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OFFICE OF INFORMATION SERVICES

POPULATION DISTRIBUTION AROUND

NUCLEAR POWER PLANT SITES

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BACKGROUND AND DISCUSSION

Prepared by Accident Analysis Branch
Directorate of Licensing

The evaluation of nuclear power reactor sites from a radiological risk standpoint is performed by the Regulatory staff primarily by comparison of the results of design basis accident dose computations against the numerical guidelines in 10 CFR Part 100 for individual exposure. Consideration is given to population risk in paragraph 100.11 of 10 CFR Part 100 which states that "Where very large cities are involved, a greater distance may be necessary because of total integrated population dose consideration." Because the consequences of an accident decrease with distance from the point of release as a result of atmospheric dispersion and radioactive decay, the total population exposed to a significant dose can be minimized by use of sites away from highly populated areas.

Given the state-of-the-art for engineered safety features used on current generation plants, the technology exists to make siting in metropolitan areas feasible from the standpoint of meeting the individual dose guidelines in 10 CFR Part 100; however, reactors have been excluded from metropolitan areas to date for several reasons. It has been felt, as indicated in statements before the Joint Committee in 1965 and 1967, that advances in safety systems in terms of design, testing and reliability would be needed before siting in metropolitan areas would be allowed. There has been no reason to take the additional incremental risk, however small, of incurring doses to a large metropolitan population as a result of any accident in the nuclear facility when other suitable sites, less densely populated, remain available. Also, the difficulty of instituting effective protective measures for the surrounding populace in the event of an accident increases with increased population density. At the present time the staff uses an informal guideline that sites with a population density greater than that of an envelope of the Zion, Newbold Island and Indian Point site populations are not considered acceptable.

While the above considerations have been formally applied to the calculated consequences of "design basis" accidents, they would be no less significant for a more remote sequence of events. Such events are defined in the proposed Annex to Appendix D of 10 CFR Part 50 as involving "sequences of successive failures more severe than those postulated for the design basis for protective systems and engineered safety features."

When evaluated realistically, for example with meteorology which might occur 50% of the time, a very large uncontained reactor accident such as a release of all gaseous fission products might have significant whole body dose consequences. The calculated whole body dose for this large uncontained release would be at a level where injury would be sustained to persons downwind for about ten miles and fatalities could result in a downwind area a few miles from the plant. In the case of the calculated thyroid dose, doses greater than 100 times the thyroid guideline doses of 10 CFR Part 100 could be incurred a few miles from the plant for average meteorological conditions. Although this magnitude of thyroid dose could result in possible damage to the thyroid, the associated whole body dose incurred as a result of the inhaled iodine would be only a small fraction of the whole body dose received from a passing cloud. While a loss of thyroid function can occur at high doses, an individual can survive; whereas high whole body doses can affect individual survival.

In the event of extremely unfavorable meteorology, damaging doses from an uncontained accident could be delivered a substantial distance from the plant within a narrow sector in the downwind direction. Under this type of meteorological condition, however, several hours would be available to institute protective actions, such as evacuation from the path of the plume. (For example, nine hours could elapse before cloud passage at a distance of twenty miles.)

These qualitative considerations lead to the conclusion that siting in metropolitan areas, unless shown mandatory from the standpoint of environmental, economic or other factors, should continue to be discouraged.

Previous case-by-case reviews of population distributions have effectively discouraged large numbers of plants in areas of relative high population density by requiring engineered safety features to reduce computed consequences of design basis accidents to levels which are well within the dose guidelines of 10 CFR Part 100. (This practice has also probably increased, by some undefined margin, the capability of plants so designed to cope with the consequences of undesigned-for accident sequences.) This case-by-case evaluation has resulted in large expenditures of staff manpower. A single such case may require extensive discussions during a preliminary site review, the construction permit review, and during public hearings. The issues involved range from the growth and future distribution of population density to the adequacy of the extra engineered safety features proposed for the plant. A siting policy which provides incentives to choose sites which are clearly acceptable from a population distribution standpoint, therefore, offers attractions in staff manpower savings as well as in the realization of some incremental reduction of risk to the public.

One means of encouraging location of nuclear power plants in low population areas is by narrowly restricting the conditions under which plants may be located in moderate to high population density areas and by effectively prohibiting siting in metropolitan areas. The draft Policy Statement and draft Regulatory Guide entitled "Population Distribution Around Nuclear Power Plant Sites" which are included as Appendix A detail such conditions. No maximum acceptable population distributions are given in the proposed guide. Such an upper limit would tend to encourage large numbers of additional high population density sites comparable to those few which have already obtained staff concurrence. The maximum population at various distances at sites which have been recommended for approval by the staff to date will continue to be used informally as an upper bound, but approaching this upper bound in the future will be strongly discouraged.

Population levels are specified in the Guide which would serve as an indication of an acceptable population distribution. Above this level, it must be shown by the applicant that a high population density site offers significant advantage from the standpoint of environmental, economic or other factors. The specified levels were chosen as representative of sites available for the development of nuclear power. The judgment that such sites are available was based on the fact that about 70% of the construction permit applications submitted to date meet the indicated population levels at all three distances (5, 20 and 40 miles) specified in the proposed guide. In addition, at any given distance (5, 20 or 40 miles) 90% of the applications submitted to date meet the population value specified.

In addition to demonstrating the need for a relatively high population density site, additional engineered safety features must be provided to assure that the overall risk to the public has been minimized. This is similar to the requirement for additional features on the Newbold Island and Limerick plants to reduce the computed site boundary and low population zone doses to small fractions of the guideline values of 10 CFR Part 100. This provision assures that total population doses as well as individual doses assumed to be delivered as a result of a design basis accident are kept to very low values. Individual doses at plants not affected by this requirement are kept to acceptable levels by the dose guidelines of 10 CFR Part 100.

Information on the current population distribution around approved sites is presented in Appendix B. A "Site Population Factor" (SPF) concept is also discussed in Appendix B in which the population at longer distances is weighted less than the population adjacent to a site for the purposes of comparison among various sites. This concept has played a key role in the staff's analysis of various population patterns and the selection of the cumulative population values contained in the draft Regulatory Guide (Appendix A).

In any population criteria, future as well as existing population must be taken into account. Accurate projection of population growth in the vicinity of sites would seem to require a detailed analysis of economic and cultural considerations (which the very existence of the plant may influence). Of course this type of analysis would be most reliable in the near term. A period of about ten years from submittal of a construction permit application is suggested in the draft Regulatory Guide for this type of detailed analysis. This time period would assure examination of the population anticipated to exist at the time the plant is to begin operation. Sites with very low existing population density would not be required to submit such a detailed analysis.

Another alternative means of assuring low population densities which is currently being examined for feasibility and which could be pursued over a longer time-scale is the concept of use of large federally owned or controlled areas (for example current military or AEC reservations).

Options for Action on a Siting Policy

1. Regulatory Guide

A Regulatory Guide could be issued which is structured to encourage siting in areas of low population density. A draft of such a guide is included in Appendix A. Under the proposed guide the applicant would need to show that the high population density site offers significant advantages from the standpoint of environmental, economic or other factors. In addition, engineered safety features would be provided, above those required to meet the guideline doses of Part 100, so that there would be additional assurance that the risk has been minimized. Such engineered safety features would probably include the use of containment sprays with chemical additives and a secondary confinement system (sometimes referred to as a dual containment) to hold up and filter fission products released in a postulated design basis accident.

The staff recommends issuance of a Regulatory Guide with accompanying Policy Statement. The Guide would be subject to future revision if experience should indicate the need for modifications. Should the Commission approve issuance in principle of such a Guide, the staff would plan to discuss the Guide with the ACRS before issuance. It is recommended that the provisions of the Guide be applied to construction permits docketed after January 1, 1974. Allowing a few months notice after issuance of the Guide will reduce the impact on utilities now in the process of site selection.

2. Change to 10 CFR Part 100

At this time it would appear more appropriate to issue the statement as a Guide rather than a regulation and later issue a regulation if deemed appropriate on the basis of experience with the Guide. Issuance of a regulation would require advance notice of proposed rulemaking with opportunity for public comment and would probably require preparation of an environmental impact statement. On the other hand, the absence of a binding regulation will require the staff to address the technical merits of the Policy Statement and Guide in licensing proceedings where the issue is raised.

3. No Action Pending Further Study

Action on this matter could be postponed until after completion of the SONAR study. If this study resulted in sophisticated estimates of risk from "worst conceivable" accidents, a siting policy might then have a defined technical basis. The staff believes it is unlikely that the general shape of the policy would change from that indicated in the proposed Regulatory Guide, however. There is a present need for guidance to the industry in this area, and the timing and success of accident probability and consequence studies associated with the SONAR project is not clear.

4. Influence State Land Use Policies

Various states now have laws or are in the process of formulating laws providing for long-term land use planning. If guidelines were provided to state planning bodies indicating desirable characteristics for nuclear power plant sites, the States would screen out sites with high population densities. This could be an effort much broader in scope than population density, covering a multitude of site characteristics. It would probabily be initially effective in only a few states, however, and would not provide the immediate guidance to industry which is needed in this area.

Coordination

The opinion of Dr. H. Monson, a member of the ACRS, was sought in this matter. Dr. Monson concurred in principle but suggested that the importance of population close to the plant be emphasized. The staff has under consideration the addition of an acceptable population value of 120,000 people within 10 miles. This would be in addition to the present specification of population at 5, 20 and 40 mile distances. The addition of the 10 mile population value would not change the number of current sites which meet the population criteria at all distances as discussed in this paper. This change may be adopted before issuance of the Regulatory Guide.

A meeting with selected utility executives[1/] was held on April 12, 1973, to explain the general approach proposed and to solicit their comments on the impact of a policy such as discussed in this paper and on alternative means of achieving the same end. The consensus of the meeting was that the principal impact of the policy would be the potential adverse public reaction to any action which indicated that the safety of reactors was in question.

1/ Representatives of Commonwealth Edison Company, Consolidated Edison of New York, Pacific Gas and Electric, Philadelphia Electric, Public Service of New Jersey, and Southern California Edison were present.

It was agreed, however, that if the policy were to be implemented, there was no viable alternative to a public announcement by the AEC. It was proposed by the utility representatives present that the policy be presented by (1) stressing the good safety record of the industry to date, (2) indicating that previous policy has been to use low population sites with a view to eventual siting in metropolitan areas, (3) stating that more operating experience is required before metropolitan siting can be allowed, (4) indicating that the acceptable population values are to be used as interim guidance for the next five years, and (5) stating that the AEC will review the technology [illegible] experience again at the end of five years with a view toward siting closer to populated areas at that time. This approach has been partially adopted by the staff and is reflected in the Policy Statement which is proposed to accompany issuance of the Regulatory Guide.

APPENDIX A

PROPOSED POLICY STATEMENT
AND
REGULATORY GUIDE

PROPOSED POLICY STATEMENT

POPULATION DISTRIBUTION AROUND NUCLEAR POWER PLANT SITES

A long-standing policy of the Atomic Energy Commission* has encouraged siting of nuclear power plants away from densely populated areas until additional operating experience has been obtained. However, specific guidance has not been provided as to acceptable population characteristics for a nuclear power plant site. To facilitate early site planning and selection, the Commission believes it is appropriate to provide further guidance, from the standpoint of compliance with 10 CFR Part 100, as to low population density characteristics and to require a sufficient justification for sites where the population characteristics are higher.

This guidance will be provided in the form of a Regulatory Guide "Population Distribution Around Nuclear Power Plant Sites." The Commission expects that after additional operating experience has been obtained with systems licensed under the new standardization procedures the then current reactor technology will be reviewed and the population siting guidelines modified as appropriate. The interim guidance will be applied to construction permit applications accepted for review after January 1, 1974.

For plants proposed for sites where the population characteristics are higher than the low population density areas indicated in the Guide the Regulatory Staff will request: (1) an analysis of alternative sites including a showing that the proposed high population density site offers significant advantages from the standpoint of environmental, economic or other factors; and (2) the inclusion of state-of-the-art engineered safety features to assure that the overall risk to the public has been minimized.

The Commission recognizes that sites where populations are higher than the low population density areas indicated in the Guide have been approved in the past and anticipates other such sites may be approved in the future. The Guide should not be construed as suggesting that sites which do not meet the low population density values are no longer acceptable. Because the Guide

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* See Statement of Consideration, Reactor Site Criteria, 10 CFR Part 100, 27 FR 3509 (April 12, 1962).

will be applied by the staff to construction permit applications which are docketed after January 1, 1974, those reactors at sites already approved and for which reviews are in progress are not affected.

Under Part 100 of the Commission's regulations, "Reactor Site Criteria," population density is one of the important factors which must be considered in determining the suitability of a site proposed for a nuclear power plant. Applicants are required to postulate a large release of fission products within the reactor containment and, on the basis of acceptable assumptions for various design basis accidents provided by the Regulatory Staff, to calculate off-site exposures from such an assumed release. These calculated exposures may not exceed exposure guidelines established in Part 100. Because of the resulting conservative plant design, the risk to any individual from accidents is small. Part 100 also specifies that special considerations may apply when large population centers are near proposed power reactor sites because the large number of persons who potentially could be exposed to radioactivity in the event of an accident does present some small additional increment of risk to the total population. The use of the Guide should assure that, with reactors of current technology, sites which have high population densities are not used in the absence of sufficient justification.

PROPOSED REGULATORY GUIDE

POPULATION DISTRIBUTION AROUND NUCLEAR POWER PLANT SITES

INTRODUCTION

Section 50.34 of 10 CFR Part 50 requires that each application for a construction permit or operating license provide a description and safety assessment of the site on which the facility is to be located with special attention directed to the site evaluation factors identified in 10 CFR Part 100. Section 100.10 of 10 CFR Part 100 states that the population density characteristics of the site environs, including the exclusion area, low population zone, and population center distance, are factors the Commission will take into consideration in determining the acceptability of a site for a power or testing reactor. Permissible population density or total population in the zone surrounding a nuclear power plant is not specified although Part 100 indicates that special considerations may apply when large population centers are present. This Guide identifies acceptable population distributions in the area surrounding nuclear power plant sites from the standpoint of compliance with Part 100.

Where the population distributions in the area surrounding a proposed nuclear power plant site exceed those distributions identified in this Guide, the site may nevertheless be found to be acceptable if the design of the plant includes appropriate and adequate compensating engineered safety features and if adequate alternative sites, which meet the population guidelines, are not available.

DISCUSSION

The reason for consideration of the population distribution around a proposed nuclear power facility is primarily to assure that risks to the population as a result of any accidental releases of radioactivity are adequately taken into account in the selection of the site. Because the routine releases of radioactivity allowed under AEC regulations are extremely small, the risks to the population from routine releases, even assuming a very high population density around the facility, can be fairly characterized as negligible.

Estimated doses from postulated accidents in the nuclear facility, for example the design basis accidents, will not exceed but do approach the dose guidelines given in 10 CFR Part 100 if very conservative assumptions are made at each stage of postulated fission product release and transport. When examined with a view of obtaining a best calculational estimate of the accident consequences, however, the accident consequences are smaller. While the conservative calculation does represent a possible consequence of a postulated accident, it is not a probable consequence given the accident. (The probability of a particular radiological consequence, given an initiating event, will depend on the probability of full or degraded functioning of engineered safety features, the probability distribution of the transport phenomena and the probability of occurrence of the selected meteorological condition.)

To rigorously quantify an environmental risk, a computed radiological consequence would have to be multiplied by a numerical value for the probability of the computed radiological consequence occurring, given the event; however, because of the absence of significant radiological accidents in the nuclear power industry to date and because of the extensive precautions taken in design, construction and operation to assure a low probability of accidents in the future, definitive estimates of accident occurrence probabilities are not available. Except for frequency of occurrence information for meteorological dispersion parameters, definitive estimates of the probability of particular radiological consequences, given an event, have likewise not been established. Although a definitive and quantitative result is not available, when the probability of a design basis event occurring and resulting in a given set of consequences is (qualitatively) weighted by these consequences, the resulting expression of risk is, as in the case of routine releases, very low.

In addition to the events for which the plant is designed, other events, considered to have an extremely low probability of occurrence, are conceivable. The radiological consequences of these events may be less or

may be more than those types of releases for which the plant has been specifically designed. As indicated in the proposed Annex to Appendix D to 10 CFR Part 50, (36FR22851, December 1, 1971) these accidents, some of which could conceivably lead to significant radiological consequences, are and will remain, sufficiently remote in probability that the risk to a surrounding population is extremely low.

Notwithstanding all of the above, siting near large population centers presents some additional increment of risk above that at a site in a low population density area. It is the intent of this Guide, therefore, to encourage siting in low population density areas unless siting in high population density areas offers significant advantages from the standpoint of environmental, economic or other factors.

For plants located in areas which have populations above those set forth in this Guide, two additional factors will be considered at the time of the construction permit review. First, an analysis of alternative sites will be performed, including a showing that the high population density site offers significant advantages from the standpoint of environmental, economic or other factors. (Simple transmission losses over distances of less than 100 miles may not be accepted as a principal economic justification.) Second, certain engineered safety features may be needed to provide greater assurance of low risk. All sites will continue to be required to meet the siting criteria set forth in 10 CFR Part 100.

The Regulatory position is that a population projection for the life of the plant (as well as a detailed population projection for the near future for those plants which are close to exceeding the guidelines) would be needed. In the application of the guidelines, recognition will be given to the difficulty of predicting local population changes with accuracy and the need for additional engineered safety features during the facility lifetime would not be anticipated unless the guidelines were exceeded by a substantial margin.

It should be noted that over 90% of the sites proposed to date would meet at least two of the population levels indicated in Item 1 of the Regulatory position. About 70% of the sites proposed to date have current populations which fall below all levels indicated in Item 1 of the Regulatory position.

REGULATORY POSITION

1. Applications for sites having a cumulative population projected from the date of application for a construction permit, as indicated in Item 2, greater than 30,000 within 5 miles, 500,000 within 20 miles or 2,000,000 within 40 miles should:

   (a) Present an analysis of alternative sites, including a showing that the proposed site offers significant advantages from the standpoint of environmental, economic or other factors.

   (b) Provide state-of-the-art engineered safety features to assure that the conservatively calculated consequences of postulated design basis accidents are significantly below the dose guidelines of 10 CFR Part 100.

   (c) Have a minimum exclusion distance of at least 0.4 mile and a low population zone of at least two miles.

2. If population projections indicate that any of the values in Item 1 would be exceeded during the plant lifetime, a detailed study of economic and population growth patterns for at least 10 years after the date of application for the construction permit should be performed. The guideline values in Item 1 will be deemed to have been exceeded if (a) the detailed 10-year projection indicates that any of the guideline values are exceeded, or (b) at the time of the construction permit application, any of the guideline values can be reasonably expected to be exceeded by more than a factor of two over the projected lifetime of the plant.

3. Plant sites which fall below the population criteria of Item 1 above, and which can reasonably be expected to remain at a population level less than these guidelines over the projected plant lifetime will be individually evaluated against the dose guidelines of 10 CFR Part 100 and a detailed 10-year projection need not be performed.

4. Significant unusual population distributions within the distances specified in Item 1 above will also be taken into account in determining site acceptability.

5. Should the population at any approved site rise to unexpectedly large values during the plant lifetime, the AEC may review the population growth to determine whether additional engineered safety features should be provided or plant operations modified.

APPENDIX B

BACKGROUND INFORMATION ON CURRENT POPULATION SITING PRACTICES

APPENDIX B

TABLE OF CONTENTS

I. Previous Metropolitan Site Reviews

Two proposed sites (Ravenswood and Burlington) have been withdrawn because of population considerations. Ravenswood was a site proposed by Consolidated Edison Co. of New York in about 1963 to be located in the Borough of Queens, New York City. It has a population distribution greatly exceeding any plant ever proposed and was withdrawn by the applicant.

Public Service Electric and Gas Co. (PSE&G) of New Jersey proposed the Burlington site in about 1967 to be located in New Jersey approximately 15 miles north of Philadelphia, Pennsylvania. However, after extensive discussion with the staff and the ACRS, the applicant recognized that the site had a population distribution several times larger than the highest population distribution previously approved by the staff and PSE&G relocated the site at Salem. PSE&G later submitted an application for Newbold Island which has a cumulative population lower than Indian Point beyond 30 miles and within the first few miles, but a higher population between 4 and 30 miles.

II. Distance Versus Engineered Safety Features

In the selection of parameters for the design basis accident calculation, the applicant is permitted to select an exclusion and low population zone according to guidelines set forth in 10 CFR Part 100. If a relatively sparse population distribution exists around a site, and land acquisition costs are relatively small, the applicant may choose to select a relatively large exclusion distance and a large low population zone. By selecting large

distances, the applicant can take advantage of the natural dose reduction by meteorological dispersion that occurs as the distance from a radioactive source increases. Thus, less sophisticated mechanisms to assure the retention of any released radioactivity at the source (engineered safety features) are required.

Frequently, however, the site characteristics are such that the exclusion and low population zone selected by the applicant to comply with 10 CFR Part 100 are relatively short distances and because of special site characteristics good atmospheric dilution cannot be anticipated for a significant fraction of the time. Consequently, the reactor is equipped with engineered safety features to contain or delay release of the radioactivity at the source. These engineered safety features include chemically treated containment sprays, filtration systems, stacks to allow elevated release of activity, or systems which assure dilution and holdup in secondary containment volumes.

III. Population Data for Existing Sites

Figures 1 and 2 show a representative spectrum of existing site population distributions plotted as a function of distance in relation to hypothetical cumulative population curves which correspond to uniform population distributions of 250, 400 and 1000 people per square mile. (These figures are based on 1970 data.) Figure 1 shows the cumulative populations to 5 miles and Figure 2 shows the cumulative populations to 50 miles.

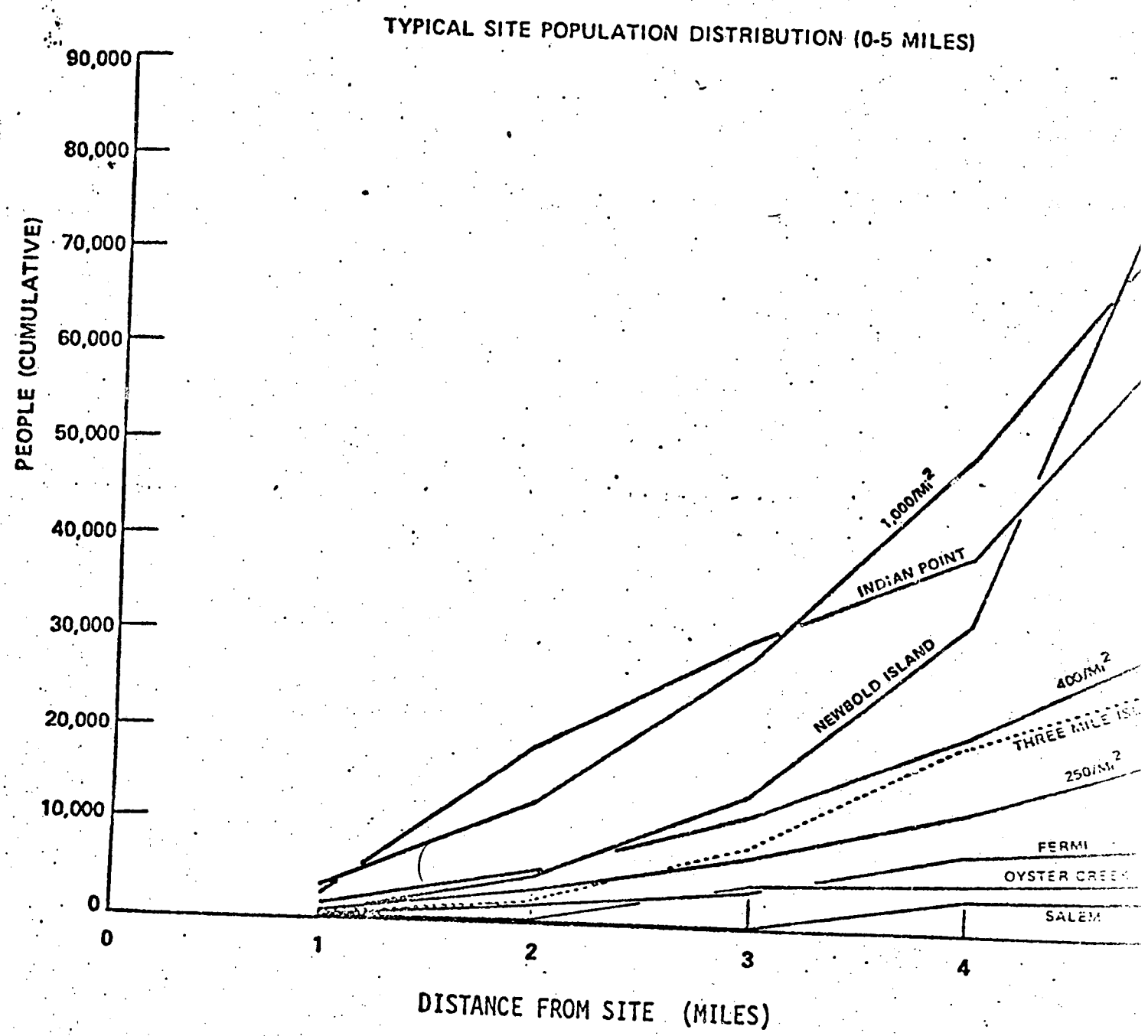

TYPICAL SITE POPULATION DISTRIBUTION (0-5 MILES)
PEOPLE (CUMULATIVE)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
1
2
3
4
DISTANCE FROM SITE (MILES)
1,000/MI.2
INDIAN POINT
NEWBOLD ISLAND
400/MI.2
THREE MILE ISL
250/MI.2
FERMI
OYSTER CREEK
SALEM

Figure 1

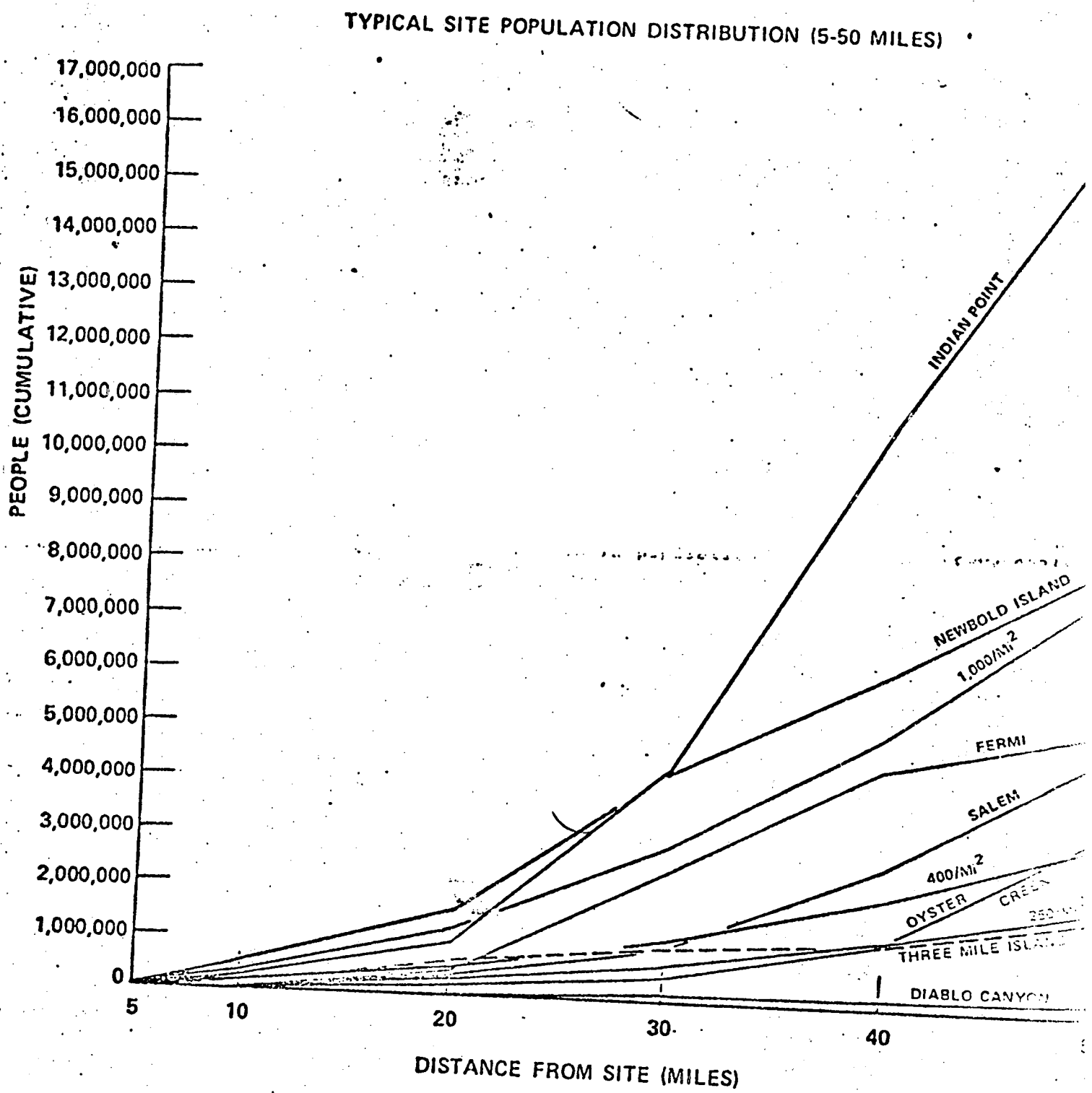

TYPICAL SITE POPULATION DISTRIBUTION (5-50 MILES)
PEOPLE (CUMULATIVE)
17,000,000
16,000,000
15,000,000
14,000,000
13,000,000
12,000,000
11,000,000
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
5
10
20
30
40
DISTANCE FROM SITE (MILES)
INDIAN POINT
NEWBOLD ISLAND
1,000/MI.2
FERMI
SALEM
400/MI.2
OYSTER
THREE MILE ISL
DIABLO CANYON

Figure 2

Figures 3 and 4 show several relatively high site population distributions in relation to the same hypothetical distributions mentioned above.

The present informal and internal population criteria for siting nuclear power plants are based on a case by case comparison against existing high population sites. Indian Point and Zion are the highest population density sites which have received construction permits. Limerick and Newbold Island are high population density sites for which the staff has issued safety evaluations. Newbold Island is currently being reconsidered by the staff in light of recently projected increases in close-in population.

Table 1 presents a comparison of six high population density sites to the maximum 1980 population level which has been approved at the construction permit stage. In addition, the proposed lower population level is listed above which state-of-the-art engineered safety features and an analysis of alternative sites would be required.

IV. Site Population Factor (SPF)

In addition to plotting the cumulative populations around the proposed reactor sites and making comparisons between the proposed population and the composite site, a reactor site population index has been devised to numerically rank any population distribution in relation to a hypothetical

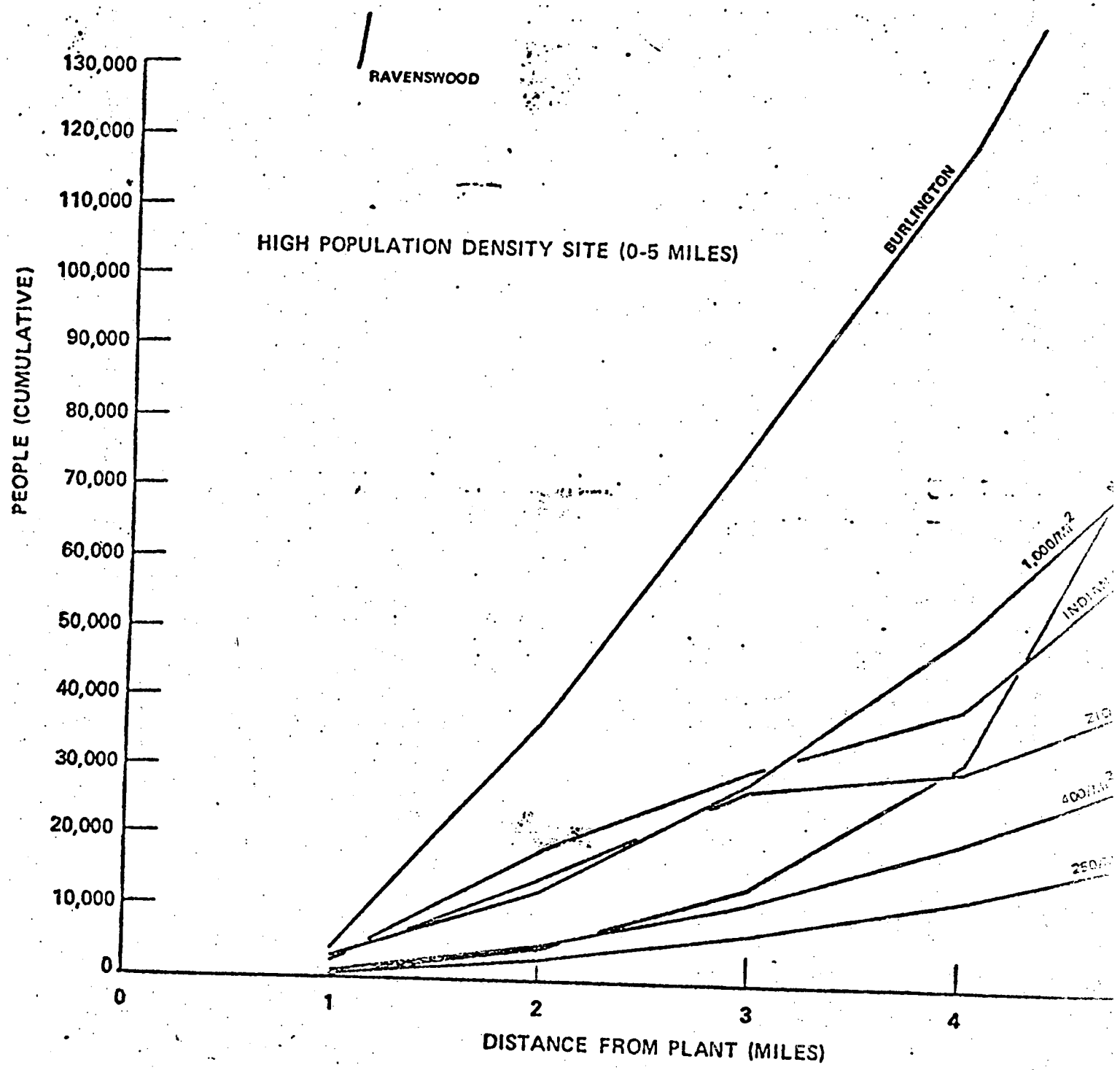

RAVENSWOOD
HIGH POPULATION DENSITY SITE (0-5 MILES)
BURLINGTON
1,000/mi²
PEOPLE (CUMULATIVE)
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
1
2
3
4
DISTANCE FROM PLANT (MILES)

Figure 3

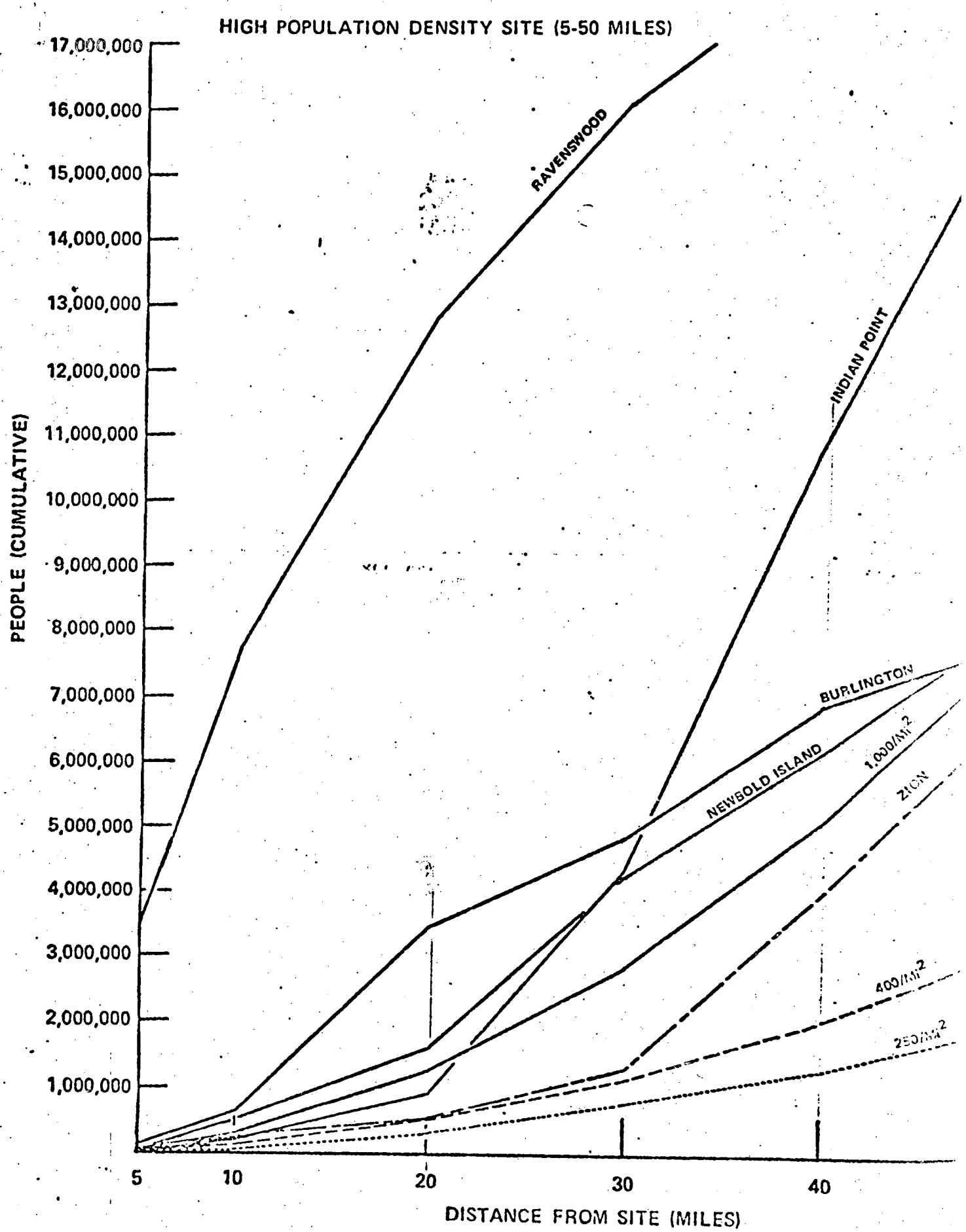

HIGH POPULATION DENSITY SITE (5-50 MILES)
PEOPLE (CUMULATIVE)
17,000,000
16,000,000
15,000,000
14,000,000
13,000,000
12,000,000
11,000,000
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
RAVENSWOOD
INDIAN POINT
BURLINGTON
NEWBOLD ISLAND
1,000/MI²
ZION
400/MI²
250/MI²
5
10
20
30
40
DISTANCE FROM SITE (MILES)

TABLE 1

CUMULATIVE POPULATION (1980 PROJECTIONS)

Distance From Site (Miles)	5	20	40
Maximum Population Approved at CP	110,000	1,200,000	13,000,000
Proposed Lower Pop. Definition (400 People/sq.mi)	30,000	500,000	2,000,000
1,000 People Sq. mi.	78,530	1,256,000	5,026,000
Zion	106,615	846,515	5,184,515
Indian Point	70,053	1,179,611	12,882,240
Newbold Island	122,335	1,843,935	7,097,935
Burlington	236,000	5,150,000	8,800,000
Ravenswood (1970)	3,599,248	12,779,748	18,324,030
Limerick	93,262	960,800	6,958,800

site. The index, called the Site Population Factor (SPF), is a weighting of the incremental populations around a reactor at the annular distances of 1, 2, 3, 4, 5, 10, 20, 30, 40 and 50 miles in comparison to a hypothetical site having a uniform population distribution of 1000 people per square mile. The weighting factors applied to the populations at the various annular distances are inversely proportional to the distance from the source. The inverse weighting is in consonance with the increased atmospheric dilution with distance for an assumed release of radioactivity emanating from a reactor. According to the weighting, a given population close to the site would be considered to present a higher risk than the same population farther away. The weighting used is the distance (d) raised to the -1.5 power.[1/]

V. SPF Categories for Presently Docketed Plants

The value of the SPF (max.) for a designated plant is the maximum SPF calculated for the series of radial distances 1, 2, 3, 4, 5, 10, 20, 30, 40 and 50 miles. A different SPF is computed for each distance. Because the SPF is normalized to a hypothetical site having a uniform population density of 1000 people per square mile, the resultant SPF can be equated directly to a uniform population density. Thus, a plant having an SPF equal to 0.4 at a particular distance is equivalent to a site with a uniform population density of 400 people per square mile to that distance.

1/ The distance to the -1.5 power relationship was selected because it approximates the annual average as well as the conservative meteorology specified in Safety Guides 3 and 4 for computation of design basis accident consequences.

Table 2 is a listing of all sites for presently docketed plants (plus the Ravenswood and Burlington sites) in order of decreasing SPF (maximum). A histogram of Table 2 showing the number of sites in each SPF category has been drawn in Figure 5. The following information can be derived from the histogram:

SPF (Max)	Percent of Plants
0.1 or less	29%
0.2 or less	51%
0.3 or less	66%
0.4 or less	77%
0.5 or less	84%
0.6 or less	88%
0.7 or less	92%
1.5 or less	100%

Most sites clearly lie at the lower end of the SPF (max) scale.

In addition to the maximum SPF's, an examination of SPF's as a function of distance allows the characterization of existing sites into five representative groups as shown on Figure 6. Group 1 contains the sites in close proximity to metropolitan areas with SPF values of 1.00 or more. Group 2 contains sites which encounter a large city 10-30 miles away and maximum SPF values of 0.3. Group 3 includes sites that are in relatively unpopulated areas, but have a small town 1-5 miles away from the reactor site. For Group 3, the SPF generally peaks in the 1-4 mile region and then drops to

1.	Ravenswood	45.0	15.5
2.	Burlington	2.84	.304
3.	Indian Point	1.49	1.49
4.	Newbold Island	1.35	1.19
5.	Zion	1.02	.730
6.	Standard (1000/mile^2)	1.00	1.00
7.	Limerick	.903	.835
8.	Shoreham	.657	.451
9.	G.E.T.R.	.638	.583
10.	Bailly	.619	.616
11.	Midland	.557	.238
12.	Fermi	.531	.50
13.	H. B. Robinson	.514	.095
14.	Oyster Creek	.490	.238
15.	Tortuguera	.481	.38
16.	Haddam Neck	.451	.370
17.	Millstone	.435	.300
18.	Beaver Valley	.432	.412
19.	Three Mile Island	.390	.304
20.	Waterford	.388	.215
21.	Peach Bottom	.387	.308
22.	Salem	.385	.353
23.	San Onofre	.343	.240
24.	Portland	.339	.339
25.	Pilgrim	.322	.322

PLANT	MAXIMUM SPF	SPF AT 50 MILES
26. B.A.W.T.R.	.295	.133
27. Humboldt Bay	.274	.090
28. Saxton	.273	.099
29. Cook	.273	.144
30. Ft. St. Vrain	.256	.224
31. Ginna	.247	.180
32. Davis Besse	.234	.147
33. Trojan	.229	.192
34. Zimmer	.218	.194
35. McGuire	.218	.186
36. Calvert Cliffs	.188	.142
37. Maine Yankee	.184	.128
38. Turkey Point	.182	.172
39. Susquehanna	.180	.175
40. LaSalle	.163	.077
41. Vermont	.161	.122
42. Surry	.159	.159
43. Sequoyah	.153	.112
44. Rancho Seco	.152	.135
45. Prairie Island	.151	.151
46. Duane Arnold	.144	.097
47. Monticello	.143	.143
48. Yankee Rowe	.135	.117
49. Quad Cities	.118	.091
50. Palisades	.109	.099

PLANT	MAXIMUM SPF	SPF AT 50 MILES
51. Oconee	.093	.088
52. FitzPatrick	.093	.082
53. Hutchinson Island	.091	.057
54. North Anna	.085	.061
55. Browns Ferry	.076	.076
56. Atlantic	.072	.072
57. Watts Bar	.063	.053
58. Point Beach	.061	.061
59. Arkansas	.054	.032
60. Kewaunee	.055	.055
61. LaCrosse	.040	.038
62. Sefor	.038	.036
63. Farley	.038	.037
64. Cooper	.036	.018
65. Big Rock Point	.034	.021
66. Brunswick	.034	.027
67. Diablo	.030	.026
68. Crystal River	.030	.020
69. Hatch	.020	.018

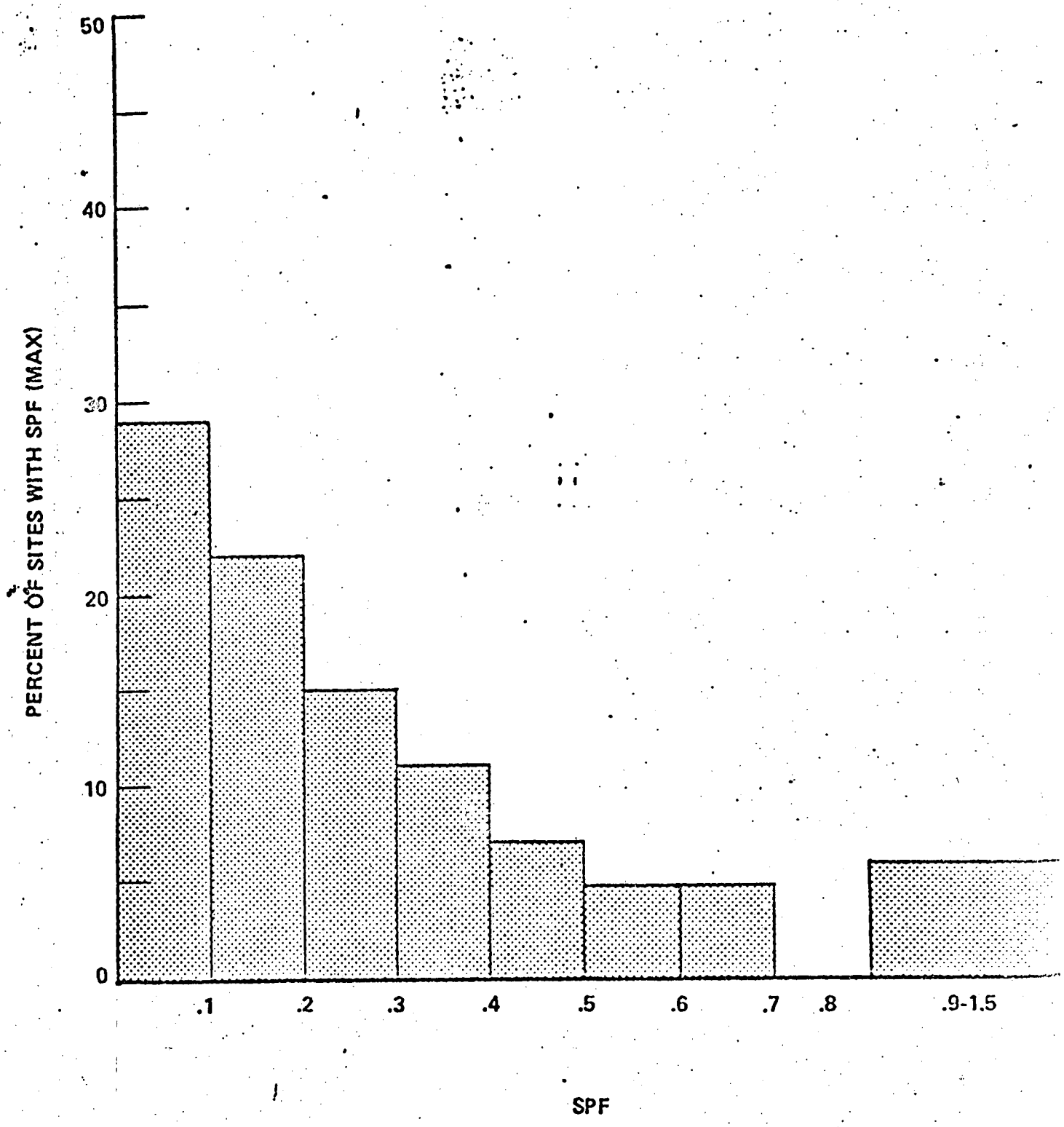


Figure 5

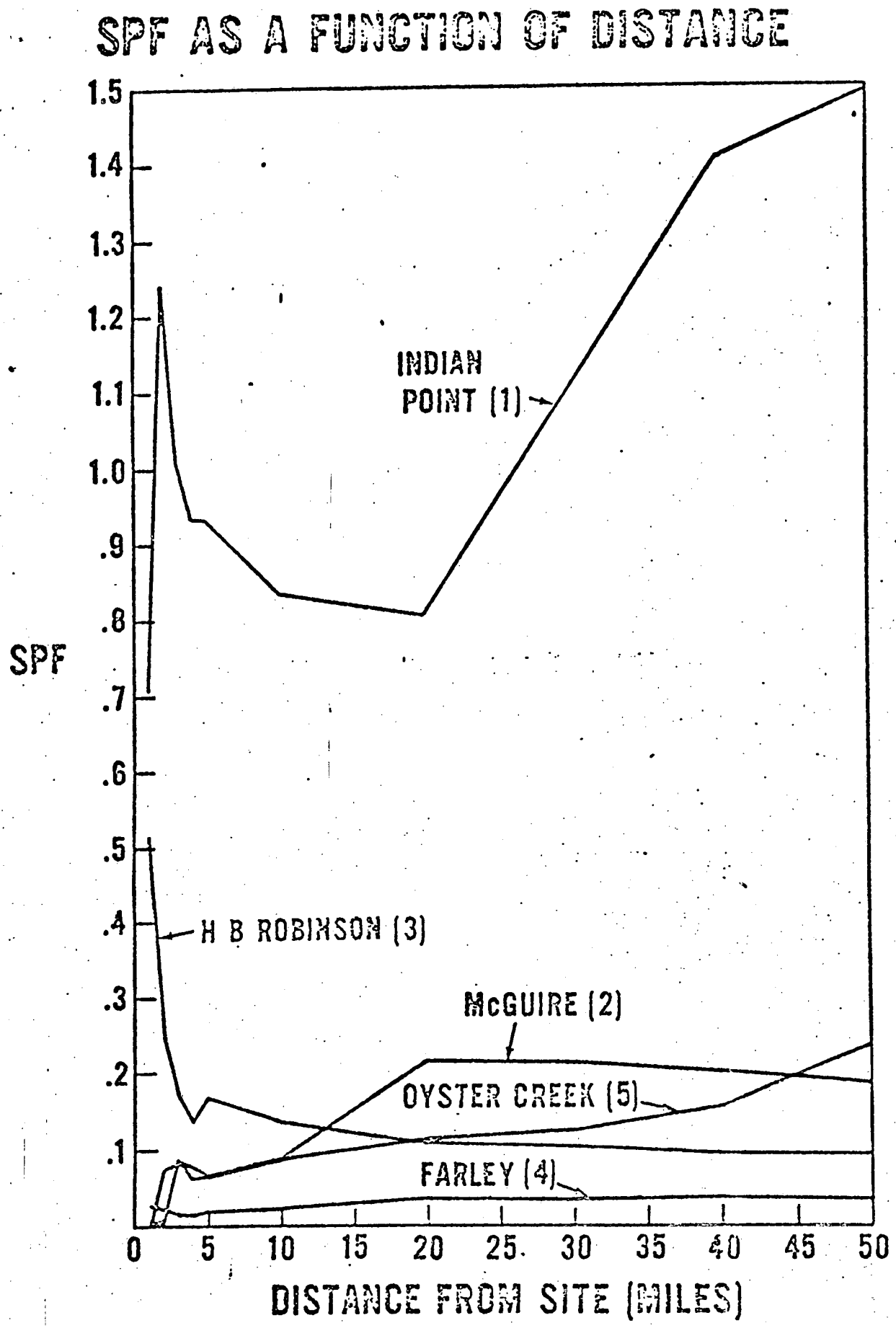

SPF AS A FUNCTION OF DISTANCE
SPF
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
INDIAN POINT (1)
H B ROBINSON (3)
McGUIRE (2)
OYSTER CREEK (5)
FARLEY (4)
0
5
10
15
20
25
30
35
40
45
50
DISTANCE FROM SITE (MILES)

Figure 6

a constant level of 0.3. Group 4 contains sites in unpopulated areas whose SPF remains constant at 0.3 or less. Finally, Group 5 contains those sites that encounter large metropolitan areas in the 40-50 mile region. The SPF curve of this category is an increasing function. Figure 6 is a plot of the SPF's of representative plants as a function of distance for each of the five groups.

Histograms were also drawn to illustrate the distribution of plants for the specific distances (5, 20 and 40 miles) which are used to specify maximum allowable cumulative populations in the draft Regulatory Guide "Acceptable Population Distribution for Nuclear Power Plant Sites." These histograms (Figures 7, 8 and 9) indicate that about 90% of the currently approved sites have an SPF below 0.4 at the 5-mile distance. Similarly, 90% of currently approved sites have an SPF below 0.4 at a distance of 20 miles and 85% have an SPF below 0.4 at 40 miles. An equivalent uniform cumulative population corresponding to these values was chosen at each of these distances as the definition of a low population site in the Regulatory Guide. When examined from the standpoint of cumulative population, about 70% of all sites would fit the cumulative population definition of a low population site at all three distances.

The use of the cumulative population values indicated in the guide does not take into account maldistributions of population which may well occur between the specified distances. For this purpose the SPF technique

DISTRIBUTION OF SPF'S AT 5 MILES

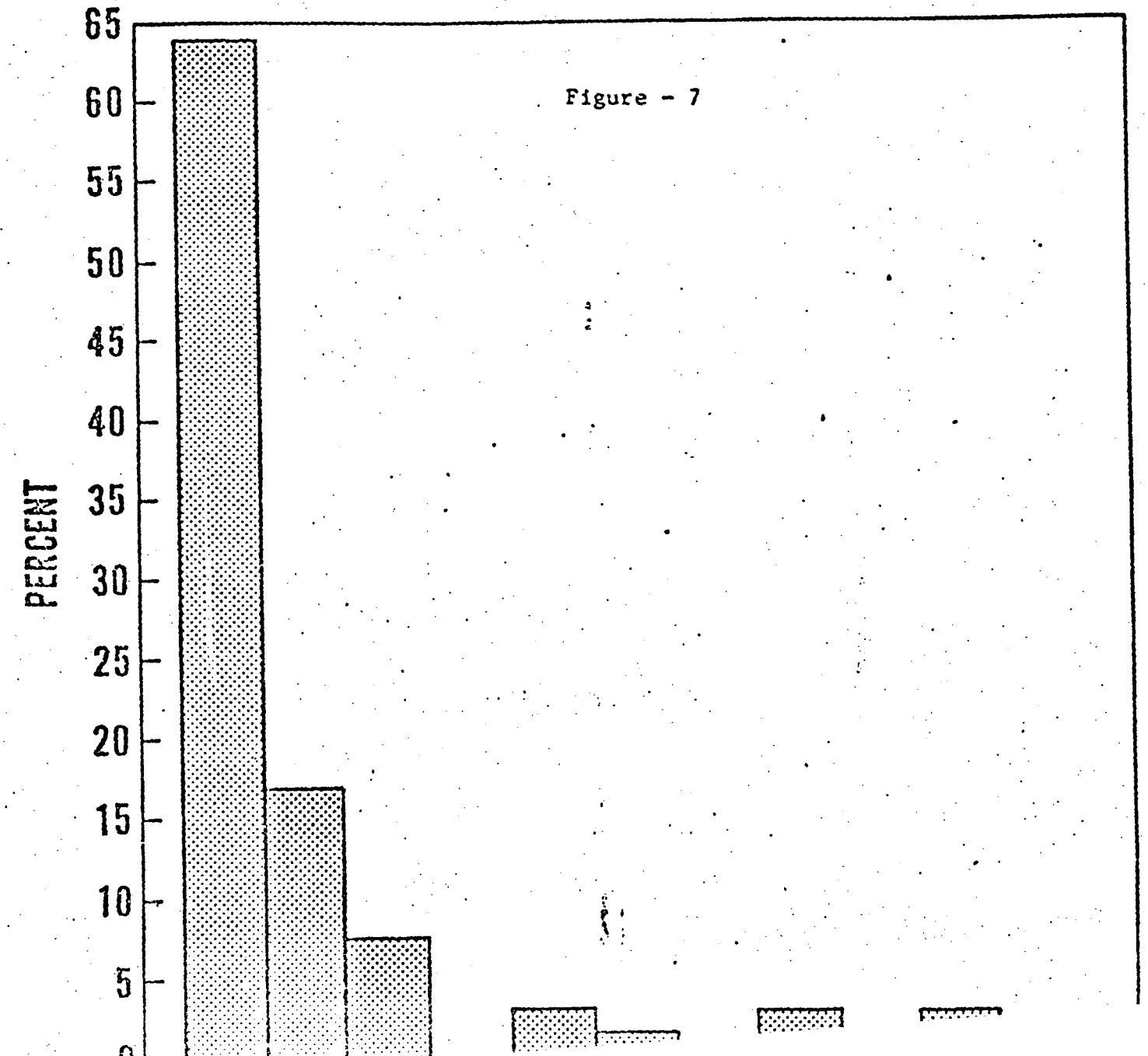
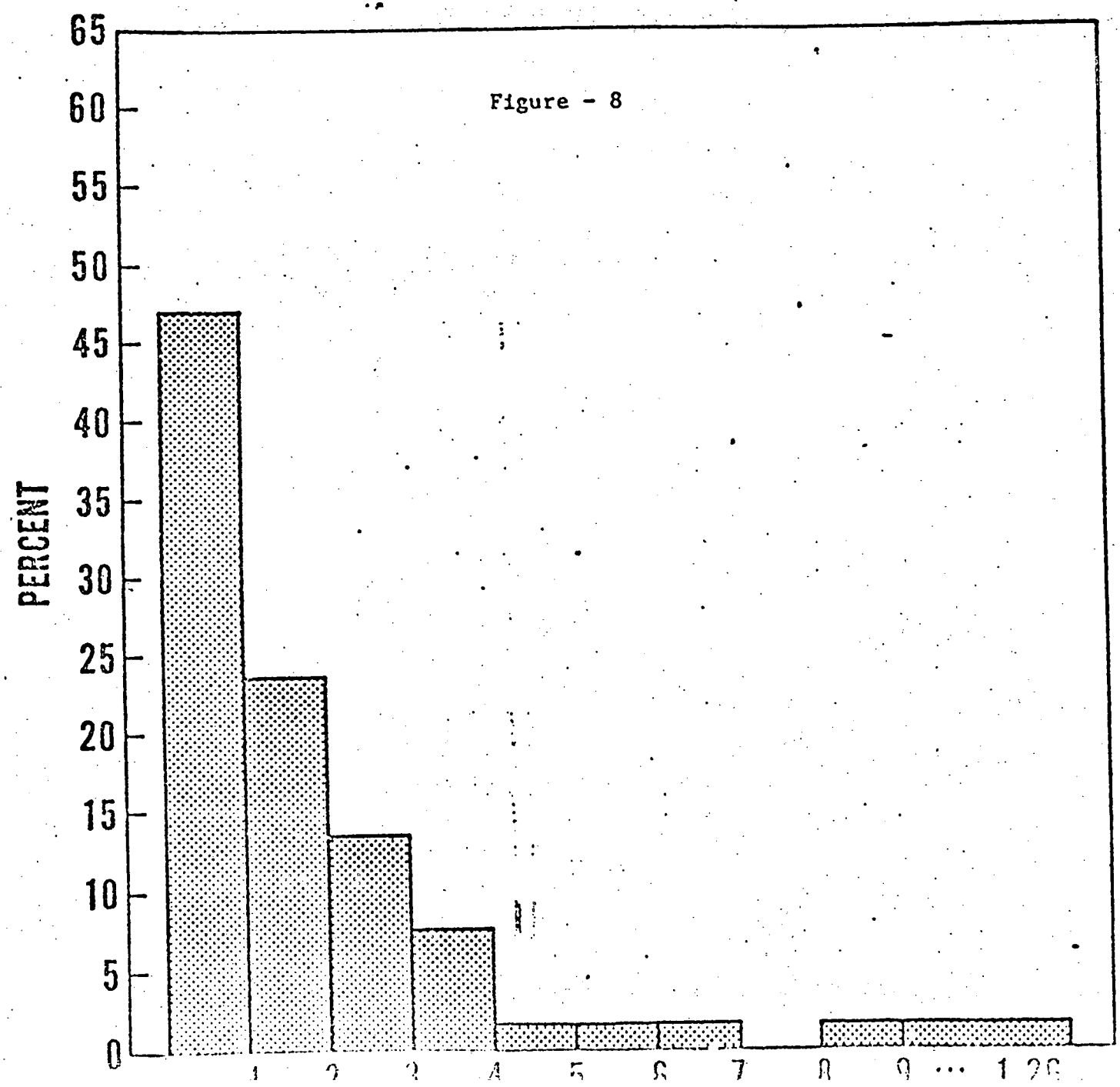
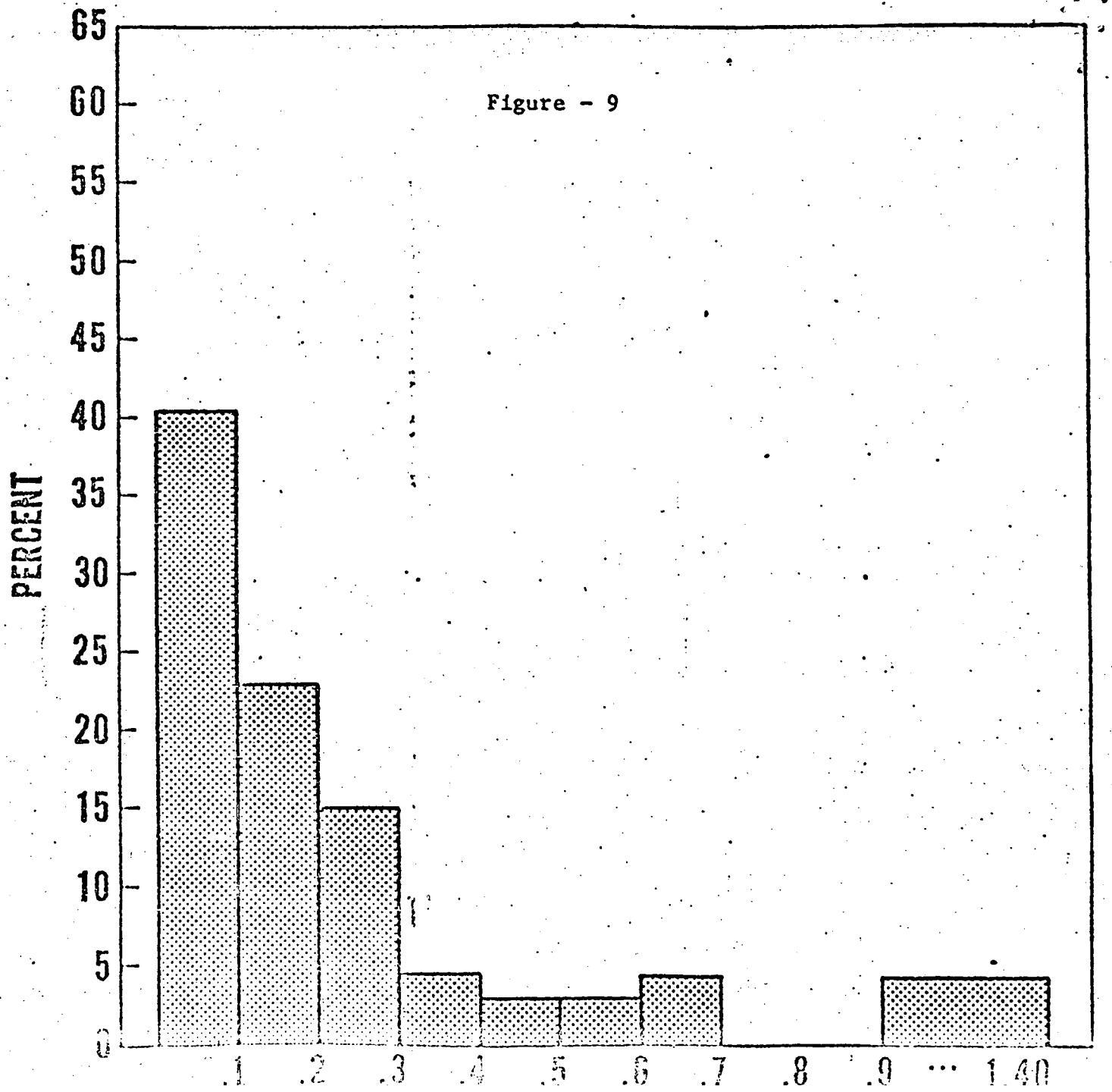


Figure - 7

DISTRIBUTION OF SPF'S AT 20 MILES



DISTRIBUTION OF SPF'S AT 40 MILES



provides a better measure of relative risk and would be used by the staff as an aid in determining the acceptability of a plant meeting the cumulat population criterion but having most of its allowable population just out side the 5- or 20-mile distance. The staff will continue to develop the SPF concept and may propose to substitute at some future time an SPF criterion for the cumulative population criteria given in the Regulatory Guide.

BEFORE THE
UNITED STATES OF AMERICA
ATOMIC ENERGY COMMISSION

BEFORE THE ATOMIC SAFETY & LICENSING APPEAL BOARD

In the matter of

CONSOLIDATED EDISON COMPANY OF NEW YORK (Indian Point, Unit No. 2)	)))	Docket No. 50-247

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing "Citizens Committee for Protection of the Environment Motion to Reopen the Record" was mailed, postage prepaid this 14th day of May, 1974 to the following:

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