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AN EVALUATION OF COOLING TOWER DRIFT DEPOSITION AT THE VOGTLE ELECTRIC GENERATING PLANT

for

Southern Company Services, Inc.

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Morton I. Goldman, Sc.D.

NUS CORPORATION
910 Clopper Road
Gaithersburg, MD 20878

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I. INTRODUCTION

On October 26, 1984 NUS was requested to review the amounts of minerals from cooling tower drift estimated to be deposited in the vicinity of the Vogtle Electric Generating Plant (VEGP). A drift deposition assessment had been submitted earlier by the Applicant based on presumptions of the similarity between the behavior of drift from the cooling towers at the VEGP and from those at several other power plants. The conclusion was reached that the VEGP towers were not likely to produce significant drift mineral deposition densities. To demonstrate the validity of that conclusion, a decision was made to model the performance of the VEGP towers to predict site specific drift mineral deposition. This report presents results of that modeling.

II. FOG DRIFT DEPOSITION MODEL

The drift mineral deposition patterns to be expected from the operation of the VEGP were predicted using the NUS FOG computer code. This code, most recently documented in the ER-OL for the Palo Verde Nuclear Generating Station(1) calculates the release, plume rise, transport and deposition of drift droplets from natural and mechanical draft cooling towers and other heat dissipation systems.

The drift deposition routines in FOG consist of the following three calculational procedures: (1) the sequential release of the entrained drift droplets from the effluent plume, (2) the subsequent horizontal transport of the drift droplets as they fall to the ground, and (3) the calculation of the airborne concentrations and deposition rates of drift minerals at pre-specified downwind distances for each of the 16 wind directions.

It is assumed in the FOG model that the excess water vapor, the temperature excess, the vertical velocity, and the concentration of drift droplets follow a Gaussian distribution normal to the plume axis. The plume is assumed to extend two standard deviations (i.e., $2\sigma_y$ and $2\sigma_z$) away from the plume axis. The release of the entrained droplets at any point within the plume depends on the relative magnitudes of the terminal fall velocity of the droplets and the vertical velocity of the air in the plume. At each downwind distance under consideration, these two velocities are compared for the various size categories of droplets in the plume, and a fraction of the droplets is released. This process is repeated until all droplets are released from the plume. When the plume reaches its maximum height, the vertical velocity throughout the plume is zero. Any droplets remaining in the plume at the level-off point are then released. Droplets released from the plume then fall, first through the plume air, and then through the ambient air beneath the plume.

The drift is carried downwind by the ambient wind until it is deposited on the ground. The rate of fall of the drift droplets is proportional to their terminal velocity, which in turn is dependent on the droplet size. The droplet size can change by evaporative processes, which depend on the physical and transport properties of the liquid droplets and the surrounding air. For relative humidities below 50%, complete evaporation of the drift droplets to dry particles is possible. A stepwise procedure is employed in FOG to compute the trajectory of the droplets by considering the above effects.

Deposition rates of drift minerals as wet droplets and dry particles are calculated for each of the sequential meteorological records included in a one or more year meteorological data set, with wind speeds increased with height according to a power law relationship. These calculated deposition rates are then summarized to obtain the mineral deposition (in terms of lb/acre-year) over the entire grid.

The FOG code was recently evaluated and validated by an independent consultant, Dr. William Dunn of the University of Illinois, "as one of the better-performing" of the computer models evaluated on behalf of the NRC.(2)

III. FOG MODEL INPUT DATA

As with most contemporary computer models, the FOG code requires a great degree of detail with respect to the meteorological parameters of the site, the design and performance characteristics of the towers, the size distribution of the droplets emitted as drift, and their chemical composition. Hour-by-hour meteorological records for two periods (from April 4, 1977 to April 4, 1978, and from April 1, 1980 to March 31, 1981) taken from the site meteorological tower were used for the analyses. The latter year is that used for the Applicant's comparative drift analyses, and the earlier year of record is one felt by the Applicant's meteorological consultant to be representative of average site meteorology.(3) Annual wind roses for these two data years are presented in Figure 1.

Since the tower effluent plume rises considerably higher than the elevation of the site tower, the reasonableness of the site data as a basis for calculation was checked using wind data measured by the Savannah River Laboratory[4] at higher elevations on a 1000 foot TV tower across the Savannah River from the VEGP. These data are presented as annual wind roses in Figure 2. It can be noted that aside from expected increases of wind speed with elevation, and the slight change in wind direction with height, these data agree well with those taken from the VEGP meteorological tower.

The majority of the cooling tower input information used came from the VEGP-OLSER, Section 3.4, supplemented with more detailed information on tower design details provided to the Applicant by Research-Cottrell, the tower vendor. A tabulation of the pertinent design and operating parameters used as input to the FOG model are shown in Table 1.

One of the more significant parameters not available specifically for the VEGP towers is the mass distribution by droplet size of the drift emitted from the top of the tower during operation. Values reported for natural draft towers[5-10] were examined with the objective of selecting mass-size distribution spectra to bound the likely range of drift droplet sizes, and the consequent deposition patterns. The spectra examined are presented in Figure 3 as a probability distribution of mass versus droplet diameter. Of these distributions, those curves labelled 1 through 5 and HC represent measured data; the remaining curves either represent design objectives or assumptions, or are not specifically identified as measured spectra in the references cited.

It can be noted in Figure 3 that most of the curves are relatively closely grouped, with mass median (50th percentile) diameters ranging from about 80 to 150 microns. It is the larger drift droplets (i.e., those in excess of a few hundred microns in diameter) which tend to produce the most significant deposition because of their greater fall velocities and mass. The size distribution labelled "[illegible]" in Figure [illegible], with a mass median diameter in excess of 200 microns, was selected as a "conservative" spectrum almost certain to produce an upper bound deposition pattern. Although the mass median diameter of the distribution labelled "4" attributed to the Pennsylvania State University (PSU) measurements at the Keystone station is even greater, this distribution was measured by aircraft sampling in the plume rather than at the tower exit and was rejected as too deviant from the remainder of the spectra.

The distribution labelled "NUS", with a mass median diameter of 100 microns, is used by NUS as the "default" spectrum for evaluations in which the data appropriate to the particular natural draft tower are not available. It is a hypothetical distribution, one representative of most of those reported and therefore likely to be similar to droplet sizes (and resulting distribution patterns) observed from operating towers. In the absence of a droplet mass-size distribution specifically determined for the VEGP towers, the NUS spectrum was used to provide the "realistic" values for this evaluation. Each of these spectra was distributed into 16 size classes, or bins, for use as input to the FOG code as presented in Tables 2 and 3 for the conservative and realistic distributions, respectively.

[illegible] RESULTS

As indicated above, two runs of the FOG code were made for each year of meteorological data, one with the conservative and the other with the realistic droplet size spectrum. The isopleths of total mineral deposition (both in droplets and as dry particles) in pounds per acre per year are presented in Figures 4 and 5 for the representative data year and the conservative and realistic droplet spectra, respectively. Figures 6 and 7 present corresponding results for the later year.

Several conclusions can be drawn from the results shown in these figures:

1. Of the two input parameters varied, the meteorological data year and the drift droplet spectrum, the latter is by far the more significant, producing about an order of magnitude change in mineral deposition. This is generally consistent with observations by others.[2,5]

2. The conservative drift droplet size spectrum produces a maximum mineral deposition of about 1.7 pounds per acre-year (0.16 kg/ha-mo) to the east of the cooling towers at the boundary of the plant site during the representative year of record. The less typical year changed the shape of the deposition patterns somewhat and reduced the maximum to about 1 pound per acre-year (0.09 kg/ha-mo).

3. The realistic drift droplet spectrum produces an estimate of the maximum mineral deposition of about 0.1 pounds per acre-year (0.009 kg/ha-mo) at the plant site boundary east of the cooling towers during the representative year of record. This is a factor of 17 less than that resulting from the use of the conservative droplet spectrum. The less typical year

yielded an estimate for maximum deposition at the site boundary of less than 0.1 pounds per acre-year, again located to the east of the towers.

4. Even the most conservative of the four runs shows a maximum total mineral deposition rate off the plant site which is less than two pounds per acre-year (0.18 kg/ha-mo) of which NaCl is less than one-fourth, well below any value expected to result in adverse effects. For example, the US NRC states(11): "Deposition of salt drift (NaCl) at rates of 1 to 2 kg/ha-mo is generally not damaging to plants."

V. CONCLUSIONS

It is concluded that the operation of two units of the Vogtle Electric Generating Plant in accordance with expected design and performance parameters will not result in a detectable addition to the natural environment in respect to deposition. This conclusion confirms the earlier analysis by the Applicant using an extrapolation of the predicted performance of other plants with natural draft cooling towers, an analysis much more conservative than the site-specific drift deposition analysis reported herein. The best estimate of the deposition of solids from the drift of two cooling towers at the downwind site boundary is a value of less than one pound per acre-year.

VI. ACKNOWLEDGMENTS

Contributions to this review were made by S. R. Tammara (FOG runs), B. L. Orndorff (library research and VEGP meteorological data reduction), and R. W. Brode (SRP TV Tower data reduction).

VII. REFERENCES

1. Palo Verde Nuclear Generating Station ER-OL, Section 6.1.3.3.3.3.

2. Dunn, W.E., "Evaluation of NUS/FOG Computer Model for Predicting Cooling Tower Drift Deposition Rates", July 15, 1983.

3. Personal Communication from Mark Abrams, Pickard, Lowe and Garrick, Inc., December 1984.

4. US DOE-Savannah River Laboratory supplied data tape; see also Hoel, D., "Climatology of the Savannah River Plant Site", DP-1679, June 1984.

5. Chen, N.C.J., and Hanna, S.R., "Drift Modeling and Monitoring Comparisons", Atmospheric Environment, Vol.12, pp 1725-1734, 1978.

6. DeVine, J.C., "The Forked River Program: A Case Study in Salt Water Cooling", GPU Service Corporation, Parsippany, NJ, February 1974.

7. Personal Communication from Mark Abrams, Pickard, Lowe and Garrick, Inc., December 1984.

8. Susquehanna SES ER-OL, Figure 5.1.4, May 1978.

9. Beaver Valley Power Station Unit 2 ER-OLS, Appendix 3B.

10. Grand Gulf Nuclear Station ER, Table 5.1.11, Amendment 5, February 1981.

11. Environmental Standard Review Plans for the Environmental Review of Construction Permit Applications for Nuclear Power Plants, NUREG-0555, Section 5.3.3.2, US NRC 1979.

TABLE 1

VOGTLE ELECTRIC GENERATING PLANT
COOLING TOWER DESIGN AND OPERATING PARAMETERS

Parameter	Value per Tower	
Number of towers	2 (1 per unit)	(a)
Height, feet	550	(b)
Exit diameter, feet	303	(b)
Heat dissipated, BTU/hr	8×10^9	(a)
Range, °F	33	(a)
Circulating water flow, gpm	484,600	(a)
Expected drift rate, %	0.008	(c)
Avg. blowdown TDS conc, mg/l	240	(d)
Avg. concentration factor	4	(d)

(a) Vogtle Electric Generating Plant - OLSER, Table 3.4-1

(b) Vendor design information

(c) Letter, H.D. Burnum, Southern Co. Services, Inc. to M.Shuman, Research-Cottrell, Dec. 14, 1984.

(d) Vogtle Electric Generating Plant - OLSER, Table 3.6-2

TABLE 2

"CONSERVATIVE" DRIFT DROPLET DISTRIBUTION [(a)]

Bin No.	Diameter Range, microns	Representative Diameter, microns	Mass Fraction %	Cumulative Mass Fraction, %
1	<50	30	5	5
2	50 - 80	65	6	11
3	80 - 120	100	9	20
4	120 - 140	130	6	26
5	140 - 160	150	7	33
6	160 - 180	170	6	39
7	180 - 200	190	8	47
8	200 - 220	210	8	55
9	220 - 240	230	6	61
10	240 - 260	250	7	68
11	260 - 290	275	6	74
12	290 - 320	305	7	81
13	320 - 360	340	6	87
14	360 - 400	380	5	92
15	400 - 450	425	4	96
16	>450	500	4	100

Mass Median Diameter = 208μ

(a) See Figure 3, Curve "6"

TABLE 3

"REALISTIC" DRIFT DROPLET DISTRIBUTION [a]

Bin No.	Diameter Range, microns	Representative Diameter, microns	Mass Fraction, %	Cumulative Mass Fraction, %
1	<30	20	2	2
2	30 - 40	35	4	6
3	40 - 50	45	6	12
4	50 - 60	55	7.5	19.5
5	60 - 70	65	8.5	28
6	70 - 80	75	8	36
7	80 - 90	85	8	44
8	90 - 100	95	7	51
9	100 - 110	105	7	58
10	110 - 120	115	6	64
11	120 - 135	127.5	7	71
12	135 - 150	142.5	6	77
13	150 - 180	165	8.5	85.5
14	180 - 220	200	6.5	92
15	220 - 300	260	5.4	97.4
16	>300	350	2.6	100

Mass Median Diameter = 98μ

(a) See Figure 3, Curve "NUS"

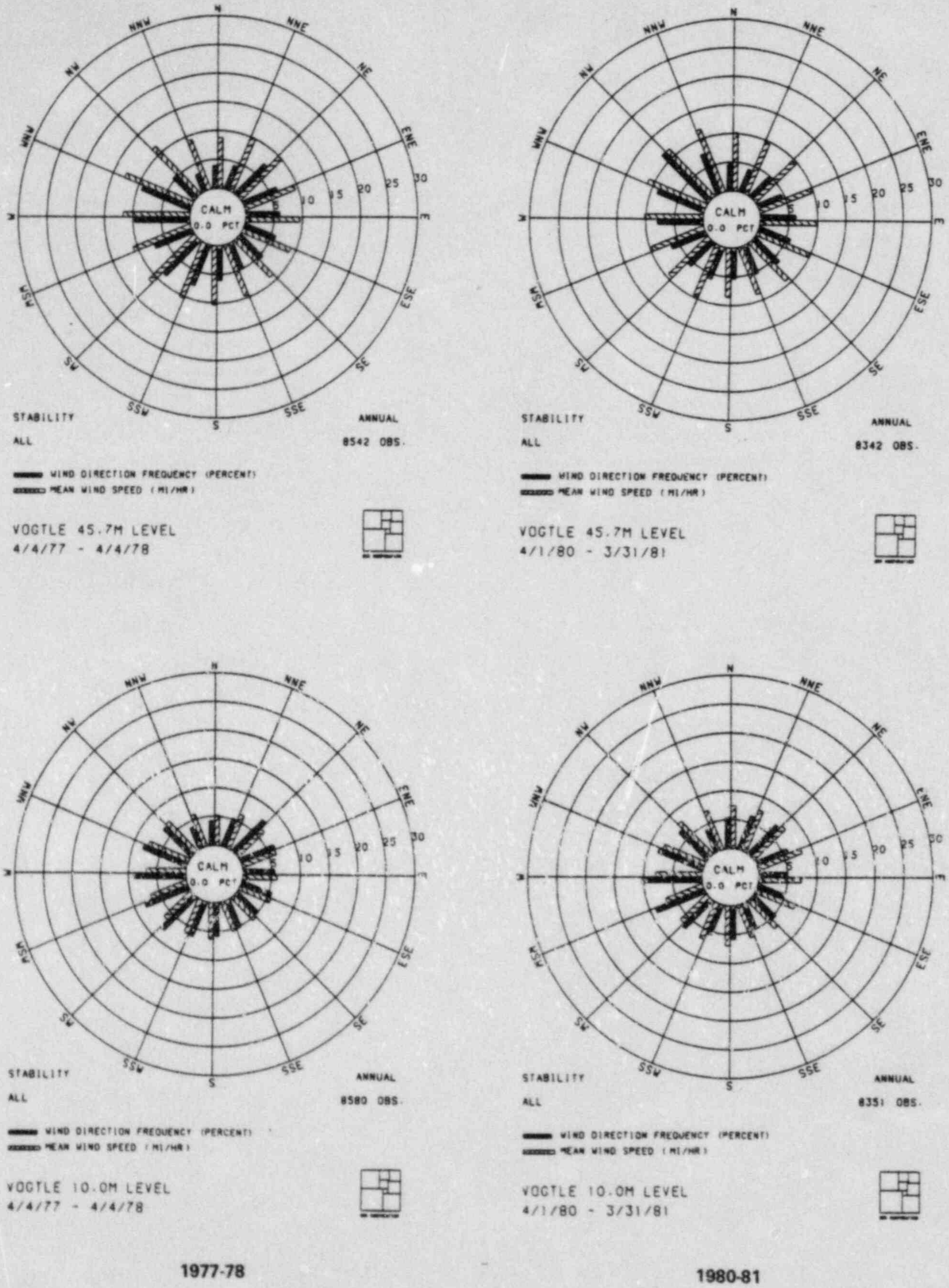
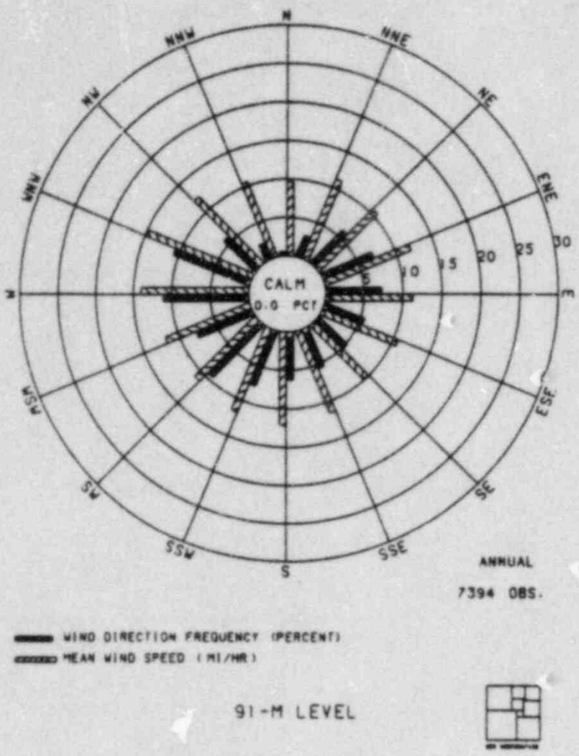
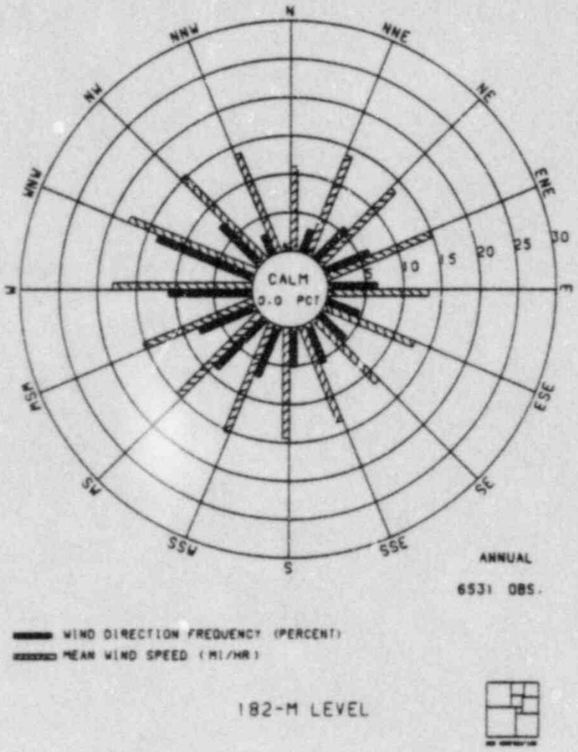


Figure 1.
ANNUAL WIND ROSES
VOGTLE ELECTRIC GENERATING PLANT





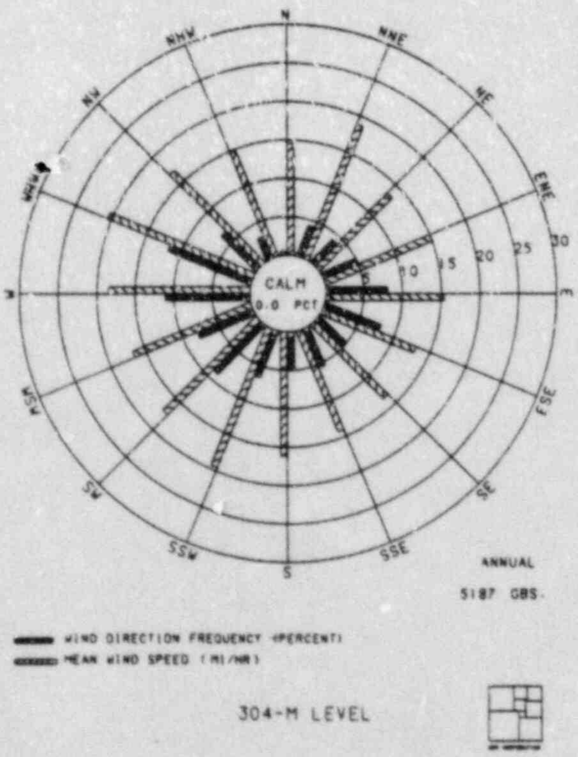


Figure 2.
ANNUAL WIND ROSES
WJBF-TV TOWER
SAVANNAH RIVER LABORATORY DATA
4/4/77 - 4/4/78

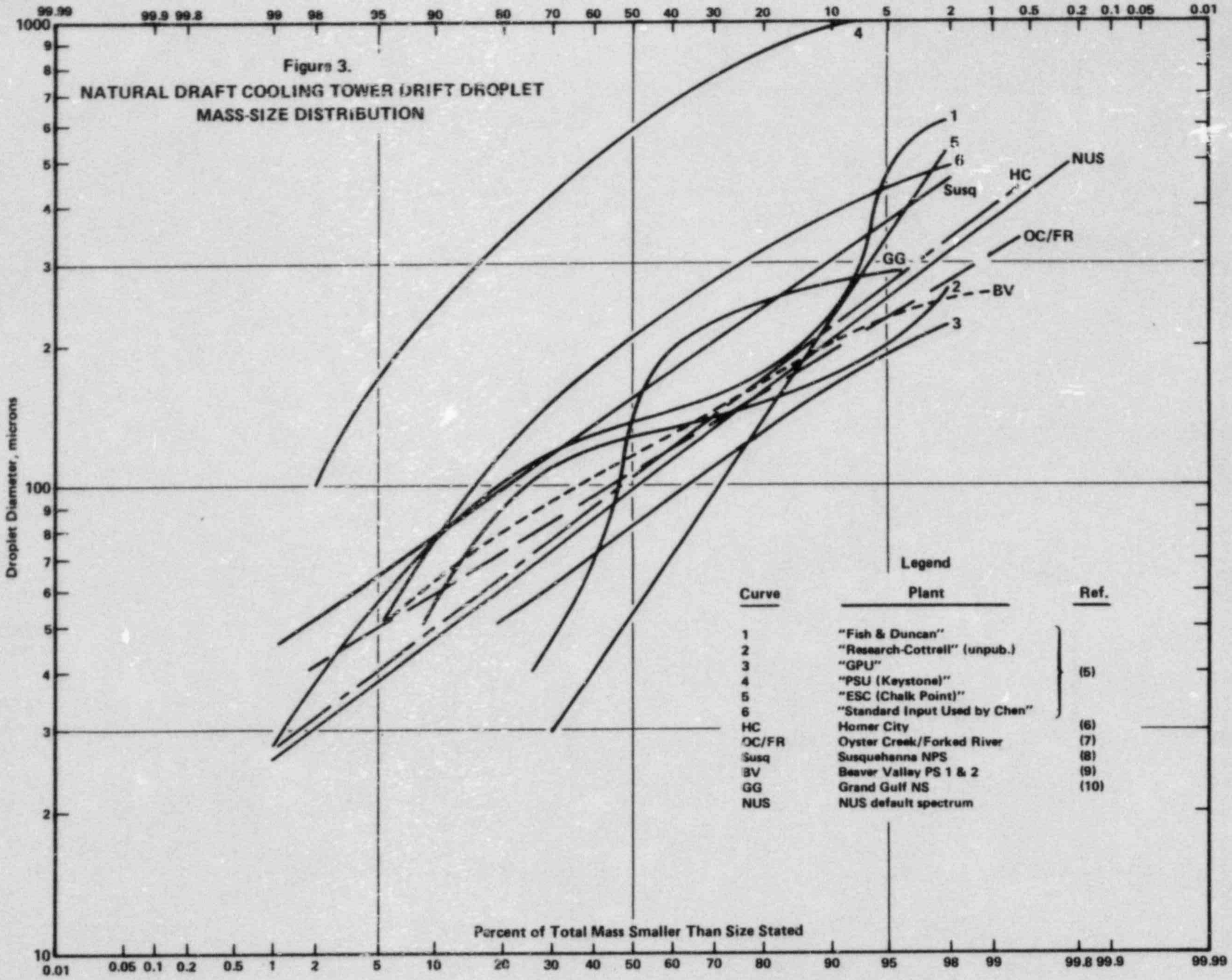
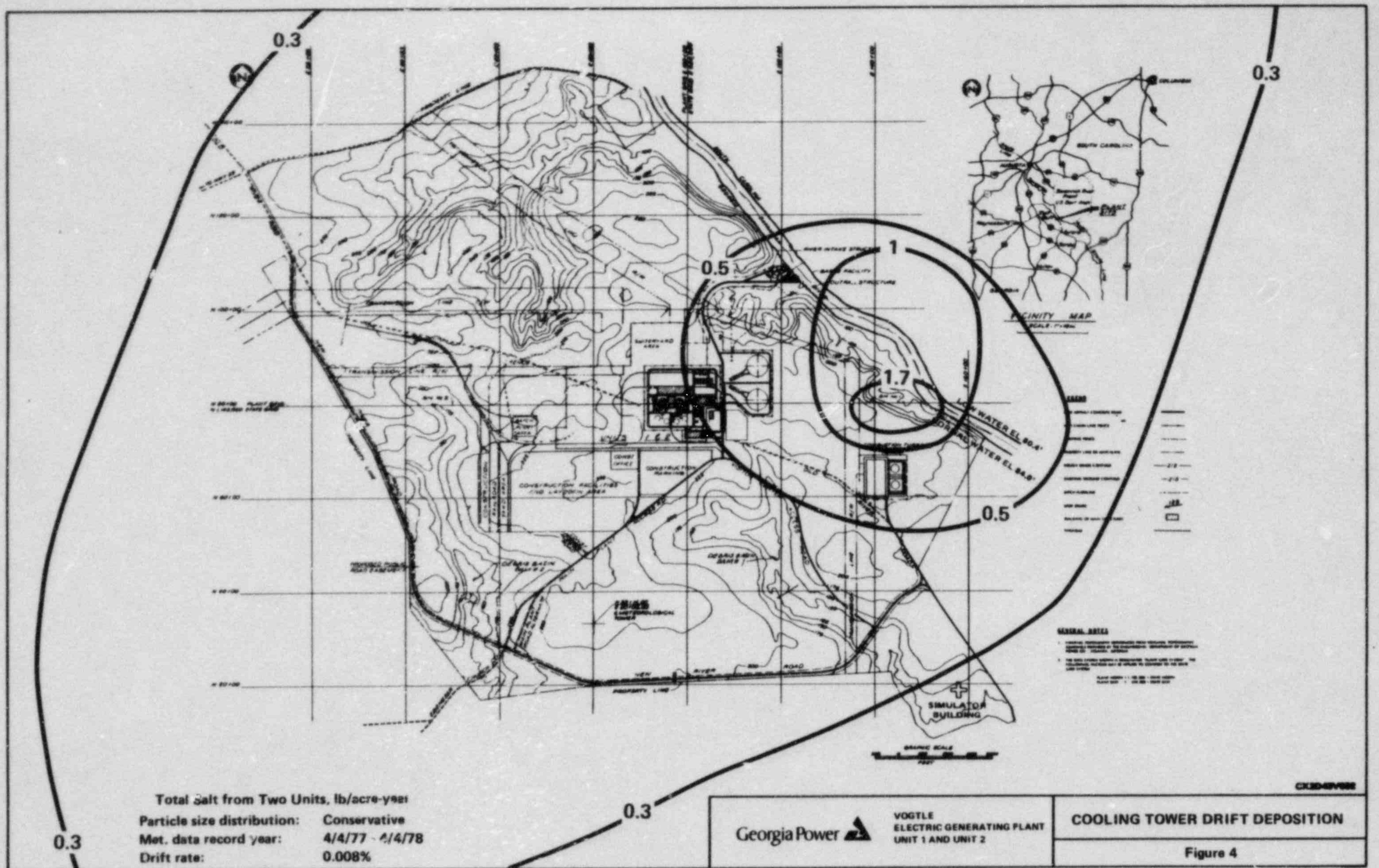


Figure 3.
NATURAL DRAFT COOLING TOWER DRIFT DROPLET MASS-SIZE DISTRIBUTION



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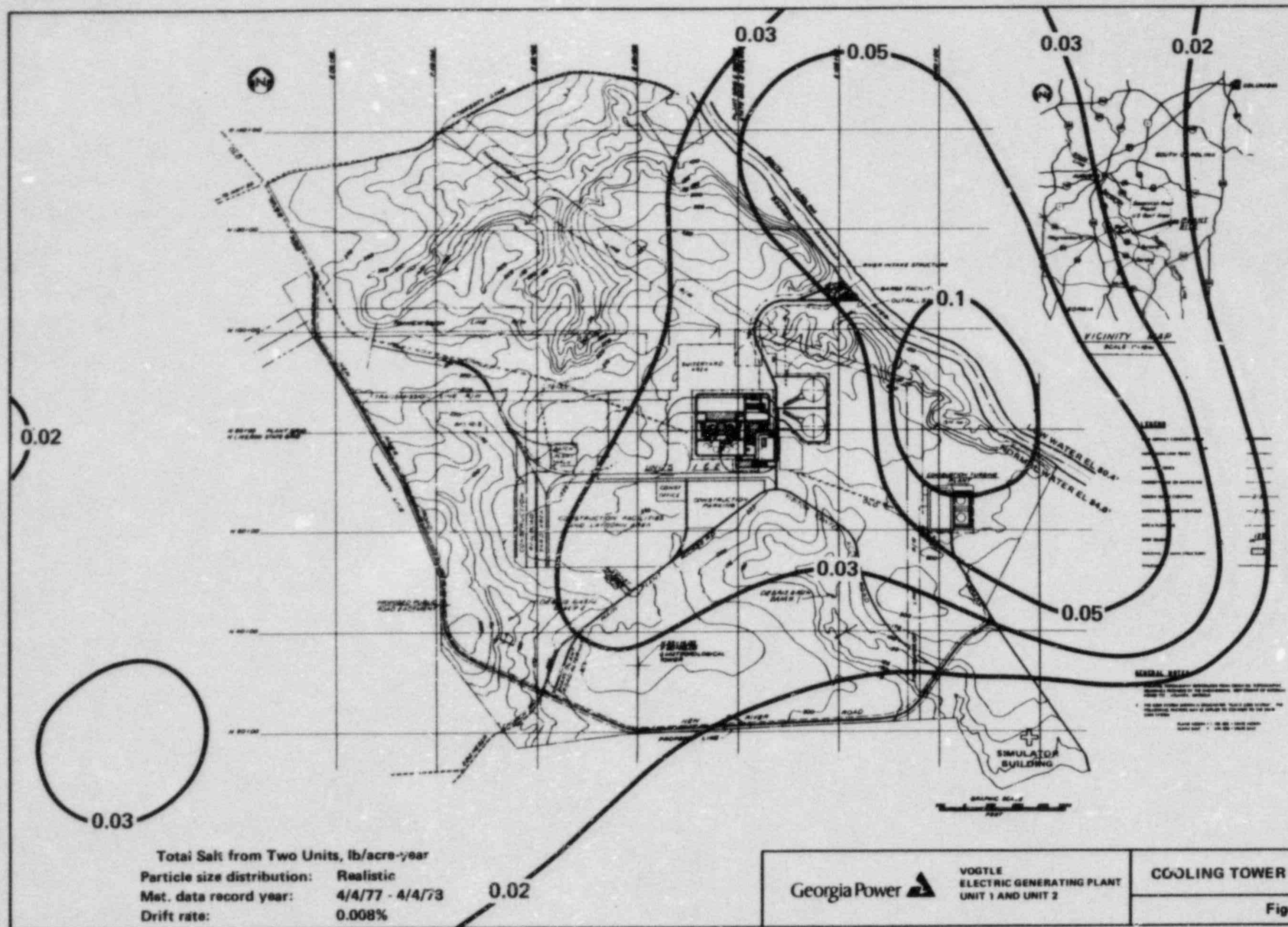
VOGTLE
ELECTRIC GENERATING PLANT
UNIT 1 AND UNIT 2

COOLING TOWER DRIFT DEPOSITION

Figure 4



Total Salt from Two Units, lb/acre-year

Particle size distribution: Realistic

Met. data record year: 4/4/77 - 4/4/73

Drift rate: 0.008%

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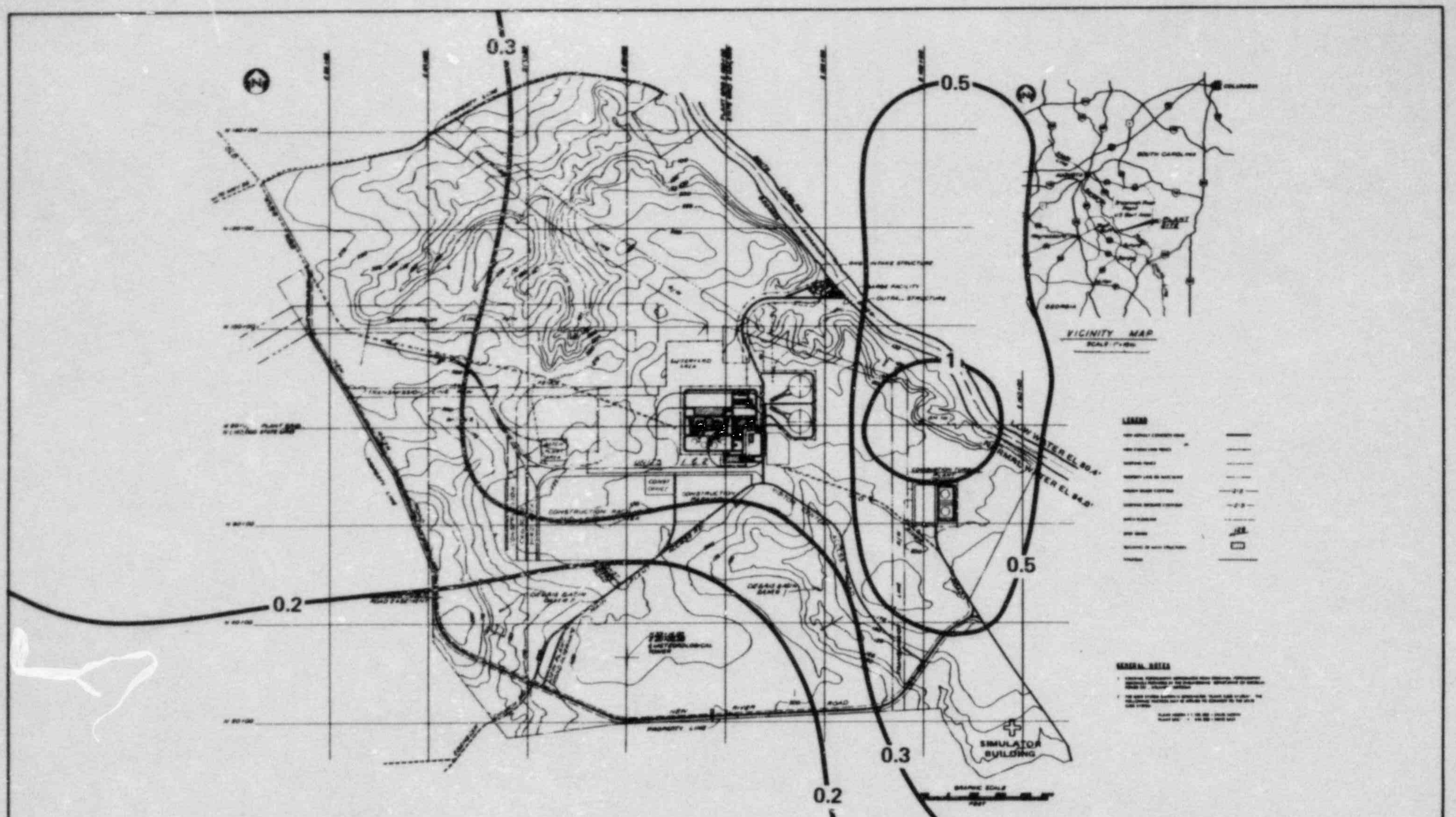
VOGTLE
ELECTRIC GENERATING PLANT
UNIT 1 AND UNIT 2

COOLING TOWER DRIFT DEPOSITION

Figure 5



Total Salt from Two Units, lb/acre-year

Particle size distribution:	Conservative
Met. data record year:	4/1/80 - 3/31/81
Drift rate:	0.008%

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ELECTRIC GENERATING PLANT
UNIT 1 AND UNIT 2

COOLING TOWER DRIFT DEPOSITION

Figure 6

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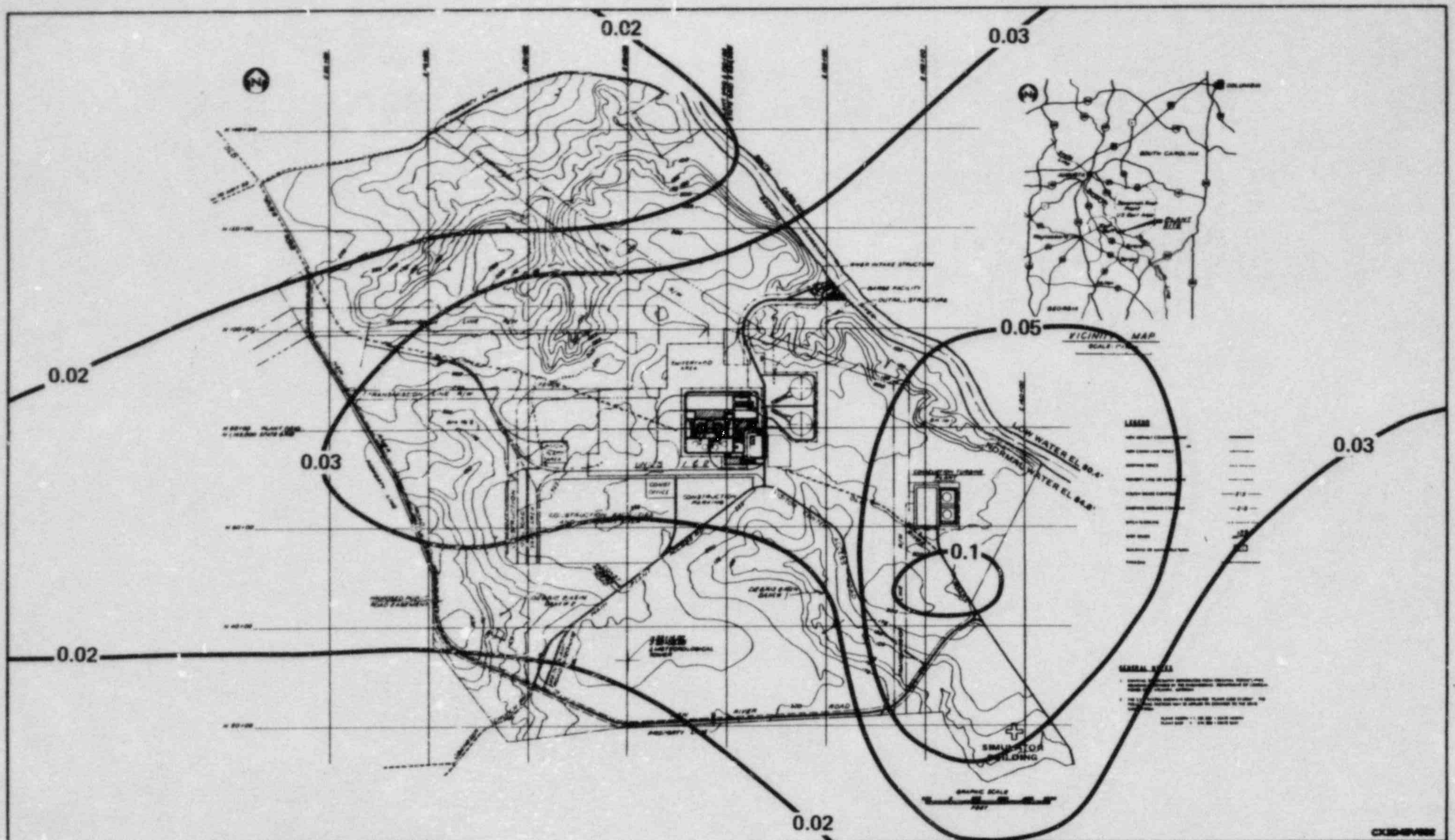

Total Salt from Two Units lb/acre-year

Particle size distribution:	Realistic
Met. data record year:	4/1/80 - 3/31/81
Drift rate:	0.008%

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ELECTRIC GENERATING PLANT
UNIT 1 AND UNIT 2

COOLING TOWER DRIFT DEPOSITION

Figure 7

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