location of the plant (urban or sparsely populated region). The number of people employed for construction of the NEC will not be very different from that for a 4-unit plant (possibly 15%). The principal difference is the duration of the construction peak. This is shown for a schedule that puts one reactor on line every 12 months in Fig. 14. For the 4-unit plant, the construction force peaks at about 5500 workers, but at the end of eight years only the 350 operating and routine maintenance personnel remain, because the succeeding 4-unit plants would be built at other locations. For the 40-unit NEC, the peak in construction personnel occurs at about the same time as for the 4-unit plant and is only slightly higher, but

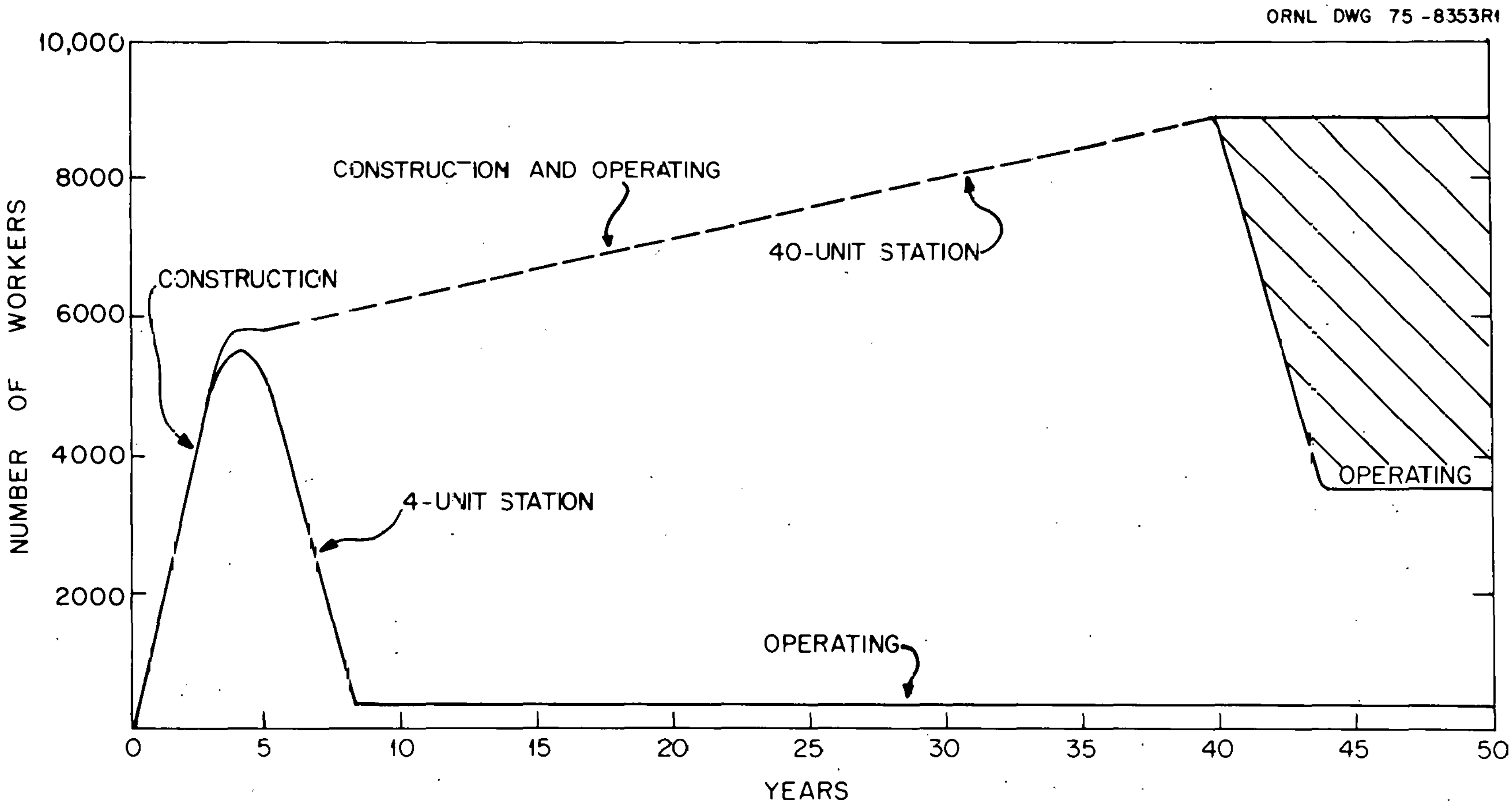


Fig. 14. Construction and operating work force for 4- and 40-unit power stations (12-month schedules).

the work force continues to increase over a 40-year period because of the addition of operating and routine maintenance personnel. At the end of 40 years, if all construction stopped, the work force would decline over a period of about four years to the 3500 operating personnel. A more realistic picture, however, is that the decline in total work force would be much less, probably in the higher part of the shaded area in Fig. 14. The reason for this is that the normal operating lifetime of a nuclear power plant is considered to be 30 to 40 years so that those facilities that had been built first would by this time be ready for replacement or remodeling. One might also contemplate construction needed for small industry, business, and housing in the area. All these factors would tend to stabilize the worker population around the NEC even after the 40 reactors had been built.

The conclusion is that new construction will be necessary to provide the physical needs of the new population, regardless of whether or not the NEC is located within commuting distance of an urban area. It is felt that siting of the NEC in an urban region would only serve to hide part of the initial cost of NEC construction, defer another part necessitated by later urban expansion, and contribute to the problems of urban sprawl. The question posed is whether the required new construction would be best directed toward a new community designed to meet the needs of its citizens and their future as they see it rather than toward the expansion of several small adjacent towns or an existing urban area in which the new citizens would have relatively little choice. The conclusion is that, regardless of the type of region in which the NEC is located, the development of a planned community for NEC workers would, with few exceptions, alleviate both the magnitude and duration of the crowding effects expected to result from those workers' demands for housing and services.

5.3 Construction Activity

The direct impacts of the construction activity itself will include dust and noise from operation of heavy machinery and blasting during site preparation and construction of foundations. Construction of railroad spurs and access roads to the site would also result in dust and noise along the route. A commuting work force would increase vehicular traffic on local roads during shift changes, and this potential for highway congestion could be increased by truck delivery of construction materials and plant equipment.

The number of local residents experiencing noise resulting from construction of either an NEC or a 4-unit station is site-specific. Although the duration of the NEC construction phase is estimated to be from three to seven times longer than that of a 4-unit station, the larger size of the NEC tract itself would serve to ameliorate the construction noise experienced by local residents. The number of local residents subjected to dust and noise as a result of construction of access roads and railroad spurs to the site is also site-specific, but the magnitude and duration of these effects would probably be about the same for both an NEC and a 4-unit station.

During the estimated 8-year period required for construction of a 4-unit station, local area residents would probably experience increased traffic congestion caused by construction workers at shift-change times. However, the development of a new community adjacent to an NEC construction site would eliminate the major portion of this impact of NEC construction activity. The effects of possible traffic congestion and road deterioration created by truck delivery of construction materials and plant equipment to the project site would be experienced by local residents over a much longer time span for the NEC than for a 4-unit station.

5.4 Additions to Local Income

The primary additions to local income resulting from construction of both an NEC and a 4-unit station are expected to arise from direct expenditures on employment and materials. However, only the local suppliers of building materials (lumber, gravel, etc.) are expected to benefit from direct expenditures on materials, as most of the plant equipment would probably be brought in from outside the local area. The duration of this benefit would be relatively temporary for the 4-unit station when compared with that for the NEC. Development of a new community for NEC workers might add to the magnitude of this benefit to local material suppliers as well as increase opportunities for secondary employment.

Little additional income from direct expenditure on employment is expected in the immediate area surrounding the construction site for either an NEC or a 4-unit station if the major portion of the work force is recruited from an adjacent urban area and commutes to the site. The expenditure on employment for construction of a 4-unit station in a sparsely populated region is expected to be of direct benefit to only a few local area residents. This addition in income of the few area residents employed on the construction project would be relatively short-lived, inasmuch as the existence of a power plant in the area is not foreseen as a stimulus to industrial or commercial development in which any newly acquired skills of local residents could be employed.

Although relatively few people from the immediate local area are expected to be employed on the project, an influx of workers to the area surrounding a construction site not within commuting distance of an urban center would increase local income through the expenditure of wages in the area. The expenditure of wages earned by workers engaged in the construction of a 4-unit station would provide a temporary increase in local income that would benefit local restaurants, grocery stores, and other convenience types of retail stores as well as local recreational enterprises. However, the demands of the transient workers likely would not lead to the development of any new permanent businesses in the local area nor could these demands be sustained by the permanent operating personnel and their families remaining in the area after completion of station construction. In an essentially rural area, the relatively high wages earned by transient construction workers is expected to drive up the cost of services and rental housing for low- and moderate-income persons throughout the area, and many of these people could be displaced by the disrupted economies of housing supply and demand.

The expenditure of wages earned by workers engaged in construction of an NEC in a sparsely populated region would add to local area income over a much longer period than such expenditures by construction workers for a 4-unit station. This additional income, together with that resulting from the development of a new community, would sustain a large increase in retail sales and secondary employment opportunities. The decline and possible cessation of construction activity at the NEC would reduce the magnitude of this commercial activity as people left the community to seek employment elsewhere; however, the number of permanent operating employees remaining, along with those construction workers who might be retained at the NEC or find other employment in the area, is expected to make the transition from initial construction to operating phases less severe for the NEC than for a 4-unit station.

Many of the adverse effects of the relatively high wages earned by construction workers on a rural area would be alleviated by development of a new community and services for NEC workers. However, approximately 5% of the construction labor force is normally made up of unskilled laborers, and hiring of these employees locally could result in a local labor shortage. This could have a severe impact on a rural area if farming is the mainstay of local economies.

5.5 Increased Tax Base

The single largest fiscal impact resulting from the construction and operation of a privately owned power generating station is the direct addition to the property tax base of the state in which it is located. However, nearly all property taxes are collected by local jurisdictions, and what would appear as a significant impact to the site as a whole would most likely be concentrated in a predominantly rural county or counties. The local tax base in some counties has been increased by 50% or more by the operation of privately owned two-unit nuclear stations constructed within their jurisdictions. The choice facing local governing bodies is to either reduce tax rates or spend on services and capital improvements or both. Either or both actions would change the future outlook of the area from that which existed prior to construction of the station. Low tax rates and improved physical and social services, health care facilities, and recreational facilities might be perceived by local residents as a mixed blessing, because these conditions could attract additional residential development and urbanization if the recipients of this additional revenue are in a location favorable to such growth.

Unless legal action is taken to distribute the revenue accruing from taxes paid by a power station over the entire state or multi-state area, the fiscal impact on the local area resulting from construction and operation of a privately owned NEC would be of much greater magnitude than that from operation of a 4-unit station. On the basis of fiscal data from the 1972 Census of Governments for ten representative states and under the assumption that these data would still hold for year 2020, an NEC with an assumed market value of $12.5 billion, which was assessed in a proportion equal to the average of that of all other taxable property in the state and taxed at a rate equal to that of the average rate imposed on assessed values throughout the state, could have contributed an increase in revenue amounting to from 5.6 to 25.4% of the total state and local tax revenue, depending upon individual state taxation practices. Depending on site-specific local institutional arrangements, the development of a new community adjacent to the NEC could also add to the local tax base increase.

However, the NEC concept suggests a scale beyond the capability of most private utility companies and implies a choice among several cooperative organizational and ownership arrangements. If a state or Federal agency were involved in the ownership agreement, the land required for the NEC likely would be removed from local tax roles and payments in lieu of taxes made to the affected state or states. Depending upon the state taxation practices, these in-lieu-of-tax payments could be based only on the amount of land actually used or occupied by NEC structures rather than on the entire tract as well as improvements thereto. Also, the revenue accruing from any form of property tax levied on an NEC as well as that from other sources, such as the sale of power, likely would be distributed throughout the entire region served by the NEC. The effects of this type of revenue distribution on the local area would be site-specific, but it would undoubtedly be less than the magnitude of any increase in the local tax base.

5.6 Institutional Issues

The institutional issues are closely related to the social and economic impacts and have been discussed in some detail in the preceding pages. For a project as large as an NEC, major changes in institutional structures clearly will be necessary. These issues have therefore been summarized here and related to the Kentucky Lake Surrogate Site.

5.6.1 Management and ownership of the NEC

That a single utility would have the financial or managerial capability to own and operate an entire NEC is doubtful. It has been postulated that several utilities would form some sort of combine to operate the NEC or that one utility might operate one or more 4-unit plants and that some sort of superstructure would be set up to manage the NEC. The managerial responsibility could be private, state, Federal, or some combination of the three. The details of any such arrangement would have to be carefully studied.

Financing of an NEC seems to be a large undertaking for anyone but the Federal government. At the very least, the Federal government likely would have to underwrite or guarantee that adequate capital would be available to finance the project.

At Kentucky Lake, many of these problems would not exist. The NEC at this location would be owned and operated by TVA. The waterway and adjacent lands are already controlled by TVA. The project would be financed by the Federal government, and TVA is a large enough organization to undertake a management job of this magnitude; however, this is a unique situation that would probably not occur outside the TVA area.

5.6.2 Public services and taxes

In the early years of the project, when tax revenues from the power plant are low, the municipality (especially a rural one) would find it next to impossible to finance the needed public services for the expanding population — services such as schools, hospitals, police, firemen, recreation, and improved roads. In contrast, when the plant is in full operation, the municipality would have more income than they can possibly spend unless some changes are made in the method of distribution of tax monies. This problem exists now for small (relative to NECs) power plants and will be much amplified for an NEC.

For the NEC, the concept of building a new planned community or expanding an existing small town would very much relieve the problem of supplying public sector services, but the problem of how to finance this new community still remains.

Existing communities should not have to bear the entire impact of the influx of people caused by the construction and operation of the NEC. Likewise, communities within the service area (perhaps a 100-mile radius) of the NEC should share in the tax revenues. Establishment of a more equitable method of tax collection and distribution would be essential.

For the Kentucky Lake Surrogate NEC, the TVA, being a Federal government organization, would not pay taxes, but would make payments in lieu of taxes. The TVA is empowered to pay 5% of its gross revenues in lieu of taxes, approximately 95% of which in the past has gone to state governments and the remaining to local governments. As is customary for Federal projects, payments to develop the community could start when needed, and arrangement for communities within the NEC service area to share in the payments in lieu of taxes should be easy.

5.6.3 Legal changes

With a project as large as the NEC, visualization of a whole host of jurisdictional and anti-trust problems is not difficult. To facilitate the licensing process, provide for a stable labor pool, and permit fair distribution of costs and benefits, a change in certain existing ordinances, regulations, and laws may be necessary. The extent to which this may be necessary will depend on the location chosen for the NEC. Legal authority would be needed for the management company to make long-term commitments to ensure the supply of material and a stable labor force. The legal framework for the more equitable tax collection and distribution system would need to be established.

At Kentucky Lake, most of the legal problems would also disappear because TVA would be building and operating the NEC.

6. SUMMARY

6.1 Thermal and Ecological Impacts

Table 14 is a summary comparison of factors considered as part of the surrogate analysis. Although it is by no means complete, the comparison does point out some of the differences in environmental cost between the nuclear energy center concept and dispersed siting.

In many cases, analyses are extremely tentative in that more research is needed and/or site-specific data are lacking. To more realistically deal with the problem of comparative analysis, work is needed in the following areas:

(1) Development of methodology to assess impacts on regional ecosystems.

(2) Development of concepts and techniques for the evaluation of concentrated vs dispersed impacts of the same absolute magnitude.

(3) Development of a conceptual framework, based on ecological and evolutionary principles, to evaluate the biological significance of impacts.

(4) The effects of the discharge of heat and moisture on cloud cover and rainfall in the immediate area of an NEC.

6.2 Social and Economic Impacts

The most concentrated and relatively severe social and related economic impacts resulting from construction and operation of either an NEC or a 4-unit station will occur in the immediate environs of the construction site. In the absence of site-specific data, only a few generalizations can be made relative to the magnitude and duration of the effects of these possible impacts on the people living in the local area, which is assumed to be of an essentially rural character.

The acquisition of one 75-sq-mile tract would in all probability displace a larger number of people, result in a greater change in local land-use patterns, and have a more significant effect on local tax rolls than would the acquisition of ten 3.1-sq-mile tracts at dispersed sites,

Table 14. Summary comparison of environmental impact of Kentucky Lake and its counterparts — freshwater power stations with natural-draft wet cooling towers

Environmental impact	40-reactor NEC	Four 10-reactor NECs	Ten 4-reactor stations
Land use for cooling towers, acres/MWe	0.01	0.01	0.01
Water consumption, cfs/reactor	30	30	30
Fog (ground)	None	None	None
Visible plume	Most frequent	Less frequent	Least frequent
Draft deposition (scales linearly)	Negligible	Negligible	Negligible
Airborne salt (scales linearly)	Negligible	Negligible	Negligible
Minimum flow, cfs/site	30,000	7500	3000
Blowdown, cfs/site	260	65	26
Weather modification	Unknown	Unknown	Probably slight
Aesthetic	Least severe	More severe	Most severe

Table 14 (continued)

Environmental impact	40-reactor NEC	Four 10-reactor NECs	Ten 4-reactor stations
Noise from cooling tower, dB(A) at site	About 50 to 65	About 50 to 65	About 50 to 65
Aquatic habitat alteration	11 river miles subject to repeated (24) disturbances over 40 years	2.6 river miles subject to repeated (7) disturbances over 12 years for each site	1.5 river miles subject to 3 disturbances over 6 years for each site
River flow alteration	Negligible	Negligible	Negligible
Eutrophication	Increased nutrient levels up to 20 miles	Increased nutrient levels up to 5 miles	Not detectable
Sedimentation	Concentrated (one 11-mile site), long-term (44 years) deposition (3.2 to 27 x 10^6 tons)	Scattered (four, 2.6-mile sites), shorter-term (12 years) deposition (22,500 tons per site)	Dispersed (ten 1.5-short-term (6 years) deposition (9000 tons per site)
Far-field warming, °F	3 (winter) 1 (summer)	0.9 (winter) 0.3 (summer)	0.3 (winter) 0.1 (summer)
Warming interaction with eutrophication	Increased productivity for up to 20 miles	Increased productivity for up to 5 miles	Negligible

Table 14 (continued)

Environmental impact	40-reactor NEC	Four 1C-reactor NECs	Ten 4-reactor stations
Forested acreage requirement, acres	41,156	19,060	48,565
Nonforested acreage requirement, acres	33,538	34,124	21,226
Total land requirement, acres	74,694 (greatest requirement)	53,184 (least requirement)	69,791
Atmospheric heat and mositure dissipation	Adverse environmental effects highly probable	Adverse effects likely	Adverse effects not likely
Soil loss	Most severe	Less severe	Less severe

which would be required for the construction of a comparable amount of generating capacity.

The influx of a large number of construction workers with their attendant demands for housing and services is seen as the single largest impact causing the greatest disruption of the activity patterns and life-style of local residents in a rural area. Depending on the schedule followed for construction of individual generating units at an NEC, the number of workers required during the peak of construction activity could be about the same as that required for construction of a 4-unit station over an 8-year period. Whereas the magnitude of the initial impact made by demands for housing and services by incoming NEC workers might be comparable to that made by workers for a 4-unit station, the duration of the effects of this impact would be much longer. Both the magnitude and duration of this impact and its effects on the local area would be alleviated by the development of a planned community to accommodate NEC workers and their families.

Construction of a 4-unit station in an urban region would lessen the magnitude of the demand for housing and services made by transient workers in the area immediately surrounding the project site. However, a commuting work force would probably result in local traffic congestion during shift changes and contribute little to local income. Although relatively temporary, the effects on local area residents, resulting from housing shortages and crowding of local schools, shopping areas, roads, and recreation areas brought about by the influx of transient workers constructing a 4-unit station in a rural area not within commuting distance of a major urban center, would be much more severe than those experienced by local residents in the immediate environs of an NEC with a planned community for workers. The conclusion made, therefore, is that the magnitude of the impact resulting from the demands for housing and services made by transient workers constructing 4-unit power stations at ten dispersed sites would be much greater than that made by the semipermanent workers constructing comparable generating capacity at a 40-unit NEC.

Direct expenditure on materials for construction of either a 40-unit NEC or a 4-unit station is expected to benefit only local suppliers of construction materials. The magnitude of this benefit would be much greater to those suppliers in the area of an NEC than to those in the area of a single 4-unit station, but construction of comparable generating capacity at ten dispersed sites would distribute this benefit among suppliers in ten areas.

The expenditure of wages by semipermanent NEC workers, together with the development of a new community, would sustain a large increase in local income, along with secondary employment opportunities, over a relatively long period. The conclusion made, therefore, is that the benefits of an increase in local area income resulting from construction of a 40-unit NEC would be much greater than those resulting from construction and operation of 4-unit stations at ten dispersed sites.

Current taxation arrangements in most states are such that counties and communities of the local taxing jurisdiction, within which a privately owned power plant is located, receive the bulk of the increased revenue resulting from construction and operation of the plant. The assumptions are made that possible ownership arrangements and legal actions will serve to lessen the magnitude of a local tax base increase that could result from the construction and operation of a 40-unit NEC and that the adverse social effects that could arise from a local tax base increase associated with a privately owned 4-unit station might not occur as a result of construction and operation of a 40-unit NEC.

In summary, the conclusion has been drawn that there will be little long-term benefit accruing to local area residents, other than a possible tax base increase, as a result of construction and operation of a privately owned 4-unit station in the area. Although of a relatively temporary nature, the local disruption caused by the influx of transient workers required for construction of the 4-unit station in a rural area would be much more severe than that for construction of a 40-unit NEC with a planned community for NEC workers. Some of this local disruption could be alleviated by prior planning to accommodate the transient workers. Increases in local income resulting from expenditures on construction materials for the 4-unit station and expenditure of workers' wages would also be of a temporary nature. However, the semipermanent benefits to local entrepreneurs from such expenditures for a 40-unit NEC and from possible secondary employment opportunities resulting from the development of a new community must be weighed against the adverse effects on local area residents resulting from the displacement of a number of those residents, the removal of a large tract of land from local use, and the creation of a new community with its attendant semipermanent population increase ranging from 20 to 30 thousand (including NEC workers and incoming people with business and professional interests in the community).

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