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APPENDIX 2B

REPORT

ENVIRONMENTAL STUDIES - SEISMOLOGY AND METEOROLOGY

PROPOSED OCONEE NUCLEAR POWER STATION

NEAR SENECA, SOUTH CAROLINA

FOR

DUKE POWER COMPANY

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REPORT

ENVIRONMENTAL STUDIES - SEISMOLOGY AND METEOROLOGY

PROPOSED OCONEE NUCLEAR POWER STATION

NEAR SENECA, SOUTH CAROLINA

FOR

DUKE POWER COMPANY

INTRODUCTION

GENERAL

This report presents the results of our investigations for the proposed Oconee Nuclear Power Station located near Seneca, South Carolina.

The proposed site is situated between Little River and Keowee River, approximately eight miles northeast of Seneca. The location of the site is shown with respect to topography and nearby communities on Plate I-1, Map of Area.

PURPOSE

The purpose of this report is to provide a portion of the environmental analysis information for the Safety Analysis Report (SAR) which will be presented to the Atomic Energy Commission. The SAR will consider four major aspects of the environment surrounding this plant. These are:

1) the effect of the geologic setting;
2) the effect of seismic activity;
3) the effect of hydrological conditions; and
4) the effect of meteorological conditions.

Some portions of the environmental analysis are being performed by others. This report is concerned only with aseismic design criteria as developed from geologic and seismologic studies, and with the establishment of weather parameters which will become a part of potential overall on- and off-site calculations.

METHODS USED

In the accomplishment of the site evaluations, we reviewed relevant information, conducted field investigations, and performed

appropriate laboratory tests. The results of this work provided the basis for our seismologic and meteorologic conclusions. These studies were performed under the supervision of Dames & Moore technical personnel.

PROJECT STAFF

The following staff members provided principal contributions to the information and conclusions presented herein:

Francis E. Courtney	Consulting Meteorologist
Joseph A. Fischer	Partner responsible for Seismology
Malcolm D. Horton	Partner responsible for Meteorology
Richard L. Lea	Project Manager
Monzell Louke	Geophysicist
Benjamin S. Persons	Responsible Partner
Forrest D. Peters	Project Geophysicist
Polidoro Velasco	Civil Engineer

The following plate is attached and completes this section of the report:

Plate I-1 ..... Map of Area

SEISMOLOGY

INTRODUCTION

The purpose of this study was to develop aseismic design parameters from a study of the regional tectonics and seismic history and the response of the foundation materials to earthquake motion. The terminology used in this portion of the report is defined in Appendices II-D and II-E.

SCOPE

The scope of our investigations included:

1) a review of the available geological and seismological literature pertaining to the region;

2) a geological reconnaissance of the site, performed primarily for the purpose of evaluating the possibility of active faulting in the area;
3) geophysical explorations and laboratory tests to provide parameters for evaluating the response of foundation materials to earthquake ground motion;
4) an evaluation of the seismic history to aid in the selection of the design earthquake that the power plant might experience; and
5) the development and recommendation of aseismic design parameters for the proposed structures.

SUMMARY AND CONCLUSIONS

No active or recent faulting has been recognized in the immediate area of the proposed plant site. The closest known faulting is the Brevard fault zone, 11 miles northwest of the site. Minor seismic activity has been recorded in the vicinity of the Brevard fault zone and may be associated with it. Thus, we would expect no slipping or tearing of the ground at the plant site.

The foundations of the proposed major structures will be located in crystalline metamorphic rock. This rock would have excellent strength properties and relatively small amplification of ground motion resulting from an earthquake.

Conservatively, we have estimated that the maximum vertical and horizontal ground acceleration that might be experienced at the plant site during its economic life is on the order of five percent of gravity. This maximum ground motion is predicated on an earthquake of a Richter Magnitude less than five located in the Brevard zone.

It is our opinion that these ground accelerations conservatively represent the maximum acceleration expected at the site. Thus, from a seismologic point of view, the planned nuclear power station can be satisfactorily constructed at the investigated site.

TECTONICS

This section of the report will discuss only those portions of tectonics and geology most pertinent to the engineering seismologic evaluation of the site. A discussion of regional and local geology including lithology and geologic structure is found in the report "Engineering Geology of Oconee Nuclear Station" dated October 26, 1966, and prepared by William V. Conn.

The geology of the region is highly complex and in many respects is incompletely known. The region (defined as North Carolina and South Carolina, and parts of Georgia, Alabama, Tennessee and Virginia) is comprised of three large northeast-southwest trending tectonic zones: The coastal plain, the crystalline-metamorphic zone and the overthrust zone. These zones are shown on Plate II-1, Regional Tectonics.

The site is located nearly in the center of the crystalline-metamorphic zone, which consists of six generally recognized metamorphic belts. From southeast to northwest these are: The Carolina slate belt, Charlotte belt, Kings Mountain belt, Inner Piedmont belt, Brevard belt and Blue Ridge belt. The site location is within the Inner Piedmont belt. The rocks in the belts consist of metamorphosed sediments and volcanics that have been folded, faulted and intruded with igneous rocks. These belts are delineated by differing degrees of metamorphism. Generally, the degree of metamorphism becomes progressively less from the northwest to the southeast.

The oldest metamorphic rocks are located in the Blue Ridge belt. The more easterly belts of younger rocks have undergone progressively less metamorphism.

To the north and west are found a series of fault systems. Since these faults are both numerous and extensive, they can be grouped together and referred to as the overthrust zone, as shown on Plate II-1. These faults no doubt resulted from the formation of the Appalachians.

The great system of thrust faults in the overthrust zone and most of the known faulting within the crystalline-metamorphic zone apparently occurred during the last period of metamorphism (260 million years ago).

Subsequently, during the Triassic Period (180 to 225 million years ago), sediments were deposited over parts of the exposed metamorphic belts. These deposits and the older metamorphics were intruded by a system of northwest-trending diabase dikes and were faulted by northeast-trending normal faults in late Triassic time (200 million

years ago). Some of the older faults within the crystalline-metamorphic zone may have been active at this time.

From late Triassic time until the present, the coastal plain has accumulated a sedimentary cover over its crystalline-metamorphic bedrock. These sediments overlap the bedrock and thicken toward the southeast, effectively masking any ancient faulting in the basement.

It is considered possible that igneous activity has occurred in the region after the Triassic because volcanic bentonitic clays of Eocene (approximately 50 million years ago) and possible Miocene age (12 million years ago) have been mapped in the sediments of the coastal plain in South Carolina. The source of this volcanic activity is presently unknown.

Faulting: The names, distances and directions from the proposed site, and the probable age of the known faulting in the region are as follows:

Name	Distance-Direction From Site	Probable Age Millions of Years
Brevard Fault	11 Miles NW	260
Dahlonega Fault	40 Miles W	260
Whitestone Fault	47 Miles NW	260
Towaliga Fault	90 Miles S	260
Cartersville Fault	104 Miles W	260
Gold Hill Fault	115 Miles E	260
Goat Rock Fault	140 Miles SW	260
Triassic, Deep River Basin, N.C. and S.C.	140 Miles E	200
Triassic, Danville Basin, N.C.	145 Miles NE	200
Crisp and Dooly Counties, Ga.	190 Miles SW	12 to 70
Probable Triassic Basin, Charleston, S. C.	200 Miles SE	200

The locations of these faults with respect to the site are shown on Plate II-1.

The first seven faults are all associated with the last metamorphic period. The Brevard, Whitestone, Dahlonega and Cartersville faults apparently form an interrelated system. This system separates the eastern metamorphic belts from the Blue Ridge metamorphic belt and the overthrust zone on the west.

The Towaliga, Goat Rock and Gold Hill Faults and the Kings Mountain belt apparently form another interrelated alignment within the eastern metamorphic belts. The Kings Mountain belt is not considered a fault. Its association and alignment in relation to the three known faults mentioned and the location of earthquake epicenters within the area bounded by these features, lead to the conclusion that these features form an interrelated alignment.

There is no surface indication that any of these three faults have been active since the Triassic Period (200 million years).

Two fault locations in the region have been thoroughly investigated by borings. These are the Cartersville fault near the Allatoona Dam and the Ocoee-Conasauga fault in Georgia. These faults were found to be completely healed and not to have moved in many millions of years.

The Triassic basins of the Carolinas and further north may be due to the release of the compressional forces which formed the Appalachians. These basins are down-faulted grabens which are filled with Triassic sediments. Two earthquakes in the vicinity of McBee, South Carolina, may be related to an extension of a Triassic basin which has been inferred in the Chesterfield-Durham area.

Some faulting within the tertiary sediments in Dooly, Crisp and Clay Counties, Georgia, has been mapped. The true areal extent of this faulting is unknown. This faulting apparently ranges from Cretaceous to possibly Miocene in age (70 to 12 million years).

The earthquake activity near Charleston, South Carolina, may indicate an active fault in that region. However, no evidence of surface faulting has been found.

SITE GEOLOGY

The bedrock at the site consists of a banded biotite-hornblende gneiss and granite gneiss. The surface of the gneiss has weathered unevenly. The depth to sound, but weathered, rock ranges from about five to about 37 feet below present ground surface in the site area.

There are no apparent faults in or near the plant site. However, small concealed faults are possible in the area. It is considered unlikely that any such small faults could be considered to be active. Any such small faults are likely to be associated with the last igneous activity in the area, which occurred during either late Permian or late Triassic time (260 or 200 million years ago).

SEISMIC HISTORY

A considerable number of earthquakes have been felt in the region. However, most of these shocks resulted in little or no damage. A plot of the more significant shocks, those having a recorded intensity of Modified Mercalli V or larger, is shown on Plate II-2, Earthquake Epicenters.

Accurate locations for earthquake epicenters have only been available since the installation of modern seismographs in the region. Previous to these installations, epicentral locations, based upon known damage and reports of people who felt the earthquake, could be in considerable error. Even with instrumental locations, epicenters could be in error by 20 miles or so. It is estimated that major shocks in the

region would probably have been recorded for at least 200 years. However, smaller earthquakes before about 1850 were probably either unrecorded or were unreliably located.

Several large earthquakes outside the area shown on Plate II-2 have been felt in the region. North of the region, the closest major shocks had epicenters in the St. Lawrence Rift valley or on the folded and faulted coast of Massachusetts. The catastrophic earthquakes of 1811 and 1812 near New Madrid, Missouri, approximately 480 miles from the site, are the closest known large earthquakes to the west. These shocks were probably related to the Ozark Dome. With the exception of the earthquakes at Charleston, South Carolina, no major shocks have occurred south or east of the site within the continental United States. These distant large earthquakes are unrelated to any of the known faulting within the crystalline-metamorphic or overthrust zones in which the site is located.

The largest earthquakes close to the site occurred near Charleston in August, 1886, some 200 miles from the site. Two shocks, occurring closely in time, had an intensity estimated to be about Modified Mercalli IX at the epicenter and were perceptible over an area of greater than two million square miles. However, damage was confined to a relatively small area. Aftershocks of the main earthquake had intensities ranging up to Modified Mercalli VII. These shocks may be associated with a downfaulted Triassic basin under the coastal plain.

The large number of small to moderate sized earthquakes close to the site are of greater significance than the aforementioned large but quite distant shocks.

The region surrounding the site can be divided into three major areas on the basis of the regional tectonics and the seismic history. These major seismic areas are:

1) the overthrust zone and Blue Ridge metamorphic belt;
2) the crystalline-metamorphic zone, exclusive of the Blue Ridge belt; and
3) the coastal plain.

These zones are similar to the zones already discussed under Tectonics, but have slightly different boundaries. The greatest number of recorded shocks have occurred within the overthrust zone and the Blue Ridge metamorphic belt northwest of the Brevard, Whitestone, Dahlonega and Cartersville fault system. The epicenters in this area are generally widely scattered.

There have been a small number of earthquakes within the crystalline-metamorphic zone, exclusive of the Blue Ridge metamorphic belt. These earthquakes, extending from central Georgia to North Carolina, may be associated with the Towaliga, Goat Rock, Gold Hill, Kings Mountain alignment.

The coastal plain has experienced few earthquakes outside of the Charleston area. Four shocks, at Wilmington, North Carolina and Savannah, Georgia, have occurred but are unrelated to any known faulting, although the Wilmington shocks were adjacent to the Cape Fear Arch.

The only earthquake which does not closely fit this system of seismic areas is the 1924 shock in Pickens County, South Carolina (MM V Intensity). However, it is likely that this earthquake is associated with the overthrust-Blue Ridge seismic area.

A list of the shocks in the region has been prepared and is presented in Appendix II-C.

EFFECTS OF EARTHQUAKE MOTIONS

Two different methods of evaluating earthquakes are in general use. These are the Modified Mercalli (MM) Intensity (damage) Scale and the Richter Magnitude Scale. The magnitude of, and the intensities resulting from, an earthquake are only indirectly related. The Richter Magnitude is an approximate measure of the total amount of energy released by an earthquake. The Modified Mercalli Intensity, however, is an estimate of the amount of damage caused at a particular site by an earthquake. The intensity of an earthquake at a particular site is only a general indicator of the amount of ground motion since it is a damage criteria and, therefore, dependent on structural considerations as well as ground motion amplitude. The actual amplitude of ground motion at a particular site is dependent upon the following factors:

1) the total amount of energy released by an earthquake;
2) the distance of the site from the focus of the earthquake; and
3) the thickness and dynamic properties of the materials above the basement rock complex.

The Richter and Modified Mercalli scales are further explained in Appendix II E.

It is understood that the proposed foundation level for the major units of the plant is between Elevations 765 and 770. The planned depths will place all foundations within the sound gneissic bedrock.

In general, it may be said that structures founded upon firm soils and rock have performed well in major earthquakes.

Certain general conclusions can be drawn from the information available from a number of earthquakes.

1) the amplification of ground motion which can occur in soft soils would not be expected in a hard rock site, such as the Oconee Nuclear Power Plant site; and

2) damaging occurrences such as liquefaction or fatigue-type failure observed in soils would not be expected in a rock formation.

Geophysical studies were made at the site to further evaluate the site response characteristics. These investigations are described in Appendix II-A. Seismic refraction surveys and uphole velocity measurements indicate that the sound bedrock has a compressional wave velocity of between 10,000 and 14,000 feet per second.

Although the information can only be considered in a qualitative manner, it is of interest to note that unusually large amounts of explosives were required to produce the required amplitude of wave motion for the seismic surveys. Up to 70 pounds of explosives were used in a single shot. The subsurface materials at the site appear to be extremely absorbent. Similar work would normally require only approximately five pounds of explosives to produce the same or more energy. Recordings of microtremors also showed an extremely low amplitude of natural ground motion at the site.

ASEISMIC DESIGN CRITERIA

The assignment of probable future earthquake activity can only be based upon the previous record and the known geology of the area. Although the seismic history of the region is fairly short, a reasonable picture of the seismicity of the area becomes apparent from a study of the epicenter locations and the regional tectonics.

There are three significant zones of seismic activity in the general vicinity of the site; the Brevard and related faults zone, the overthrust zone and the Towaliga, Goat Rock, Gold Hill, Kings Mountain alignment.

An evaluation of the earthquake activity and the regional geology can result in the selection of a series of maximum-sized shocks which are likely to occur in these various areas. Conservatively, we can assume that the previous maximum-sized shock on a particular fault zone can occur during the economic life of the proposed power station at perhaps the nearest approach of the particular fault system to the proposed site. This assumption will result in an investigation of the following shocks:

Zone	Location	(MM) Intensity at Epicenter	Estimated Magnitude (Richter)
Brevard Fault Zone	11 Miles NW	VI	Less than 4½ to 5
Overthrust Zone	75 Miles NW	VIII	Less than 5½ to 6
Towaliga, Goat Rock, Gold Hill, Kings Mountain Alignment	30 Miles SE	VII-VIII	Less than 5½ to 6

It is considered likely that these shocks could occur no closer than the indicated distances from the site during the life of the planned facilities. Since the magnitudes of these shocks are fairly small, the distance from the epicenter becomes extremely important. Ground accelerations would diminish rapidly with the distance from the epicenter. Although larger earthquakes occur within other fault zones, the highest ground accelerations at the site would be experienced from an earthquake along the Brevard fault zone. The assumption of a shock of less than Richter Magnitude five occurring along the Brevard fault zone at its closest location to the site (11 miles), would give ground motions on the order of five percent of gravity at the site. Vertical ground accelerations, as contrasted to the horizontal accelerations, would be only slightly less than five percent of gravity in the competent rock at the site. Five percent of gravity should be used for both vertical and horizontal ground accelerations in the design of the station.

Our estimate of the ground motion and response spectrum for the design shock as mentioned above is presented on Plates II-3 and II-4, Recommended Ground Motion Spectrum and Recommended Response Spectra.

The Recommended Ground Motion Spectrum on Plate II-3 shows the expected maximum ground acceleration, velocity and displacement versus frequency at the site for the design earthquake. This plot is the expected ground motions of a particle within the rock at foundation level, and does not indicate the motions to be expected within a structure. For any but a rigid or highly damped structure, amplification of the imposed ground motion will take place. Thus, another plot, representing the effect of the earthquake ground motion on the building, is needed. This plot is called the Recommended Response Spectra.

The upper curve on the Recommended Response Spectra, Plate II-4, shows the expected maximum acceleration, velocity and displacement versus frequency that would be experienced by a simple inverted pendulum which has no damping if the pendulum was excited by the ground motions specified in the Recommended Ground Motion Spectrum. The other curves on Plate II-4 are plotted to show the effects of damping.

In conclusion, it is believed that the foundation material, a competent rock, would have excellent strength properties during an earthquake and relatively low amplifications of ground motion over that in the basement rock complex.

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The following Plates and Appendices are attached and complete this portion of the report:

Plate II-1	Regional Tectonics
Plate II-2	Earthquake Epicenters
Plate II-3	Estimated Ground Motion Spectrum
Plate II-4	Estimated Response Spectrum
Appendix II-A	Field Studies
Appendix II-B	Laboratory Tests
Appendix II-C	Significant Earthquakes in the Southeast United States
Appendix II-D	Glossary
Appendix II-E	Intensity and Magnitude Scales
Appendix II-F	List of References

Respectfully submitted,

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APPENDIX II-A

FIELD STUDIES

Geologic Investigations

A geologic reconnaissance of the site and surrounding area was made. This reconnaissance consisted of examining nearby rock outcrops and rock cores from some of the borings drilled by Law Engineering Testing Company.

Seismic Investigations

An uphole velocity survey was performed on Boring NA-9. A Dynametric Interval Timer, Model 117-A, capable of measuring times of 0.0001 seconds, was used. Explosives in the boring of up to one-half pound of dynamite were used to create the shock wave.

The calculated velocities from this survey are somewhat anomalous because of the weathered and fractured character of the rock.

Two seismic refraction lines were shot across the site. A Mandrel Industries Interval Timer, ER-75, 12-trace refraction seismograph was used to record the lines. Explosives were used to provide the shock waves.

The location of the uphole boring and the seismic lines are shown on Plate II-A1, Location Map, Seismic Field Work.

Two cross sections through the site along the seismic refraction lines are presented on Plate II-A2. The interpretations on these cross sections are based upon the uphole velocity survey, the seismic refraction lines and velocity measurements on core samples. This interpretation of the velocities is considered generally reliable. These velocites are general averages and small areas within the site may not fit the cross section because the character and the depth and degree of weathering of the rock at the site varies greatly in short distances. The water table elevation may also vary somewhat from that shown on the cross sections.

The pattern of microtremor motion was recorded at the site. The instrument used is capable of a maximum gain of 150,000. However, this site is extremely quiet and no appreciable amplitudes were recorded. (For example, a truck passing along the road less than 75 feet from the geophone produced double amplitudes of only 2.5×10^{-6} inches of ground motion.)

Because of the extremely low amplitudes of both the microtremor and the refraction energies, it was decided to perform an attenuation curve of the ground motion produced by explosives. Both the microtremor equipment and a Sprengnether Blast Recorder were used to measure the ground motion at 50, 100, 200 and 400 feet from 40-pound charges. This attenuation curve was compared with attenuation

curves from sites with known characteristics to gain a better idea of the probable ground motion characteristics of the site. The results of this data indicated a marked attenuation of ground motion with distance.

The data acquired from the field investigation is retained in our files and is available upon request.

-oOo-

The following Plates are attached and complete this Appendix:

Plate II-A1 . . . . . Location Map, Seismic Field Work

Plate II-A2 . . . . . Diagrammatic Cross Sections Through Seismic Lines

APPENDIX II-B

LABORATORY TESTS

Various laboratory tests were run on cores from Borings NA-4 and NA-10.

Compressional wave velocity and specific gravity measurements were performed on four cores. The results of these measurements are shown in Table 1.

TABLE 1

VELOCITY MEASUREMENTS

BORING	DEPTH of CORE	ROCK DESCRIPTION	VELOCITY (ft/sec)	SPECIFIC GRAVITY
NA-9	8.5'	Weathered Granite Gneiss	5,270	2.44
NA-4	31.0'	Granite Gneiss	11,900	2.85
NA-4	66.0'	Biotite Hornblende Gneiss	10,000	2.65
NA-9	90.0'	Granite Gneiss	10,100	2.68

The following measurements were run on eight cores from the two borings: Young's modulus, Poisson's ratio and ultimate crushing strength. The results of these measurements are shown in Table 2.

TABLE 2

BORING	DEPTH of CORE	DESCRIPTION OF ROCK	AVERAGE YOUNG'S MODULUS (E) (psi)	AVERAGE POISSON'S RATIO (σ)	ULTIMATE CRUSHING STRENGTH (psi)
NA-4	14.0'	Weathered Granite Gneiss	1.5×10^6	(0.50)* (0.28)	5,000
NA-9	26.5'	Weathered Granite Gneiss	1.8×10^6	0.15	6,610
NA-9	41.0'	Slightly Weathered Granite Gneiss	2.4×10^6	0.20	7,540
NA-4	47.5'	Granite Gneiss	4.8×10^6	0.18	15,520
NA-9	55.0'	Biotite Hornblende Gneiss	4.1×10^6	0.11	***
NA-9	59.5'	Granite Gneiss	5.1×10^6	0.20**	16,480
NA-9	71.5'	Biotite Hornblende Gneiss	(3.2×10^6)* (11.4×10^6)	0.21	8,270
NA-9	98.0'	Granite Gneiss	5.9×10^6	0.20	12,320

NOTES: * Values are too far apart to average.

** Single value, other strain gauge set did not work.

*** End failure on weak area of core, value approximately 11,000.

APPENDIX II-C

SIGNIFICANT EARTHQUAKES IN THE SOUTHEAST UNITED STATES
(Intensity V or Greater)

YEAR	DATE	INTENSITY (Modified Mercalli)	EPICENTRAL LOCATION			PERCEPTIBLE AREA (Square Miles)
			LOCALITY	N.LAT.	W.LONG.	
1843	January 4	VIII	Western Tennessee	35.2	90.0	400,000
1857	December 19	Not Listed	Charleston, S.C.	32.8	79.8	Not Listed
1872	June 17	V	Milledgeville, Ga.	33.1	83.3	Not Listed
1874	February 10 April 17	V	McDowell County,N.C.	35.7	82.1	Local
1875	November 1	VI	Northern Georgia	33.8	82.5	25,000
1875	December 22	VII	Arvonia, Virginia	37.6	78.5	50,000
1877	November 16	V	Western N.C. and Eastern Tennessee	35.5	84.0	5,000
1879	December 12	V	Charlotte, N.C.	35.2	80.8	Not Listed
1884	January 18	V	Wilmington, N.C.	34.3	78.0	Local
1885	August 6	IV-V	North Carolina	36.2	81.6	Local
1886	February 4	V	Alabama	32.8	88.0	1,600
1886	August 31	IX-X	Charleston, S.C.	32.9	80.0	2,000,000
1886	October 22 October 22	VI VII	Charleston, S.C. Charleston, S.C.	32.9 32.9	80.0 80.0	30,000 30,000
1886	November 5	VI	Charleston, S.C.	32.9	80.0	30,000

YEAR	DATE	INTENSITY (Modified Mercalli)	EPICENTRAL LOCATION			PERCEPTIBLE AREA (Square Miles)
			LOCALITY	N.LAT.	W.LONG.	
1889	July 19	VI	Memphis, Tenn.	35.2	90.0	Local
1897	April 30	IV - V	Tennessee and Ill.	Not Listed	Not Listed	Not Listed
1897	December 18	V	Ashland, Virginia	37.7	77.5	7,500
1900	October 31	V	Jacksonville, Fla.	30.4	81.7	Local
1902	October 18	V	Southeastern Tenn. and Northwestern Ga.	35.0	85.3	1,500
1903	January 23	VI	Georgia and S.C.	32.1	81.1	10,000
1904	March 4	V	Eastern Tenn.	35.7	83.5	5,000
1905	January 27-8	VII	Alabama	34	86	250,000
1907	April 19	V	South Carolina	32.9	80.0	10,000
1911	April 20	V	North Carolina-South Carolina Border	35.2	82.7	600
1912	June 12	VII	Summerville, S.C.	32.9	80.0	35,000
1912	June 20	V	Savannah, Georgia	32	81	Not Listed
1913	January 1	VII-VIII	Union County, S.C.	34.7	81.7	43,000
1913	March 28	VII	Eastern Tennessee	36.2	83.7	2,700
1913	April 17	V	Eastern Tennessee	35.3	84.2	3,500
1914	January 23	V	Eastern Tennessee	35.6	84.5	Local
1915	March 5	VI	Georgia	33.5	83.5	50,000

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YEAR	DATE	INTENSITY (Modified Mercalli)	EPICENTRAL LOCATION			PERCEPTIBLE AREA (Square Miles)
			LOCALITY	N.LAT.	W.LONG.	
1914	September 22	V	South Carolina	33.0	80.3	30,000
1915	October 29	V	North Carolina	35.8	82.7	1,200
1916	February 21	VI	Western N. C.	35.5	82.5	200,000
1916	August 26	V	Western N. C.	36	81	3,800
1916	October 18	VII	Alabama	33.5	86.2	100,000
1917	June 29	V	Alabama	32.7	87.5	Local
1918	June 21	V	Tennessee	36.1	84.1	3,000
1918	October 15	V	Western Tennessee	35.2	89.2	20,000
1920	December 24	V	Eastern Tennessee	36	85	Local
1924	October 20	V	Pickens County, S.C.	35.0	82.6	56,000
1926	July 8	VI	Southern Mitchell County, N.C.	35.9	82.1	Local
1927	June 16	V	Alabama	34.7	86.0	2,500
1928	November 2	VI	Western N.C.	36.0	82.6	40,000
1931	May 5	V - VI	Northern Alabama	33.7	86.6	6,500
1933	December 19	IV - V	Summerville, S.C.	33.0	80.2	Local
1935	January 1	V	North Carolina-Georgia Border	35.1	83.6	7,000

YEAR	DATE	INTENSITY (Modified Mercalli)	EPICENTRAL LOCATION			PERCEPTIBLE AREA (Square Miles)
			LOCALITY	N.LAT.	W.LONG.	
1939	May 4	V	Anniston, Ala.	33.7	85.8	Not Listed
1941	November 16	V - VI	Covington, Tenn.	35.5	89.7	Local
1945	June 13	V	Cleveland, Tenn.	35	84.5	Not Listed
1945	July 26	VI	Murray Lake, S.C.	34.3	81.4	25,000
1952	November 19	V	Charleston, S.C.	32.8	80.0	Not Listed
1952	July 16	VI	Dyersburg, Tenn.	36.2	89.6	Not Listed
1954	January 22	V	Athens and Etowah, Tennessee	35.3	84.4	Not Listed
1954	April 26	V	Memphis, Tenn.	35.2	90.1	Not Listed
1955	January 25	VI	Tenn-Arkansas-Missouri Border	35.6	90.3	30,000
1955	March 29	VI	Finley, Tenn.	36.0	89.5	Not Listed
1955	September 5	V	Finley, Tenn.	36.0	89.5	Not Listed
1955	September 28	V	Virginia-N.C. Border	Not Listed	Not Listed	1,700
1955	December 13	V	Dyer County, Tenn.	36	89.5	Not Listed
1956	September 7	VI	Eastern Tennessee	35.5	84.0	8,300
1956	January 28	VI	Tennessee-Arkansas Border	35.6	89.5	Not Listed
1957	April 23	VI	Northern Alabama	34.5	86.7	11,500

YEAR	DATE	INTENSITY (Modified Mercalli)	EPICENTRAL LOCATION			PERCEPTIBLE AREA (Square Miles)
			LOCALITY	N.LAT.	W.LONG.	
1957	May 13	VI	Western N. C.	35.7	82	8,100
1957	June 23	V	Eastern Central Tennessee	36.5	84.5	Not Listed
1957	July 2	VI	Western N.C.	35.5	83.5	Not Listed
1957	November 24	VI	North Carolina-Tennessee Border	35	83.5	4,100
1958	March 5	V	Wilmington, N.C.	34.2	77.7	Not Listed
1958	April 8	V	Obion County, Tenn.	36.2	89.1	400
1958	October 20	V	Anderson, S.C.	34.5	82.7	Local
1959	August 3	VI	South Carolina	33	79.5	25,000
1959	August 12	VI	Alabama-Tennessee Border	35	87	2,800
1959	October 26	VI	Northeastern S.C.	34.5	80.2	4,800
1959	December 21	V	Finley, Tenn.	36	89.5	400
1960	January 28	V	Dyer County, Tenn.	36	89.5	Local
1960	March 12	V	Near Coast, S.C.	33	79.	3,500
1960	April 15	V	Eastern Tenn.	35.7	84	1,300
1960	April 21	V	Lake County, Tenn.	36.3	89.5	Local
1960	July 23	V	Charleston, S.C.	33	80	Local

APPENDIX II-D

GLOSSARY

TERM	DEFINITION
Focus	Point within the earth at which the earthquake starts.
Epicenter	The point on the surface of the earth directly above the focus of an earthquake
Intensity	A term to describe earthquakes by the degree of shaking at a specified place. This is not based upon measurement, but is a rating assigned by an experienced observer using a descriptive scale. The descriptive scale is called the Modified Mercalli Scale, and is described in Appendix II-E.
Magnitude	The rating of an earthquake based on a measure of the energy released. The rating scale is called the Richter Scale, and is described in Appendix II-E.
Ground Motion Spectrum	A plot of the maximum amplitudes of the simple harmonic components of ground motion against the period of the ground motion. The spectrum may be prepared from records or may be calculated.
Response Spectrum	A plot of the maximum amplitudes of simple oscillators (of varying natural periods) for a recorded or calculated ground motion.
Ground Acceleration	The acceleration observed at the ground surface due to an earthquake or other energy source.
Microtremor	Short-period, low-amplitude ground motions which normally reflect the dynamic characteristic of the ground.
Attenuation Curve	A plot of the decreasing amplitude of ground motion with respect to increasing distance from an energy source.
Velocity of Wave Propagation	Velocity at which energy moves through soil or rock in the form of wave motion.

APPENDIX II-E

INTENSITY AND MAGNITUDE SCALES

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Abridged)

The Modified Mercalli Intensity Scale is a measure of the perceptibility of and the damage caused by an earthquake. It has no relationship to the amount of energy released by an earthquake.

I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel Scale.)

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale.)

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale.)

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale.)

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale.)

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale.)

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale.)

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously.Underground pipes broken. (IX+ Rossi-Forel Scale.)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale.)

XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown upward into the air.

THE RICHTER SCALE

Dr. C. F. Richter developed a magnitude scale which is based on the maximum recorded amplitude of a standard seismograph located at a distance of 100 kilometers from the source of a shallow earthquake. The magnitude is defined by the relationship $M = \log A - \log A_o$. In this equation, A is the recorded trace amplitude for a given earthquake at a given distance written by the standard instrument, and A_o is the trace amplitude for a particular earthquake selected as a standard. The zero of the scale is arbitrarily fixed to fit the smallest recorded earthquakes. The largest known earthquake magnitudes are on the order of 8-3/4; however, this magnitude is the result of observations and not an arbitrary scaling. The upper limit to magnitude is not known. It is estimated that it may be about 9.

An approximate relationship between Magnitude M and the Energy E liberated has been given by Richter in the form $\log E = C + BM$. The constants C and B have been revised a number of times. For large magnitude shocks, C = 7.5 and B = 2.0 can be used. The Richter Scale is therefore a measure of the comparative amounts of energy released by different earthquakes.

APPENDIX II-P

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METEOROLOGY

INTRODUCTION

The purpose of this study was to document the meteorological history of the general site area and provide information concerning all weather parameters pertinent to the design and operation of a nuclear plant site. Where possible, meteorological events and their frequencies are discussed as they would be expected to occur at the site.

Major modification of the central portion of this site (lake, dams, etc.) will create significant climatology changes. This study attempts to assess what the changes will be and how they will affect nuclear plant operations.

Realistic values for meteorological parameters are provided for entry into diffusion equations; and justification in turn is given for those values which represent any significant departure from standard practice.

SCOPE

The scope of our studies included:

1) description of the general weather conditions which might affect nuclear plant design and/or operations;

2) documentation of the diffusion climatology for the site area;

3) assessment of the probable drainage wind conditions at the site from a study of the terrain;

4) estimation of the diffusion and dilution parameters appropriate for use under varying conditions at this site; and

5) preparation of recommendations and conclusions as to site adequacy from a meteorological standpoint.

CLIMATIC DATA SOURCES

Plate III-1 illustrates the location of all stations subsequently referred to in this section of the report. Stations to the north and west were deemed unrepresentative since they would tend to be dominated by full-scale mountain-valley effects. The nuclear site will be only a few miles, relatively speaking, from the first 2000-foot contour elevation to the west and north as shown on Plate III-1. Higher mountains are only a few miles further in these directions.

Clemson, South Carolina was the closest long-term record station where data could be readily found. The nearest 24-hour observing station was Greenville WBAS, South Carolina, later to become Greenville-Spartanburg WBAS as the two cities merged their facilities in 1962. Athens WBAS, Georgia was the closest upper air station of record. Columbia and Parr, South Carolina, Charlotte and Winston-Salem, North Carolina, and Augusta and Dawsonville, Georgia are all stations which are mentioned in the subsequent data and study material. Paris Mountain Fire Tower, North Carolina is specifically mentioned in the inversion frequency study.

GENERAL SITE CLIMATOLOGY

Surface Temperatures: The nearest station of long-term record was that of Clemson, South Carolina where some 68 years of record were available. The means and extremes shown in Table 1 for minimum temperatures were all on the cooler side than records available from the Greenville WBAS, South Carolina weather station and are regarded as more representative of the nuclear site area. The references for these records are listed as 1a through 1f.

Surface Precipitation: Clemson, South Carolina records were also used to gain estimates of rainfall statistics. Some 71 years of record were available as shown in Table 2. Again references 1a through 1f were used as source material. Considerable fluctuation in precipitation from month to month and from year to year is experienced from the normals shown in Table 2. From a brief examination of reference 2, it can be postulated that the normal annual precipitation for the site area will be actually about ten percent higher than at Clemson. The creation of a major lake area in the vicinity of the nuclear plant will serve to increase the precipitation approximately an additional five to ten percent, making the annual precipitation values roughly 60 to 61 inches. It is interesting to note that the maximum rainfall occurrences in short periods of time have all been associated with proximal tropical storms or their aftermath. However, severe thunderstorms can produce similar amounts of rainfall in the same periods of time.

SEVERE WEATHER

Strong Winds: Reference 2 indicates that winds can be expected to reach a highest speed in excess of 50 miles per hour in any month of the year as an estimate of maximum winds to be encountered. Fourteen years of record for Greenville, South Carolina Municipal Airport indicate that 50 miles per hour has been exceeded at least once for every month of the year except September where it was 47. Two months of the year showed values of 70 and 79 miles per hour, the former in January 1948, and the latter in October 1946. Clemson, South Carolina records (reference 1b) indicate that the highest one-minute wind speed was 73 miles per hour in June of 1948.

TABLE 1

SURFACE TEMPERATURE (^{O}F)

CLEMSON, S. C. (68 YEARS OF RECORD)*

MONTH	ABSOLUTE MIN.	MEAN MIN.	MEAN	MEAN MAX.	ABSOLUTE MAX.
Jan	-5	+33	43.6	54	80
Feb	-7	34	45.5	57	82
Mar	+10	40	52.2	64	89
Apr	24	48	60.5	73	93
May	33	57	68.9	81	100
Jun	42	65	76.2	88	105
Jul	49	68	78.6	89	104
Aug	52	67	77.8	88	104
Sep	38	62	73.1	84	104
Oct	23	50	62.2	75	98
Nov	10	39	51.4	64	86
Dec	+2	33	44.0	55	81
ANNUAL	22.6	49.7	61.2	72.7	93.8

* Refs 1a-f.

TABLE 1

TABLE 2

SURFACE PRECIPITATION (INCHES)

CLEMSON, S. C. (71 YEARS OF RECORD) **

NORMALS

MONTH	AMOUNT
Jan	4.88
Feb	5.28
Mar	5.23
Apr	4.16
May	3.83
Jun	4.32
Jul	5.09
Aug	4.91
Sep	3.64
Oct	3.25
Nov	3.04
Dec	5.27
ANNUAL	52.90

Highest Annual	73.70 (1936)
Lowest Annual	37.07 (1941)
Heaviest Snowfall	14.1 inches (Dec 1930)

Heaviest Rainfall - Short Periods of Time *

in 1 hour	3.18 inches 7/17/40
in 2 hours	4.38 inches 7/17/40
in 3 hours	4.48 inches 7/17/40
in 6 hours	4.48 inches 7/17/40
in 12 hours	5.42 inches 8/12-13/40
in 24 hours	9.92 inches 9/29/36

* All Records Were Associated with Tropical Storms

** Refs 1a-f.

Tropical Cyclones: In general, the threat of tropical storms in the fall months of the year (and sometimes in other months) is present almost every year. Table 3 indicates the frequency of occurrences of conditions which produce some effect on the weather at the nuclear plant site. In the 95 years of record shown, 164 storms of tropical origin affected the area in some manner. There were only 11 years in the 95 in which no storms affecting the area occurred. There were six years where more than twice the average number of storms occurred.

Despite the fact that so many storms have influenced the area, no hurricane conditions which would include damaging winds of major proportions have every been reported, so far as is known. Normally, by the time a tropical cyclone has passed onto the continent to the nuclear site area, winds have always been reduced below hurricane strength. However, major problems have been encountered with rainfall amounts generally four to five inches within a 24-hour period and occasionally up to nine to ten inches. Stations within a 50-mile radius of the nuclear site have reported up to double the latter amount but normally over more than a single 24-hour period. (References 3, 4, 5 and 6.)

Tornadoes: Tornado events are rather rare and cover extremely small areas. In order to provide for more than a superficial estimate, it was decided to ascertain the frequency of tornadoes for Oconee County in South Carolina as well as those which occurred in the peripheral counties in Georgia, South Carolina, and North Carolina. Accordingly, records were examined for the following counties:

In Georgia: Rabun, Habersham, Stephens, Franklin and Hart
In South Carolina: Oconee, Pickens and Anderson
In North Carolina: Macon, Jackson, Transylvania and Henderson

(References 7, 8, 9, 10, and 12 were consulted.)

The records revealed that five tornadoes had occurred in Oconee County and 17 in the peripheral counties in the 50-year period from 1916 through 1965. These storms, however, were only those which had tracks long enough to plot. In order to gain a more realistic figure, the overall statistics showed that each of these figures should be multiplied by 2.5 yielding 55 tornadoes in the 12-county area in the 50-year period. This is considered a reasonable estimate of those tornadoes which reached the ground. Funnel clouds not reaching the ground have also been observed but are not included in the above statistics. Tornadoes reach their maximum frequency during the spring months of the year and normally are more likely in April and May at the site.

The values above would indicate only 13 tornadoes in Oconee County in the 50-year period and the relative incidence of tornadoes proximal to the site area would be small.

TABLE 3

FREQUENCY OF TROPICAL CYCLONES

IN GEORGIA, SOUTH CAROLINA AND

NORTH CAROLINA PLUS COASTAL WATERS

PERIOD (YEARS)	TOTAL	AVERAGE PER YEAR	NO. YEARS WITH NO TROPICAL STORMS	NO. YEARS WITH DOUBLE THE AVERAGE NO.
1871-1875	8	1.6	0	0
1876-1885	18	1.8	1	1
1886-1895	19	1.9	2	1
1896-1905	21	2.1	1	0
1906-1915	16	1.6	0	0
1916-1925	12	1.2	3	2
1926-1935	16	1.6	1	0
1936-1945	12	1.2	1	1
1946-1955	25	2.5	2	0
1956-1965	17	1.7	0	1
TOTAL (95 YEARS)	164		11	6

(References 3, 4 and 5)

Thunderstorms: Table 4 indicates the mean number of thunderstorm days which are encountered in the plant site vicinity. A thunderstorm day is defined as a day in which thunder is heard at any time in the 24-hour period. Past experience indicates that increasing the thunderstorm day statistic by 10 to 15 percent will provide a reasonable estimate of the frequency of actual thunderstorms in the area.

DIFFUSION CLIMATOLOGY

Surface Winds: Table 5 illustrates the overall wind direction and speed statistics for a five-year period at Greenville, South Carolina. In general, the NE sector and the WSW sector (22.5 degree sectors) dominate the flow over the site area. The NNE, NE, and ENE sectors account for 30.7 percent of all winds while the SW, WSW, and W sectors account for 25.2 percent. These sectors combined then account for 55.9 percent of all winds at the Greenville, South Carolina airport station. This dominance is important as it continues to appear in all wind statistics in varying degrees as the study progresses. Apparently, the main reason for this dominance is the nearby Appalachian Mountain range which causes surface winds to channel toward these directions whenever the opportunity affords itself.

Winds of three knots or less occurred 17.4 percent of the time at Greenville. Winds greater than ten knots appear to favor the prevailing directions. (One knot = 0.515 meters per second.)

Table 6 illustrates the diurnal variation of wind speeds at various hours of the day. Lighter winds dominate the nighttime hours while the strongest winds tended to occur in the afternoon. The statistics illustrate the typical diurnal pattern of wind speeds.

Table 7 shows the frequency of calms and near-calm (winds equal to or less than one knot) conditions at three locations. Calm conditions occurred on the average some 332 hours per year or about 4.0 percent of the time. Of these calms, 93.4 percent lasted less than six hours. Wind speeds equal to or less than one knot occurred 4.21 percent of the time and of these conditions 93.5 percent lasted less than six hours. (The prolonged calm condition shown on Table 7 in the 36 - 41 hour -winter block was investigated. The observation was made at Charlotte, North Carolina immediately after the anemometer had been moved from a building top level to the ground. Thus one can ignore this as a statistic applicable to the discussion.)

Upper Winds: Tables 8 and 9 illustrate the percentage distribution of annual winds at Athens, Georgia as observed at 0630 Eastern Standard Time. These statistics were derived from an analysis of the Adiabatic Chart records of the Athens, Georgia Rawinsonde data. The period of record was December 1, 1959 through November 30, 1961. The data have been analyzed and documented in reference 16.

TABLE 4*

MEAN MONTHLY THUNDERSTORM DAYS AND

THUNDERSTORMS FOR NUCLEAR PLANT SITE

MONTH	THUNDERSTORM DAYS	THUNDERSTORMS
Jan	1	1.1
Feb	1.5	1.6
Mar	3.5	3.8
Apr	4	4.6
May	7	8.0
Jun	11	12.6
Jul	13	15.0
Aug	10	11.5
Sept	5	5.8
Oct	1.5	1.6
Nov	1.5	1.6
Dec	1	1.1
ANNUAL	60	68.3

* Reference 13

TABLE 5#

ANNUAL SURFACE WIND ROSE FOR

GREENVILLE, SOUTH CAROLINA (J '59 - 12/63)*

Wind Direction	Wind Speeds in Knots 1-3	4-6	7-10	11-16	17-21	22-27	Total Freq.	Mean Speed
N	1.2**	2.4	2.2	1.1	0.1	.0	7.0	7.1
NNE	0.8	2.7	2.7	1.0	0.1	.0	7.3	7.2
NE	1.2	5.2	6.0	2.1	0.2	.0	14.7	7.5
ENE	0.8	3.6	3.2	1.0	0.1	.0	8.7	7.0
E	1.3	2.5	1.5	0.2	.0	.0	5.5	5.5
ESE	0.8	1.3	0.5	.0	.0	.0	2.6	4.8
SE	0.9	1.4	0.4	.0	.0	.0	2.7	4.6
SSE	0.5	1.0	0.4	.0	.0	.0	1.9	5.1
S	1.0	2.0	1.0	0.1	.0	.0	4.1	5.4
SSW	0.5	1.9	1.5	0.4	.0	.0	4.3	6.6
SW	1.0	3.6	3.5	1.3	0.1	.0	9.5	7.2
WSW	0.7	2.9	3.7	1.8	0.3	0.1	9.5	8.2
W	0.8	2.4	2.0	0.6	0.2	.0	6.2	7.2
WNW	0.6	2.2	1.2	0.4	0.1	.0	4.5	6.6
NW	1.1	2.4	0.7	0.2	.0	.0	4.4	5.3
NNW	0.6	1.5	0.9	0.4	0.1	.0	3.5	6.7
CALM							3.6	
	13.8	39.0	31.4	10.8	1.3	0.1	100.0	6.6

* Reference 14

** Percent Frequency

These data are plotted on a schematic rose on Plate III-A1 located in Appendix A.

TABLE 6

PERCENT FREQUENCY OF WIND SPEEDS AT VARIOUS HOURS THROUGH THE DAY - GREENVILLE, S. C. (1/59 - 12/63)*

Hour	Wind Speeds in Knots							
	0	1-3	4-6	7-10	11-16	17-21	22-33	34+
01	4.3	20.1	42.8**	25.2	7.0	.6	0	0
04	4.7	21.0	42.9**	23.8	7.3	.4	0	0
07	4.1	19.0	39.6**	29.4	6.9	.9	.2	0
10	1.5	8.2	34.6	39.0**	15.7	1.4	.1	0
13	0.7	4.9	32.0	41.1**	18.4	2.6	.4	0
16	0.6	6.1	31.6	41.2**	16.8	3.2	.6	0
19	2.9	14.0	46.5**	26.1	9.0	1.3	.1	.1
22	7.5	16.2	43.1**	25.3	6.6	1.1	.1	0
Average	3.3	13.7	39.1**	31.4	11.0	1.4	.1	.1-

* Reference 14

** Indicates the Speed Class of the 50% Level

TABLE 7

DURATION AND FREQUENCY OF CALM AND NEAR-CALM WINDS

AVERAGE OF THREE LOCATIONS*
(1/59 - 12/63)

A. Calm Conditions: Calm at all Locations

Incidents/Season/Station

Duration (Hours)	Winter	Spring	Summer	Fall	Annual
01-05	74.2	70.4	94.7	92.5	331.8
06-11	3.9	3.4	5.9	6.9	20.1
12-17	0.3	0.3	0.8	1.3	2.7
18-23	0.0	0.0	0.1	0.3	0.4
24-29	0.0	0.0	0.0	0.0	0.0
30-35	0.0	0.0	0.0	0.0	0.0
36-41	0.1	0.0	0.0	0.0	0.1
TOTAL					355.1

B. Average Wind Speed 1 Knot or Less

01-05	76.2	74.5	98.9	95.6	345.2
06-11	4.0	3.5	6.[illegible]	7.1	20.7
12-17	0.3	0.3	0.8	1.3	2.7
18-23	0.0	0.0	0.1	0.3	0.4
24-35	0.0	0.0	0.0	0.0	0.0
36-41	0.1	0.0	0.0	0.0	0.1
TOTAL					369.1

Frequency of incidents/season/station were determined by dividing 15 into total number of occurrences for each season-duration group (5 years of record times 3 stations = 15).

* Reference 15 - The three locations were Charlotte WBAS, Winston-Salem WBAS, North Carolina; and Greenville WBAS and Greenville-Spartanburg WBAS, South Carolina.

TABLE 8

PERCENTAGE DISTRIBUTION OF ATHENS, GEORGIA

ANNUAL WINDS AT 0630 EASTERN STANDARD TIME

(800-1300 FEET ABOVE GROUND) #

Wind Direction	1-5 *	6-10	11-14	≥15	Totals
N	1.84	1.55	0.14	0	3.53
NNE	0.99	0.14	0.28	0	1.41
NE	2.11	1.55	0.42	0	4.09
ENE	2.82	5.08	3.24	1.97	13.12
E	2.26	3.95	1.13	0	7.33
ESE	2.12	2.12	0.71	0.14	5.08
SE	1.41	0.99	0.85	0.14	3.39
SSE	1.27	1.27	0.28	0.14	2.96
S	1.83	0.42	0.28	0.14	2.68
SSW	2.12	2.12	0.71	0.28	5.22
SW	1.41	3.95	1.13	0.42	6.91
WSW	1.55	2.96	1.13	0.28	5.92
W	2.96	4.09	2.54	0.71	10.30
WNW	2.40	4.94	4.37	1.13	12.83
NW	1.85	5.22	3.10	0.14	10.30
NNW	2.12	1.83	0.28	0	4.23
Calm					0.71
	31.03	42.17	20.6	5.50	100.01

* Wind Speeds in Meters/Sec

A wind rose portraying the above statistics is shown on Plate III-A2 located in Appendix A.

TABLE 9

PERCENTAGE DISTRIBUTION OF ATHENS, GEORGIA

ANNUAL WINDS AT 0630 EASTERN STANDARD TIME

(2300-2800 FEET ABOVE GROUND) #

Wind Direction	1-5 *	6-10	11-14	≥15	Totals
N	1.46	1.32	0.44	0.44	3.66
NNE	1.61	0.88	0.15	0	2.64
NE	1.75	0.88	0.29	0.15	3.07
ENE	2.19	2.78	1.02	0.88	6.87
E	1.90	4.24	0.44	0.29	6.87
ESE	2.34	2.78	0.29	0.44	5.85
SE	1.32	1.02	0.29	0.29	2.92
SSE	1.61	1.31	0.29	0.88	4.39
S	1.32	1.[illegible]0	0.44	0.88	4.54
SSW	1.61	1.32	0.88	0.88	4.69
SW	2.92	3.22	1.02	1.61	8.77
WSW	1.70	4.09	1.02	1.02	7.83
W	2.78	4.53	2.34	2.49	12.14
WNW	3.95	4.53	2.92	2.19	13.59
NW	1.46	2.34	1.75	1.90	7.45
NNW	1.32	2.49	0.73	0.29	4.83
Calm					0.44
	31.24	39.93	14.31	14.63	100.+

* Wind Speeds in Meters/Sec

A wind rose portraying the above statistics is shown on Plate III-A3 located in Appendix A.

The winds observed over Athens, Georgia are probably more representative than those from any other Rawinsonde station near the site. Note that the height above ground in each table is variable. This is because the winds are normally transmitted at standard pressure levels in the atmosphere rather than at fixed heights.

Table 8 indicates that the wind sectors which dominate the flow at around 1000 feet above terrain are the NE, ENE, and E sectors (24.54 percent) and the W, WNW and NW sectors (33.43 percent). These sectors combined account for about 58 percent of all winds. Compared to the surface winds, there has been a shift of dominance from the northeast sector to the northwest - more westerly flow. Calms occurred only 12 times.

Table 9 portrays wind conditions 2300-2800 feet above the ground. At this level, wind sector dominance has shifted to westerly flow. In fact, the WSW, W, and WNW sectors account for 33.6 percent of all winds, whereas the SW, WSW, W, WNW, and NW sectors account for 49.8 percent of all winds. Calms occurred less than eight times in the total period of record.

The combination of the surface and upper winds indicates that in the layer between the ground and about 3000 feet, there is likely to be considerable wind shear. As a matter of interest, change in wind direction with height was examined in a previous study (reference 16) as a function of the lapse rate in the lower 50 meters of the atmosphere. The results for the two-year period of record are shown in Table 10. Note that the directional shear for stable conditions is from 50 to 100 percent greater than for unstable conditions. This would favor slightly greater diffusive properties at the site than would be calculated with a single wind direction prevailing throughout the diffusion period during a stable condition, particularly if any significant depth of atmosphere is taken into account.

PRECIPITATION WINDS

Statistics related to wind directions and speeds while precipitation is falling are shown in Table 11. The most frequent wind sectors are NNE, NE, and ENE which account for 52 percent of all precipitation winds. The table is set up in terms of precipitation intensities. Precipitation rates determine these intensities and are normally classed as light, moderate and heavy. Approximately 90 percent of all precipitation at Greenville, South Carolina during this five-year period was light, seven percent was moderate and about three percent was heavy.

Comparison with all of the surface wind data in Table 5 shows that with winds from the southwest through west to north (the mountain exposure side), precipitation occurs about five percent of the time, while all other directions experience twice this percentage.

TABLE 10

AVERAGE WIND DIRECTION CHANGE WITH HEIGHT,

ATHENS, GEORGIA, BY LAPSE RATES IN THE LOWEST 50 METERS

TWO YEARS OF RECORD *

Height Above Ground (meters)	Stable	Unstable
50	4.6°	3°
100	9.6°	6°
150	14.2°	8.4°
200	18.6°	11°
250	25°	13.6°
300	28°	17.5°
350	33°	19.2°
400	37°	21.1°

* Reference 16

TABLE 11

PRECIPITATION - WIND STATISTICS - GREENVILLE, S. C. 1959-1963 #

(By Precipitation Intensities*)

WIND DIRECTION	LIGHT %	LIGHT SPEED	MODERATE %	MODERATE SPEED	HEAVY %	HEAVY SPEED	TOTAL %	TOTAL SPEED
N	0.351	6.58	0.030	6.69	0.023	12.10	0.404	6.90
NNE	0.659	7.62	0.052	9.26	0.018	8.50	0.729	7.76
NE	2.526	9.19	0.219	10.97	0.082	10.00	2.827	9.35
ENE	1.381	8.24	0.128	9.52	0.034	7.53	1.543	8.33
E	0.486	6.16	0.057	6.28	0.018	10.25	0.561	6.30
ESE	0.221	5.45	0.014	5.83	0.009	7.25	0.244	5.54
SE	0.203	4.98	0.023	5.70	0.018	7.25	0.244	5.22
SSE	0.171	5.95	0.016	7.29	0.014	6.83	0.201	6.12
S	0.399	6.93	0.023	8.00	0.009	8.75	0.431	7.03
SSW	0.395	8.05	0.034	10.20	0.014	9.33	0.443	8.26
SW	0.591	7.39	0.046	8.40	0.009	6.50	0.646	7.45
SWS	0.507	7.36	0.016	7.43	0.005	17.50	0.528	7.46
W	0.278	7.29	0.014	7.83	0.014	13.00	0.306	7.58
WNW	0.157	6.35	0.001	8.40	0.016	9.71	0.184	6.76
NW	0.171	5.97	0.007	7.33	0.009	13.50	0.187	6.38
NNW	0.153	7.08	0.014	8.83	0.018	14.75	0.185	7.96
CALM	0.132	-	0.005	-	0	-	0.137	-
TOTALS	8.781		0.709		0.310		9.800	

* Reference 17.

Note: Percentages are expressed in terms of the percentage of total hours in the five-year period. Wind speeds are in knots.

A wind rose portraying these statistics is shown on Plate III-A4 located in Appendix A.

By dividing the wind directional frequency for heavy precipitation intensity by the total precipitation wind directional frequency for each direction, directions which are more likely to produce heavy precipitation can be determined. Those directions which produced frequencies greater than the average were north through west and southeast plus south-southeast. These are directions which dominate the showery weather regimes at the site, particularly the thundershowers.

Precipitation occurs only 9.8 percent of all hours of the year.

STABILITY WIND CATEGORIES

In 1961, Pasquill (reference 18) suggested that a relationship might be established which would be useful for estimating the frequency of various wind-temperature lapse rate conditions for a given area. The inputs were:

Time of Day
Cloud Cover
Surface Wind Speed

The wind speed that was used was that observed at ten meters above the ground. Essentially his classification system identified six categories of stability regimes. These have come to be known as Pasquill categories. These are:

Pasquill Categories	Stability Class
A	Extremely Unstable
B	Unstable
C	Slightly Unstable
D	Neutral
E	Stable
F	Extremely Stable

Although Pasquill suggested the initial classification scheme, it remained merely a scheme until Turner (reference 19) quantified it into a reasonably rigorous method. The technique is amenable for use with standard United States Weather Bureau hourly weather observations which are readily available at the National Weather Records Center at Asheville, North Carolina, for certain specific United States Weather Bureau weather stations - namely those which observe the weather 24 hours per day throughout the year.

The closest station to the site which maintains such records is Greenville, South Carolina. Data was procured for the Greenville WBAS, South Carolina location (references 20 and 21) and the classification of the hourly weather records into Pasquill categories was accomplished for the two-year period of records selected for analysis.

The Pasquill categories selected follow:

Pasquill Category	Stability
A-B	Unstable
C	Slightly Unstable
D	Neutral
E	Stable
F	Extremely Stable

The period of record was December 1, 1959 through November 30, 1961. The results of these classifications are shown in Tables 12 and 13.

Table 12 shows the percentage frequency of occurrence of the Pasquill categories and their associated mean wind speeds by direction. All values in the percentage columns are in terms of percent of total observations. Column 1 deals with the Pasquill C category, Column 2 with the Pasquill D category, Column 3 with the Pasquill E and F categories, while Column 4 deals with the Pasquill F category alone. All winds are in knots. Total percentages by categories are also shown.

Table 13 completes the Pasquill classification effort. Column 5 deals with Pasquill A-B, unstable categories or "Lapse" conditions. Column 6 deals with a category which normally would fall under Pasquill A-B but does not if a stack is used to vent at the site. Column 6 indicates the percentage frequency of fumigation from a stack release. Fumigation is typical of the early portion of the day between sunrise and roughly ten A. M.

Column 7 shows the results of combining all wind data. Note particularly the dominance of northeasterly and west-southwesterly flow in the sample data. Column 8 shows the results of a much larger sample of data taken for the entire five-year period, 1959-1963, (reference 14).

The frequency of wind directions for the limited sample shown in Column 7 was correlated with the much larger sample shown in Column 8. The correlation coefficient determined was +0.987, showing that the limited sample did indeed possess a very high agreement with the much larger sample.

ESTIMATES OF STABILITY FROM OTHER SOURCES

Mountain-Plain Relationships: Work completed over a period of years has produced a useful relationship which was applied to the nuclear site area in this case. It was found (reference 22) that with terrain differences of greater than about 200 feet, the minimum or early morning temperature observed on hilltops was fairly representative of the free air temperature at the same altitude above proximal valley locations. Thus, it was possible to obtain estimates of the frequency of temperature inversions by comparing hilltop minimum temperatures with valley floor minimum temperatures. Subsequent tower

TABLE 12

PASQUILL STABILITY CATEGORIES

for

GREENVILLE, SOUTH CAROLINA

WIND DIRECTION	COLUMN 1		COLUMN 2		COLUMN 3 #		COLUMN 4	
	P_C	$\bar{u}_C$	P_D	$\bar{u}_D$	P_{E+F}	$\bar{u}_{E+F}$	P_F	$\bar{u}_F$
N	1.66	10.326	2.42	10.189	2.10	4.371	1.52	3.567
NNE	1.42	9.083	2.25	8.662	1.80	4.821	1.13	3.851
NE	4.01	9.308	4.13	8.570	4.07	4.971	2.34	3.870
ENE	2.90	8.251	1.91	7.487	2.34	4.522	1.73	3.843
E	1.19	6.800	0.47	4.714	1.46	3.674	1.34	3.468
ESE	0.42	6.680	0.34	4.450	0.74	3.045	0.74	3.045
SE	0.34	5.850	0.25	4.200	1.30	3.494	1.25	3.392
SSE	0.49	6.621	0.20	5.500	0.61	3.361	0.58	3.206
S	1.19	7.486	0.59	5.257	1.47	3.966	1.32	3.705
SSW	1.37	9.247	0.51	7.733	1.10	4.538	0.75	3.614
SW	3.18	9.883	1.15	7.824	2.37	4.614	1.73	3.941
WSW	4.25	11.570	2.17	10.164	1.93	5.491	0.85	4.180
W	2.12	10.720	1.34	9.089	1.85	4.486	1.39	3.829
WNW	0.90	11.566	0.81	8.562	2.27	4.455	1.76	3.913
NW	0.68	9.425	0.47	6.214	2.74	4.130	2.18	3.574
NNW	0.51	9.700	0.36	8.810	1.10	4.277	0.85	3.640
CALM	0.20	0	0.37	0	2.76	0	2.76	0
TOTAL PERCENT	26.83	9.47	19.74	8.26	32.01	4.06	24.22	3.72

Notes:

1. $\bar{u}$ in Knots Above
2. P in % of Total Observations
3. 5904 Observations Equally Distributed Throughout the year for a two-year period.

(#) 4. A wind direction rose for Pasquill E+F conditions is shown on Plate III-A5 located in Appendix A.

TABLE 13

PASQUILL STABILITY CATEGORIES

AND SUPPLEMENTAL DATA FOR GREENVILLE, S. C.

WIND DIRECTION	COLUMN 5		COLUMN 6		COLUMN 7		COLUMN 8	
	P_L	$\bar{u}_L$	P_{fum}	$\bar{u}_{fum}$	P_{all}	$\bar{u}_{all}$	$P_{5\ yrs}$	$\bar{u}_{5\ yrs}$
N	0.36	5.286	0.35	5.000	6.90	7.93	7.00	7.1
NNE	0.81	4.375	0.19	4.553	6.41	7.09	7.30	7.2
NE	1.34	4.861	0.68	5.417	14.23	7.25	14.70	7.5
ENE	1.80	3.849	0.38	4.912	9.30	6.19	8.70	7.0
E	1.32	4.449	0.23	4.550	4.67	4.84	5.50	5.5
ESE	0.86	4.098	0.07	4.000	2.40	4.32	2.60	4.8
SE	0.93	4.473	0.05	2.500	2.82	4.40	2.70	4.6
SSE	0.76	4.178	0.05	3.500	2.08	4.69	2.00	5.1
S	1.20	4.535	0.10	3.444	4.49	5.26	4.10	5.4
SSW	1.25	4.486	0.17	4.533	4.37	6.53	4.30	6.6
SW	2.27	4.619	0.32	4.670	9.24	6.86	9.50	7.2
WSW	1.10	4.585	0.39	5.400	9.80	9.10	9.50	8.2
W	0.83	5.020	0.54	4.896	6.79	7.37	6.20	7.2
WNW	0.73	5.302	0.38	5.176	5.17	6.44	4.50	6.6
NW	0.56	4.394	0.46	4.122	5.02	4.98	4.40	5.3
NNW	0.44	4.385	0.13	4.417	2.55	6.01	3.50	6.7
CALM	0.10	0	0.27	0	3.75	0	3.50	-
TOTAL PERCENT	16.66	4.479	4.76	4.527	100.00	6.44	100.00	6.57

1. $\bar{u}$ in knots above.
2. P in % of total observations.
3. Basedon 5904 observations equally distributed throughout the two-year period.

TABLE 13

measurements in the same valley location indicated that this postulation did, indeed, possess considerable merit in assessing the strength and frequency of the low-level temperature inversions. Examination of climatic records (reference 23) for South Carolina indicated that some estimate of temperature inversion frequency might be possible through a comparison of daily minimum temperatures from Paris Mountain Fire Tower, located seven miles north of Greenville, South Carolina, at an altitude of 2047 feet and Clemson, South Carolina, at an altitude of 850 feet.

Limited data permitted the analysis of some 602 days representing the four seasons of the year for the two-year period of December 1, 1959 through November 30, 1961. It was possible to examine the daily minimum temperature difference (Paris Mountain Fire Tower minus Clemson) for these days and compare these differences with Pasquill Stability classes as observed from hourly weather observations at Greenville, South Carolina, on the same days at hours near dawn. Table 14 shows the results. The table essentially shows that in general, the Pasquill classes do match the proper average temperature differences.

Combined Pasquill E and F conditions logged for the entire two-year period from Greenville, South Carolina, for the dawn hour revealed the following frequency of inversions by season.

	Frequency of Pasquill E and F Conditions (Inversions)			
	Winter	Spring	Summer	Fall
Two Years of Dawn-Hour Records at Greenville, South Carolina	43.96%	56.52%	65.58%	60.56%
602 Days of Paris Mountain-Clemson Records	49.14%	54.30%	67.41%	53.10%

As a result of the above, it appears that the estimates shown by the Pasquill Stability classes are reasonable estimates for inversion data at and near the proposed nuclear site.

Persistence of Wind: Plate III-2 represents cumulative probability of wind directional persistence at Greenville, South Carolina, for winds observed annually. Curve A represents the duration of persistence for a single sector wind direction, i.e., from the northeast, or from the southwest. Note that about 70 percent of all wind directions persisted for only one hour. About 94 percent persisted for three hours or less, etc.

TABLE 14

AVERAGE TEMPERATURE DIFFERENCE (°F) AT

MINIMUM TEMPERATURE TIME*

(PARIS MOUNTAIN FIRE TOWER - CLEMSON)

VERSUS PASQUILL STABILITY CLASS

(FROM GREENVILLE, SOUTH CAROLINA HOURLY OBSERVATIONS)

Pasquill Stability Class	Season				
	Winter	Spring	Summer	Fall	Annual
C	-5.43	-5.75	-6.60	-4.63	-4.93
D	-1.28	-2.05	-2.28	0.00	-1.37
E	+3.96	+2.25	-1.59	+2.31	+1.75
F	+5.18	+4.87	+1.11	+4.18	+3.72

* 602 Days of Record

Curve B indicates the persistence of a single wind direction plus and minus one additional direction on either side of the prime direction, i.e., northeast plus north-northeast and east-northeast (67.5 degrees). Curve B shows that 93 percent of all winds persisted five hours or less under these conditions. Curve C indicates the persistence of a single wind direction plus and minus two additional directions on either side of the prime direction (112.5 degrees). About 90 percent of all wind directions persisted for ten hours or less.

The above wind persistence statistics were derived for all wind directions, including calms. Directional persistence statistics were also calculated. However, the statistics for a single wind sector essentially show similar results to Curve A. Table 15 reveals persistence values by direction. Two values are shown for each of the two seasons, the average value $\overline{P}$, and the root-mean-square value RMSP. The merit of the RMSP values is that these are reasonable approximations of the 65 to 70 percent frequency of occurrence level. In other words, 65 to 70 percent of all persistence values were less than the RMSP figures.

The remaining two columns in each case are those specific events when the wind condition persisted 24 hours or more. (1-41 means one case of 41 hours duration.)

Table 15 deals with wind directions for a single 67.5 degree sector (or single sector plus and minus one sector). Table 16 deals with single wind directions for a single 112.5 degree sector (or single sector plus and minus two sectors).

Table 15 reveals that the most persistent winds come from the prevailing directions as might be expected. Table 16 shows a more confused pattern in general, but again shows prevailing wind dominance.

Estimates of Site Terrain Effects: Within a 0.5 statute mile radius, reference 24 provided detailed contours of the nuclear plant site for the immediate peripheral area. Terrain profiles were plotted for the 16 principal points of the compass within the 0.5 mile radius. Maximum and minimum elevations were recorded for each of the eight principal lines drawn to gain an estimate of potential drainage wind flow. The results are shown below:

Orientation	Maximum Height Upstream	Minimum Height Downstream	Difference
From N to S	870 feet	740 feet	130 feet
From NNW to SSE	880	710	170
From NW to SE	827	690	137
From WNW to ESE	872	680	192
From W to E	910	670	240
From WSW to ENE	817	700	117
From SW to NE	917	750	167
From SSW to NNE	862	760	102

TABLE 15

67.5° SECTOR WIND DIRECTION

PERSISTENCE DURATION (IN HOURS)

(GREENVILLE, S. C. WBAS)

WIND DIRECTION	SUMMER $\bar{P}$	SUMMER RMSP	WINTER $\bar{P}$	WINTER RMSP	SUMMER $\bar{P} \geq 24$ Hrs.	WINTER $\bar{P} \geq 24$ Hrs.
N	1.49	1.82	3.23	4.67	0	0
NNE	2.75	3.51	3.47	4.65	0	0
NE	4.02	6.70	5.65	11.13	1-29	1-48
ENE	2.96	3.80	7.73	15.0	0	1-52,1-71
E	2.75	3.75	2.74	3.45	0	0
ESE	2.53	3.55	1.43	1.66	0	0
SE	1.35	1.57	1.38	1.84	0	0
SSE	2.04	2.59	3.00	3.64	0	0
S	1.86	2.79	1.72	2.13	0	0
SSW	2.02	2.70	2.41	3.01	0	0
SW	3.32	4.84	3.27	4.67	0	0
SWS	4.34	9.67	5.29	7.95	0	0
W	2.70	3.45	2.29	3.04	0	0
WNW	2.90	4.18	2.63	3.13	0	0
NW	2.26	3.01	1.60	1.86	0	0
NNW	1.67	2.10	2.33	2.99	0	0
CALM	1.58	1.77	1.87	2.28	0	0

TABLE 16

112.5° SECTOR WIND DIRECTION

PERSISTENCE DURATION (IN HOURS)

(GREENVILLE, S. C. WBAS)

WIND DIRECTION	SUMMER $\bar{P}$	SUMMER RMSP	WINTER $\bar{P}$	WINTER RMSP	SUMMER $P \geq 24$Hrs	WINTER $P \geq 24$Hrs.
N	2.51	3.09	6.24	10.28	0	1-28,1-31
NNE	4.49	6.88	4.67	6.57	0	0
NE	11.89	20.46	15.56	28.05	1-41,1-57, 1-64,1-44, 1-45	1-26,1-51, 1-66,1-101
ENE	5.03	7.53	10.00	15.70	0	1-26,1-32, 1-36,1-41
E	5.36	5.79	5.40	7.92	1-56	1-24
ESE	4.15	5.73	4.10	6.42	0	1-24
SE	2.19	3.86	4.00	6.50	0	0
SSE	2.24	2.79	3.42	3.84	0	0
S	2.76	3.26	3.92	6.28	0	1-29
SSW	3.83	5.32	2.58	3.17	0	0
SW	6.71	11.70	5.62	7.79	1-29,1-40, 1-25,1-37, 1-24	1-26
WSW	9.74	16.40	6.68	10.00	1-58,1-24 1-60,1-25	1-31
W	5.68	8.70	4.30	5.48	1-25	0
WNW	3.78	5.13	5.28	7.94	0	1-35
NW	3.71	4.74	2.83	3.66	0	0
NNW	2.47	3.13	5.20	8.10	0	0

All of the eight lines passed through the central site area, i.e., from one-half mile north through the site center to one-half mile south. In general, the results show that the drainage of wind would be toward the east within the site exclusion radius.

Within the 3.0 mile radius - references 25 and 26 permitted estimates of the overall drainage possibilities out to a three-mile radius. Plate III-3 shows the results of a gross assessment of the terrain. The terrain at elevations equal to or less than 800 feet is shaded to more readily portray the potential drainage wind area. It is important to note that this approximate plot assumes that all proposed lakes are full in the final configuration as proposed for this area. Note that, although drainage to the east and east-southeast is shown for the central site area, the terrain will modify the drainage flow direction to that following the Keowee River.

METEOROLOGICAL PARAMETERS FOR ON-SITE DIFFUSION CALCULATIONS

The Two-Hour Model:[1] Reference 27 indicates that the appropriate equation to use for calculating the two-hour site boundary relative concentration is:

$$\frac{X}{Q} = \frac{1}{\bar{U}(\pi \sigma_Y \sigma_Z + cA)}$$

(The cA term has more recently been permitted as a result of the work of F. A. Gifford and W. M. Culkowski at Oak Ridge National Laboratory concerning building wakes.)

In this equation σ_Y and σ_Z are the standard deviations of the cloud concentration in the horizontal and vertical directions, respectively. These values are normally determined from on-site observations. In lieu thereof, it is permissible to use graphical values as shown in reference 28. The $\sigma_Y \sigma_Z$ values are those which are appropriate for the one mile (1610 meters) exclusion radius of the site.

Normal assumptions to be used with this equation are:

a. Moderate temperature inversion - Pasquill F conditions prevail.

b. Unidirectional wind for two consecutive hours.

c. Average wind speed ($\bar{u}$) is one meter per second.

d. Building shape factor (c) is between 0.5 and 2.0.

e. Building cross-section (A) is in square meters.

Each of the entry values to the equation is discussed below.

(1) See Supplement No. 2, answer to Question 2.5.1.

Pasquill F conditions occur frequently at the site. Their overall frequency has been documented at 24 percent in an earlier section of this report. It is estimated that this frequency will diminish to about 12 percent when all lakes in the vicinity of the nuclear plant are full. The frequency of Pasquill F conditions is expected to diminish, while Pasquill E conditions will increase from a current eight percent to about 14 percent of all observations. Thus, there is about a 50-50 chance, once the site is completed, that an inversion condition will be either Pasquill F or E.

The assumption of the unidirectional wind for two hours was examined. Neglecting calms, in a sample of 547 hours of Pasquill F conditions, only 68 cases were found where winds persisted from the same direction for two hours. Thus, it appears that this assumption is conservative.

The average wind speed ($\bar{u}$) observed under Pasquill F conditions (neglecting calms) was found to be 1.9 meters per second for the Greenville area. It is recommended that this wind speed by used for on-site wind speed estimates.

The building shape factor (c) was assumed to be equal to 1.0.

The cross-sectional areas of the buildings are shown on Plate III-4. The minimum total building cross-section is 5180 square meters, while the front view area is 6792 square meters. The minimum building complex cross-section will be oriented in such a manner as to take advantage of increased flow due to site air drainage patterns, although no credit is taken for this in the analysis.

The values for entry into the equation are:

$\bar{U}$ = 1.9 mps

σ_Y = 60 m c = 1.0

σ_Z = 20 m A = 5180 m^2, and

$\frac{X}{Q}$ = 5.9×10^{-5}

LONG TERM RELEASES

The 24-Hour Model:(1) An investigation was conducted to determine the most pessimistic theoretical 24-hour period at the site.

Thirty months of Greenville, South Carolina, data were scanned and those days where the average wind speeds for the entire day were approximately two meters per second or less were studied in detail. Thirty-seven cases were documented. Each hour of each day was classified according to the Pasquill method and a composite was

(1) See Supplement No. 2, answer to Question 2.5.1.

derived which shows the poorest diffusion condition observed for each hour of the day during the 37 cases examined. The composite conditions are shown in Table 17.

Examination of Table 17 indicates that the poorest composite diffusion day would be to start at 1700 hours and maintain a Pasquill F condition for 16 consecutive hours, then one hour of Pasquill E, and finally seven hours of Pasquill D. This could be referred to as the most pessimistic theoretical 24-hour day for diffusion. (Meteorologically, this type of day would be difficult to achieve since cloud cover would be required to arrive immediately after dawn. Normally, if low cloud cover forms, it indicates that moisture sufficient to raise the probability of fog to very high values must have existed. In which case, fog would have been expected earlier, and some relaxation of the F and E criteria for the early morning hours would be realized.)

This condition (as shown in Table 17) was not observed. It merely serves to document what might be termed a poorest possible diffusion day. This day is recommended for use in diffusion calculations.

A further examination of the 37 poorest diffusion days was conducted to ascertain whether a high frequency of winds from a single direction was representative of the low wind speed cases. The following summary shows the results for the light wind speed days, (less than or equal to 2.0 meters per second for the entire day).

Percentage of Winds From a Single 22.5° Sector During a 24-Hour Period	Probability of Single Day Occurrence (Based on 30 Months of Data)
33.33%	.00218
29.17%	.00436
25.00%	.0109
20.83%	.0229
16.67%	.0360
12.50%	.0393
8.33%	.0404

It is recommended that a value of 20.83% be used as typical of the most frequent single sector percentage.* As a result of review of the data, it was determined that a light wind condition provided a frequency of about 20% of winds from a single direction and that as the speed of the wind rose to higher values, the frequency from a single direction increased.

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* An Addendum is planned to provide long-term values of the percentage of winds from a single sector during light wind conditions in the vicinity of the site.

TABLE 17(1)

COMPOSITE POOREST DIFFUSION CONDITIONS

OBSERVED FOR EACH HOUR OF DAY

(Based on 30 months of Data)

Hour of Day	Pasquill Class
00	F
01	F
02	F
03	F
04	F
05	F
06	F
07	F
08	F
09	E
10	D
11	D
12	D
13	D
14	D
15	D
16	D
17	F
18	F
19	F
20	F
21	F
22	F
23	F

(1) See Supplement No. 2, answer to Question 2.5.1.

It was noted that often the fluctuation of the wind during a light wind day would be extremely erratic, such that even though the wind blew from a single direction for several hours of the 24, these were not necessarily consecutive hours.

Four days in December, 1959, were examined which experienced high average wind speeds. The following summary shows the frequency of a single wind direction for strong wind days based on this extremely limited sample.

Date	Average Speed (m/sec)	Maximum Wind Direction Percentage
12/7/59	6.85	54.17
12/24/59	7.00	67.00
12/27/59	6.49	41.70
12/28/59	6.39	67.00

As a result of the review of mean wind speeds for a day versus percentage frequency of wind from a single wind direction, the following estimates were derived for various Pasquill conditions:

Pasquill Classes	Mean Wind Speed (mps)	% of Wind From a Single Direction
A	2	16%
B	3	25%
C	5	58%
D	4	50%
E	3	35%
F	2	21%

Additional work to be provided in a future addendum should prove these values to be reasonable estimates of percentage of wind from a single direction.

The One to 30 Day Model or Longer Term Releases:[1] Upon completion of the analysis of a few well-separated months of data, it was learned that conditions expressed in Tables 5, 12 and 13 were representative of wind and stability classes for the nuclear site area.

Table 12 justifies the selection of the frequencies and wind speeds for various Pasquill classes as follows:

25% Pasquill F $\bar{u}$ = 2.0 mps
10% Pasquill E $\bar{u}$ = 3.0 mps
20% Pasquill D $\bar{u}$ = 4.0 mps

In order to introduce further conservatism in the long-term model, it was decided to class all other conditions as Pasquill C and thus the remaining group became:

45% Pasquill C $\bar{u}$ = 5.0 mps

(1) See Supplement No. 2, answer to Question 2.5.2.

Further, examination of Table 5 data bears out that the maximum frequency of a single wind direction for a long-term condition is about 15 percent. Table 13 also shows this to be true. (This can be determined by adding the percentage frequencies for all Pasquill classes as shown in Column 7.)

RECOMMENDATIONS

An on-site meteorological program has been recommended and is already initiated. Basically, this program is divided into three phases:

Phase I - Pre-Construction
Phase II - During Construction
Phase III - Post-Construction or Operational Phase

During Phase I, micrometeorological readings will be documented for low-level winds on a temporary tower on the site. Assessment of the low-level stability will also be accomplished.

During Phase II, multi-wind recording levels will be installed on a permanent basis and vertical wind and temperature profiles will become available.

During Phase III, all weather equipment readouts will be available to reactor operators.

As a result of the on-site meteorological program, it is expected that confirmation of the values used in the various equations throughout the former presentation will be realized. Results of on-site measurements will be available for review by the Atomic Energy Commission.

CONCLUSIONS (1)

In general, the meteorological features of the site are favorable for a nuclear station.

Several modifications to the local climatology will occur as site development progresses. The initial clearing and leveling of land at the specific site location will produce an increase in drainage potential of light winds within the site boundary. The construction of the buildings will somewhat negate this increased drainage potential, but on the whole, there should be a net increase in drainage winds to the east and south.

The addition of the large bodies of water will serve two purposes. First, it will lessen ground frictional effects and thus will tend to increase the wind speeds; most noticeable will be under light wind conditions. Second, the numerous bodies of water will serve

(1) See Supplement No. 2, answer to Question 2.5.

to increase the humidity by about ten percent in the area, will tend to decrease the frequency of Pasquill F and to increase the frequency of Pasquill E conditions.

Documentation of on-site meteorological parameters will demonstrate the validity of the recommended diffusion model values tabulated below:

The Two-Hour Model: (1)

$\bar{u}$ = 1.9 (unidirectional wind)
c = 1.0
A = 5180 m^2 (minimum building cross-section)
σ_y = 60 (at site boundary)
σ_z = 20 (at site boundary)

The 24-Hour Model: (1)

16 hours - Pasquill F; $\bar{u}$ = 2.0 mps; 20% from single wind direction
1 hour - Pasquill E; $\bar{u}$ = 3.0 mps; all from single wind direction
7 hours - Pasquill D; $\bar{u}$ = 4.0 mps; 50% from single wind direction

The Long-Term Model: (1)

25% - Pasquill F; $\bar{u}$ = 2.0 mps
10% - Pasquill E; $\bar{u}$ = 3.0 mps
20% - Pasquill D; $\bar{u}$ = 4.0 mps
45% - Pasquill C; $\bar{u}$ = 5.0 mps

Maximum single wind directional frequency for 30 days up to one year equals 15%.

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The following Plates and Appendices are attached and complete this portion of the report:

Plate III-1 ..... Weather Station Location Chart
Plate III-2 ..... Cumulative Probability of Wind Direction Persistence Duration
Plate III-3 ..... Approximate Terrain at Nuclear Site

(1) See Supplement No. 2, answer to Question 2.5.

Plate III-4 ..... General Building Arrangements
Appendix III-A ..... Baillie Wind Roses - Specific Events
Appendix III-B ..... List of References

Respectfully submitted,

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APPENDIX III-A

BAILLIE WIND ROSES - SPECIFIC EVENTS

Specific wind distributions and frequencies were believed to be worthy of special treatment. Appendix A shows five wind roses in detail to afford comparison with population statistics presented in the preliminary Safety Analysis Report.

These wind roses supplement, but are not as complete as the basic reference tables found in the meteorology section.

Wind Rose Plate No.	Text Table No.	Wind Rose Title
III-A1	5	Surface Wind Rose
III-A2	8	Upper Air Wind Rose (800 - 1300 feet)
III-A3	9	Upper Air Wind Rose (2300 - 2800 feet)
III-A4	11	Precipitation Winds
III-A5	12	Pasquill E and F Wind Directions-Inversion Winds

APPENDIX III-B

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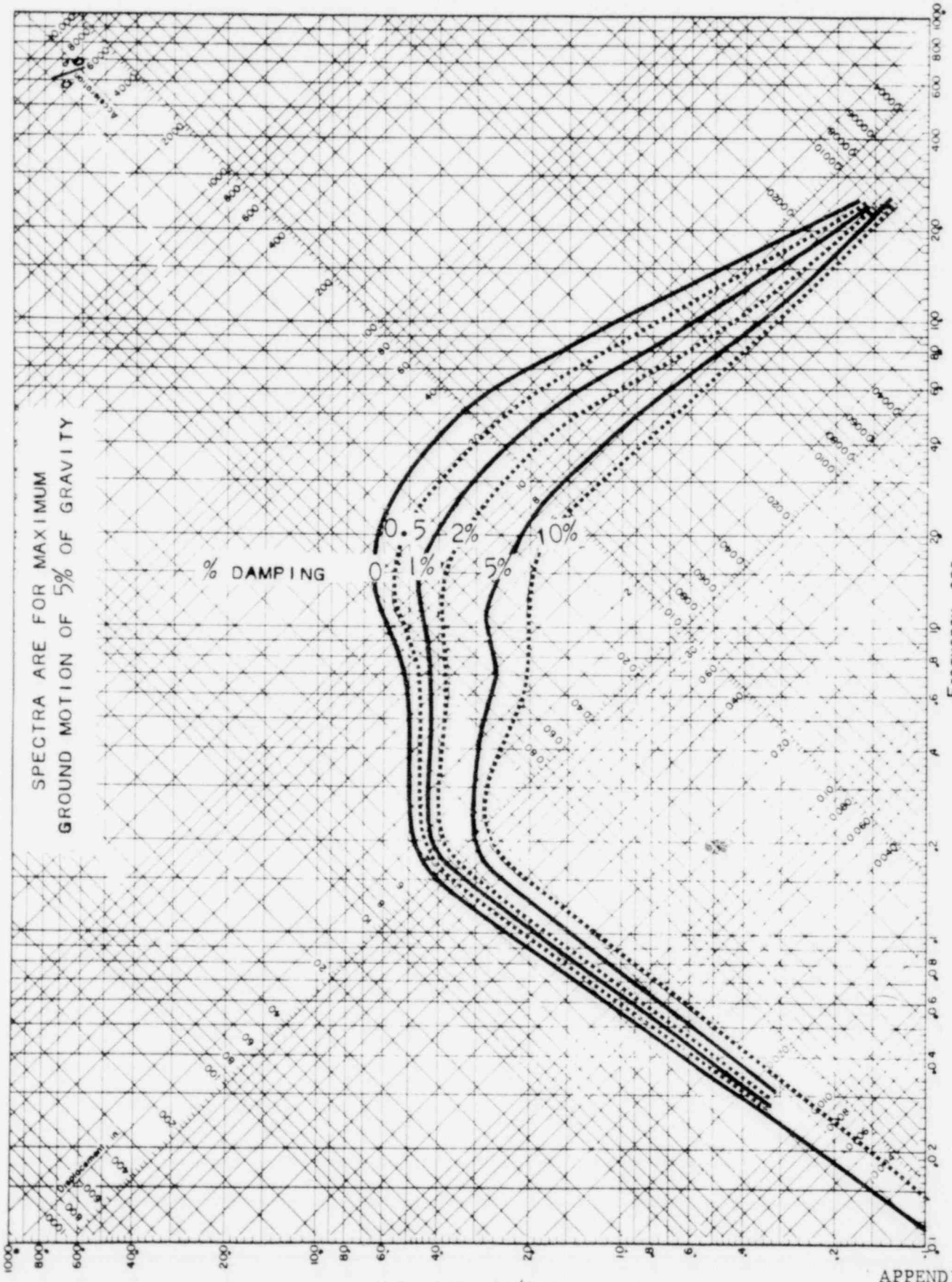

APPENDIX 2B
PLATE II-4
Revised 5-25-67

RECOMMENDED RESPONSE SPECTRA