Table 2.3-20

0.5 PERCENT GROUND LEVEL χ/Q VALUES (× 10^{-6} SEC/M^3) AT THE 15.0-MILE POPULATION RECEPTOR FOR THE 0- TO 720-HOUR PERIOD FOLLOWING AN ACCIDENT AT THE INDEPENDENT SPENT FUEL STORAGE INSTALLATION

Downwind Sector	Distance (m)	0-2 hr	0-8 hr	8-24 hr	1-4 day	4-30 day
N	24140	22.1	8.71	5.46	1.99	0.465
NNE	24140	21.3	8.28	5.16	1.85	0.423
NE	24140	19.9	7.39	4.50	1.54	0.328
ENE	24140	14.7	5.38	3.25	1.09	0.227
E	24140	6.86	2.71	1.70	0.620	0.146
ESE	24140	5.02	2.00	1.26	0.465	0.111
SE	24140	4.61	1.87	1.19	0.445	0.109
SSE	24140	4.27	1.76	1.13	0.434	0.110
S	24140	4.74	1.96	1.26	0.484	0.122
SSW	24140	2.89	1.21	0.779	0.302	0.077
SW	24140	2.28	0.982	0.645	0.259	0.070
WSW	24140	2.12	0.893	0.579	0.227	0.059
W	24140	3.35	1.39	0.897	0.346	0.088
WNW	24140	5.69	2.30	1.46	0.547	0.133
NW	24140	11.1	4.21	2.60	0.912	0.203
NNW	24140	19.0	7.22	4.46	1.57	0.348

Five percent direction independent 17.3

Table 2.3-21
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-7}$ SEC/M^3) AT THE 25.0-MILE POPULATION RECEPTOR FOR THE 0- TO 720-HOUR PERIOD FOLLOWING AN ACCIDENT AT THE INDEPENDENT SPENT FUEL STORAGE INSTALLATION

Downwind Sector	Distance (m)	0-2 hr	0-8 hr	8-24 hr	1-4 day	4-30 day
N	40234	144	54.8-	33.8	11.9	2.65
NNE	40234	136	51.3	31.5	10.9	2.39
NE	40234	129	46.5	27.9	9.19	1.87
ENE	40234	92.3	32.8	19.6	6.38	1.28
E	40234	42.1	16.2	10.1	3.58	0.812
ESE	40234	29.7	11.6	7.28	2.63	0.610
SE	40234	27.3	10.8	6.83	2.50	0.593
SSE	40234	25.3	10.2	6.50	2.43	0.594
S	40234	28.1	11.4	7.23	2.71	0.663
SSW	40234	16.8	6.88	4.40	1.67	0.415
SW	40234	13.2	5.59	3.64	1.43	0.376
WSW	40234	12.3	5.10	3.28	1.26	0.318
W	40234	19.5	7.95	5.08	1.92	0.477
WNW	40234	33.7	13.3	8.40	3.07	0.726
NW	40234	68.0	25.3	15.4	5.26	1.130
NNW	40234	123.0	45.4	27.6	9.36	1.980

Five percent direction independent 112

Table 2.3-22

0.5 PERCENT GROUND LEVEL χ/Q VALUES (× 10^{-7} SEC/M^3) AT THE 35.0-MILE POPULATION RECEPTOR FOR THE 0- TO 720-HOUR PERIOD FOLLOWING AN ACCIDENT AT THE INDEPENDENT SPENT FUEL STORAGE INSTALLATION

Downwind Sector	Distance (m)	0-2 hr	0-8 hr	8-24 hr	1-4 day	4-30 day
N	56327	108	40.3	24.6	8.47	1.830
NNE	56327	102	37.7	22.9	7.79	1.650
NE	56327	97.0	34.2	20.3	6.54	1.290
ENE	56327	69.3	24.1	14.3	4.54	0.880
E	56327	29.5	11.3	6.96	2.45	0.547
ESE	56327	20.8	8.08	5.03	1.80	0.411
SE	56327	19.1	7.51	4.71	1.71	0.397
SSE	56327	17.1	7.08	4.47	1.65	0.396
S	56327	19.7	7.87	4.98	1.84	0.441
SSW	56327	11.8	4.76	3.03	1.13	0.276
SW	56327	9.26	3.87	2.50	0.973	0.250
WSW	56327	8.59	3.51	2.25	0.851	0.211
W	56327	13.6	5.51	3.50	1.31	0.319
WNW	56327	23.6	9.25	5.79	2.09	0.486
NW	56327	50.6	18.4	11.1	3.72	0.771
NNW	56327	92.4	33.4	20.1	6.66	1.360

Five percent direction independent 84.4

Table 2.3-23

0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-7}$ SEC/M^3) AT THE 45.0-MILE POPULATION RECEPTOR FOR THE 0- TO 720-HOUR PERIOD FOLLOWING AN ACCIDENT AT THE INDEPENDENT SPENT FUEL STORAGE INSTALLATION

Downwind Sector	Distance (m)	0-2 hr	0-8 hr	8-24 hr	1-4 day	4-30 day
N	72420	86.2	31.8	19.3	6.54	1.38
NNE	72420	81.6	29.8	18.0	6.02	1.25
NE	72420	77.6	27.0	15.9	5.05	.974
ENE	72420	55.4	19.0	11.2	3.51	.665
E	72420	22.6	8.58	5.28	1.84	.407
ESE	72420	16.0	6.15	3.82	1.35	.306
SE	72420	14.7	5.72	3.57	1.28	.294
SSE	72420	13.6	5.38	3.39	1.24	.293
S	72420	15.1	5.98	3.76	1.38	.326
SSW	72420	9.02	3.61	2.28	.846	.203
SW	72420	7.09	2.94	1.89	.728	.185
WSW	72420	6.52	2.65	1.69	.634	.156
W	72420	10.4	4.18	2.65	.981	.236
WNW	72420	18.1	7.03	4.38	1.57	.360
NW	72420	38.8	14.0	8.44	2.80	.573
NNW	72420	72.4	25.9	15.5	5.08	1.02

Five percent direction independent 67.5

Table 2.3-24
0.5 PERCENT GROUND LEVEL χ/Q VALUES (× 10^{-7} SEC/M^3) AT THE 50.0-MILE POPULATION RECEPTOR FOR THE 0- TO 720-HOUR PERIOD FOLLOWING AN ACCIDENT AT THE INDEPENDENT SPENT FUEL STORAGE INSTALLATION

Downwind Sector	Distance (m)	0-2 hr	0-8 hr	8-24 hr	1-4 day	4-30 day
N	80463	78.2	28.7	17.4	5.86	1.23
NNE	80463	74.1	26.9	16.2	5.39	1.11
NE	80463	70.4	24.3	14.3	4.52	.865
ENE	80463	50.3	17.2	10.1	3.14	.590
E	80463	20.2	7.65	4.70	1.64	.360
ESE	80463	14.3	5.48	3.40	1.20	.270
SE	80463	13.1	5.09	3.17	1.14	.260
SSE	80463	12.1	4.79	3.01	1.10	.258
S	80463	13.5	5.33	3.35	1.22	.287
SSW	80463	8.06	3.21	2.03	.749	.179
SW	80463	6.33	2.62	1.68	.644	.162
WSW	80463	5.81	2.35	1.50	.561	.137
W	80463	9.33	3.73	2.35	.869	.208
WNW	80463	16.2	6.27	3.90	1.39	.317
NW	80463	34.7	12.5	7.51	2.48	.506
NNW	80463	64.8	23.1	13.8	4.51	.905

Five percent direction independent 61.2

Table 2.3-25
MAXIMUM SECTOR χ/Q VALUE (sec/m^3)

Downwind	Time Averaging χ/Q				
Distance (m)	0-2 hr	0-8 hr	8-24 hr	1-4 day	4-30 day
503	1.07E-3	7.39E-4	6.15E-4	4.10E-4	2.32E-4
805	4.99E-4	3.41E-4	2.82E-4	1.86E-4	1.03E-4
2414	1.89E-4	1.01E-4	7.42E-5	3.77E-5	1.43E-5
3218	1.47E-4	7.39E-5	5.24E-5	2.49E-5	8.51E-6
4023	1.21E-4	5.80E-5	4.02E-5	1.82E-5	5.80E-6
5633	8.86E-5	4.01E-5	2.70E-5	1.15E-5	3.34E-6
7242	6.99E-5	3.05E-5	2.02E-5	8.21E-6	2.26E-6
12070	4.31E-5	1.77E-5	1.14E-5	4.34E-6	1.09E-6
24140	2.21E-5	8.71E-6	5.46E-6	1.99E-6	4.65E-7
40234	1.44E-5	5.48E-6	3.38E-6	1.19E-6	2.65E-7
56327	1.08E-5	4.03E-6	2.46E-6	8.47E-7	1.833-7
72420	8.62E-6	3.18E-6	1.93E-6	6.54E-7	1.38E-7
80463	7.82E-6	2.87E-6	1.74E-6	5.86E-7	1.23E-7

Figure 2.3-1
SURRY WIND DIRECTION ROSES; 1974-1981; LOW LEVEL;
SEASON = SPRING

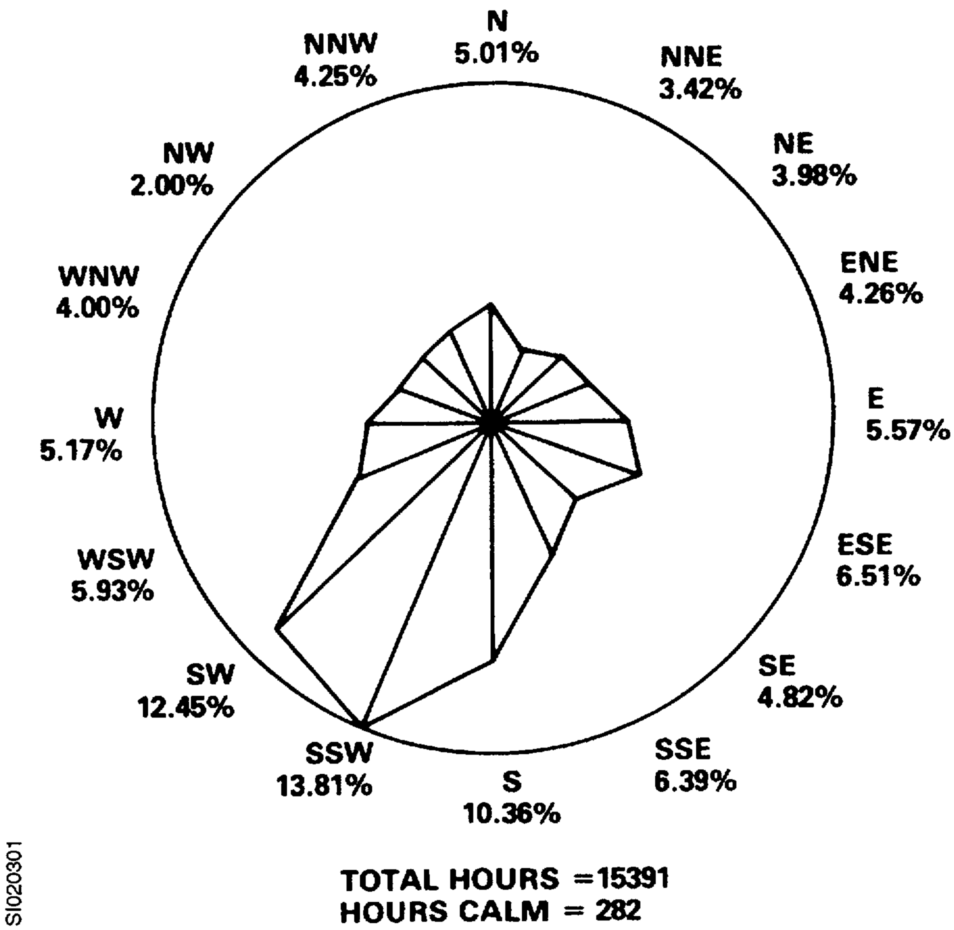
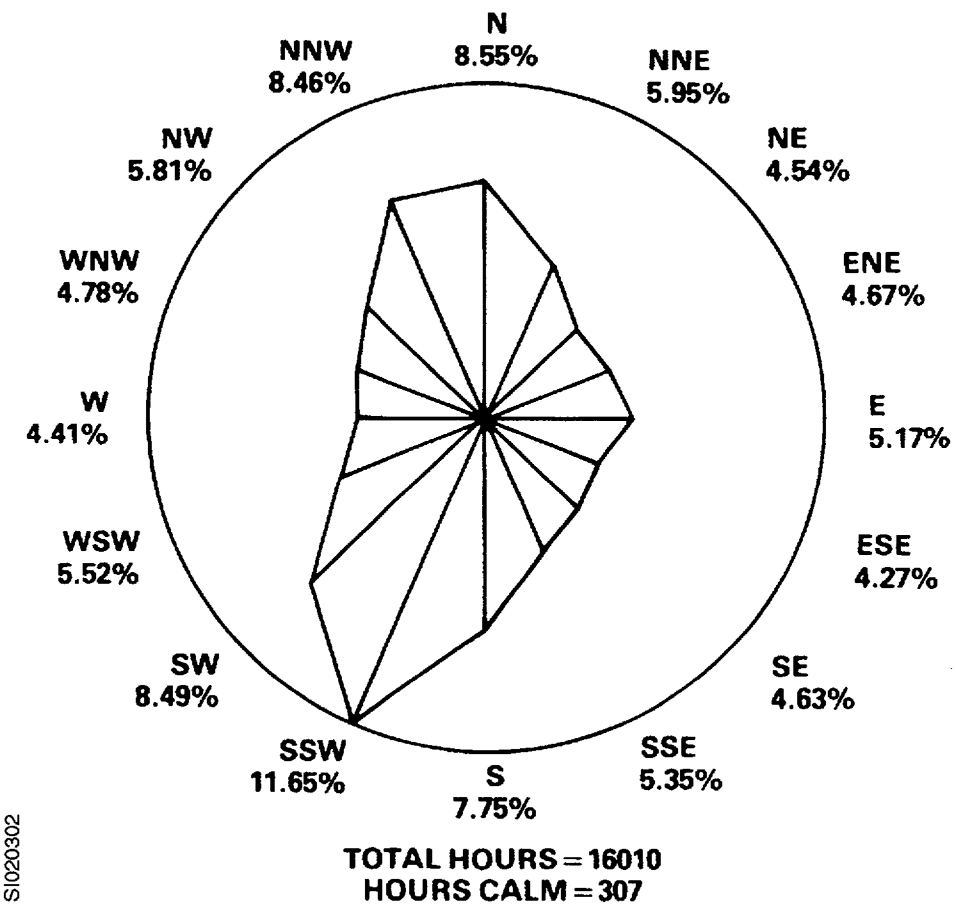
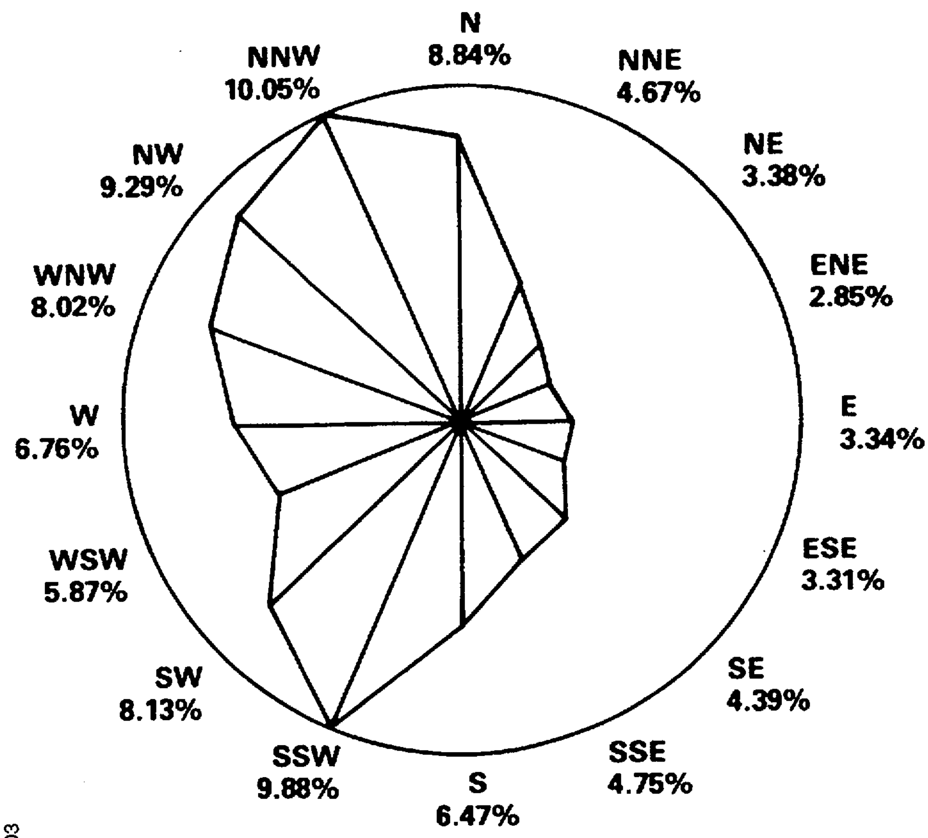


Figure 2.3-2
SURRY WIND DIRECTION ROSES (%); 1974-1981; LOW LEVEL;
SEASON = SUMMER



TOTAL HOURS = 16010
HOURS CALM = 307

Figure 2.3-3
SURRY WIND DIRECTION ROSES (%); 1974-1981; LOW LEVEL;
SEASON = FALL



TOTAL HOURS = 14114
HOURS CALM = 90

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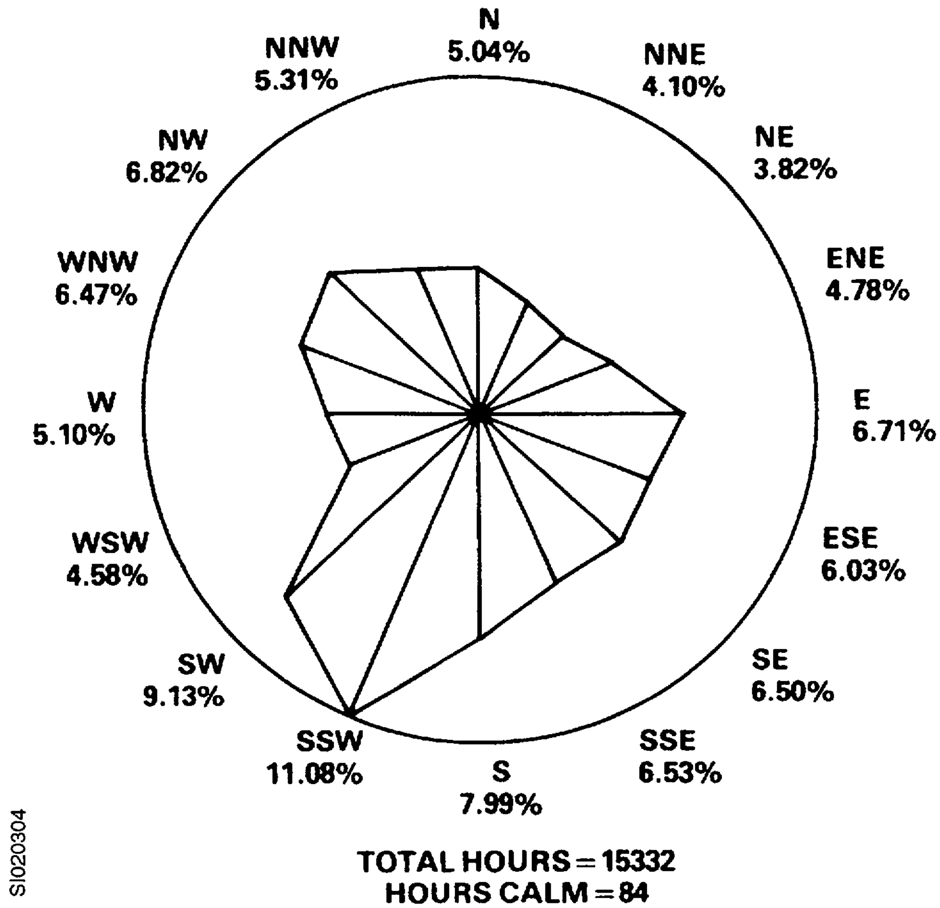
Figure 2.3-4
SURRY WIND DIRECTION ROSES (%); 1974-1981; LOW LEVEL;
SEASON = WINTER



TOTAL HOURS = 15332
HOURS CALM = 84

Figure 2.3-5
SURRY WIND DIRECTION ROSES (%); 1974-1981; LOW LEVEL; OVERALL

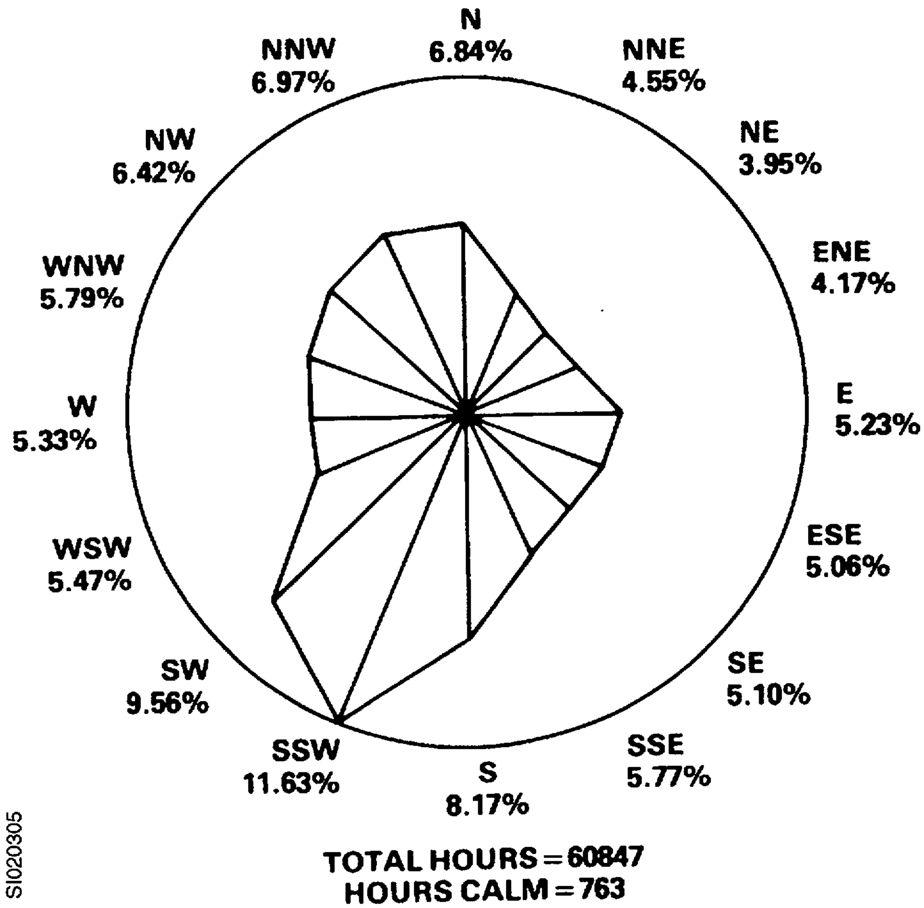
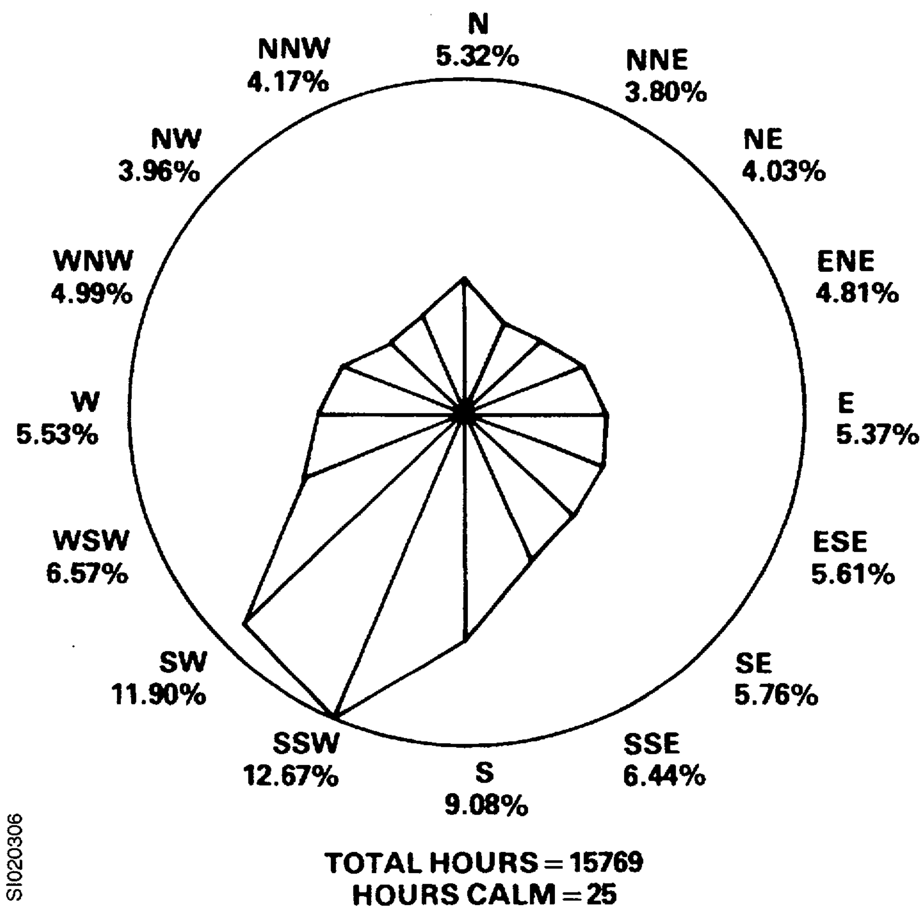


Figure 2.3-6
SURRY SEASONAL WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL;
SEASON = SPRING



TOTAL HOURS = 15769
HOURS CALM = 25

Figure 2.3-7
SURRY SEASONAL WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL;
SEASON = SUMMER

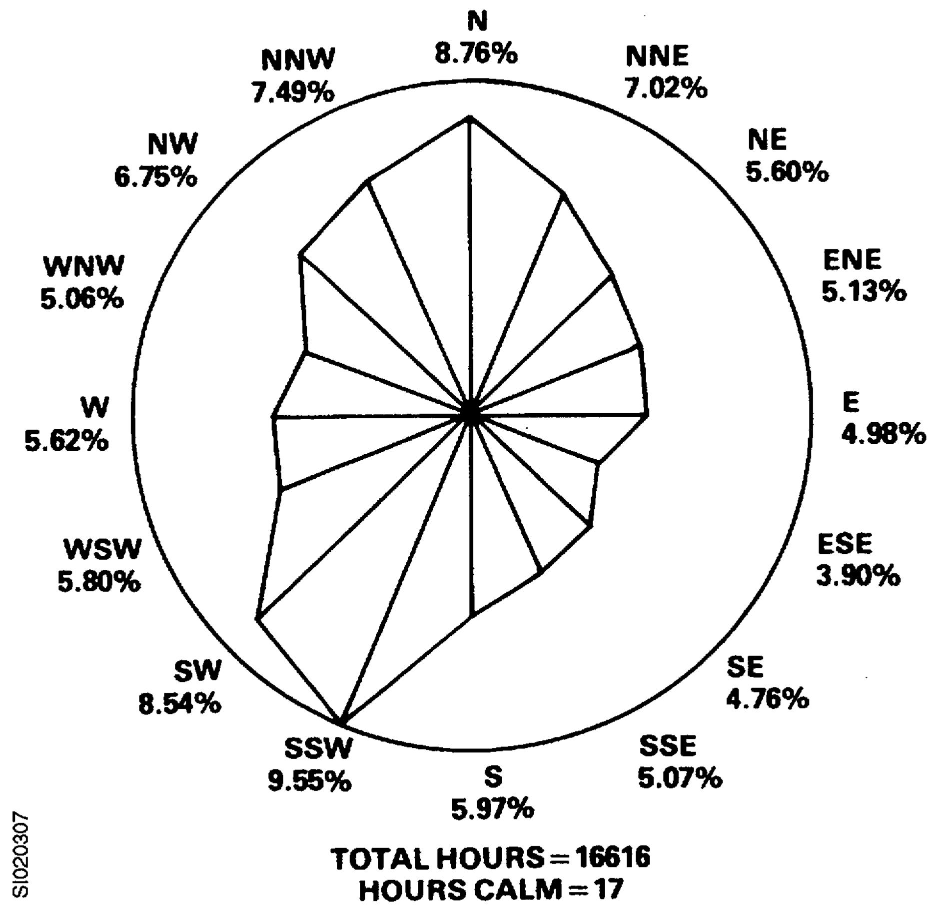


Figure 2.3-8
SURRY SEASONAL WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL;
SEASON = FALL

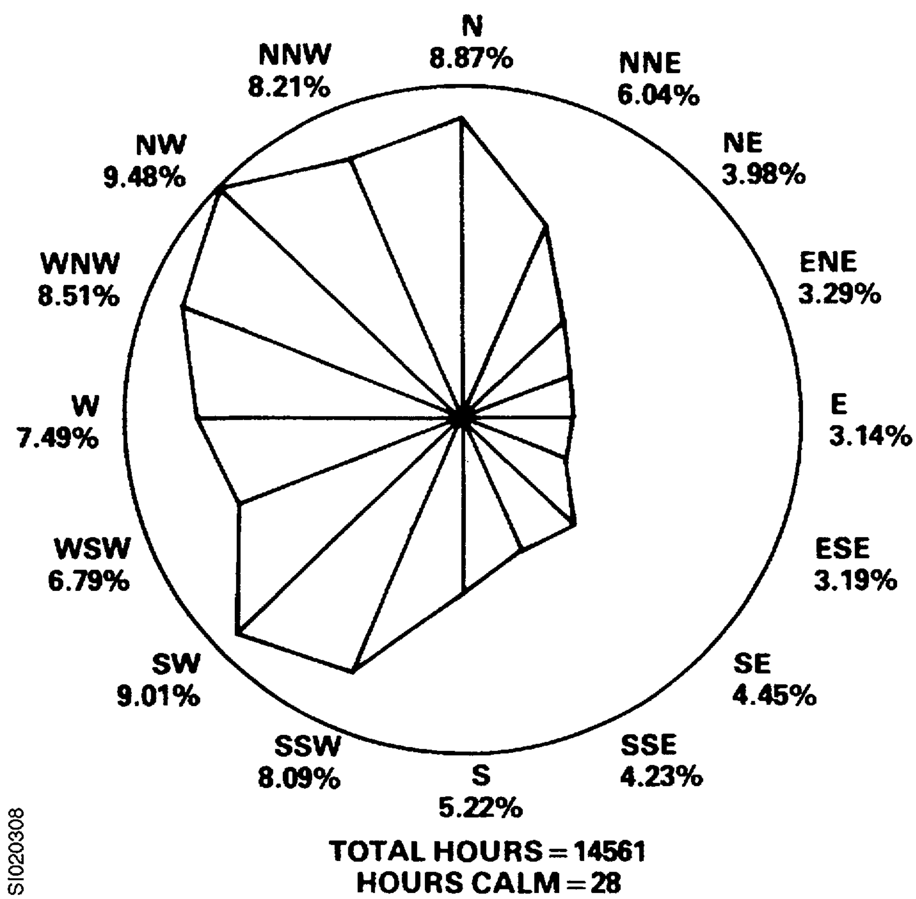


Figure 2.3-9
SURRY SEASONAL WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL;
SEASON = WINTER

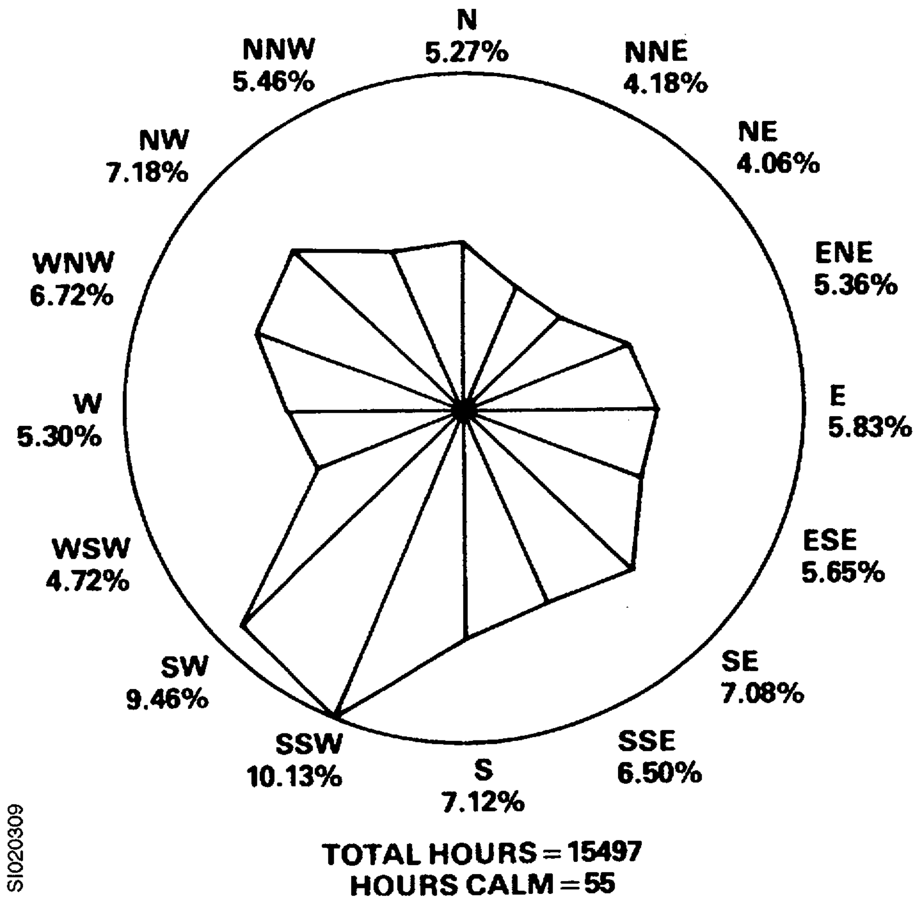


Figure 2.3-10
SURRY WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL; OVERALL

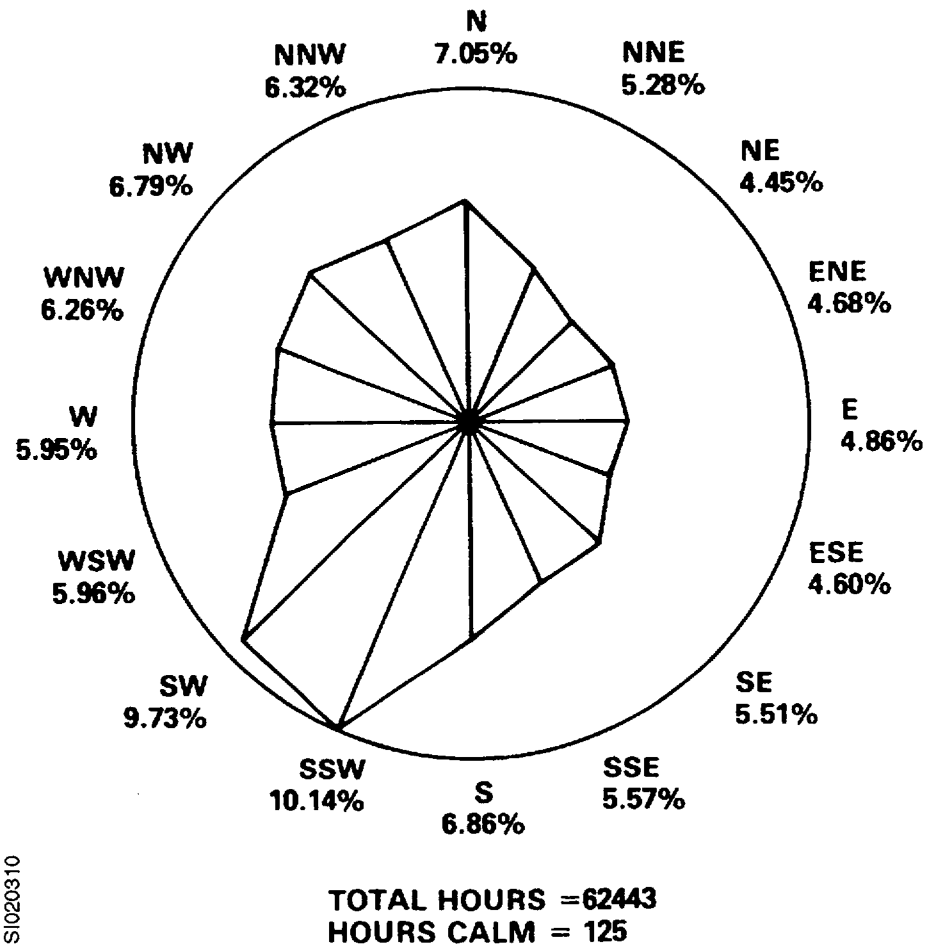


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Figure 2.3-11
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL;
SEASON = SPRING

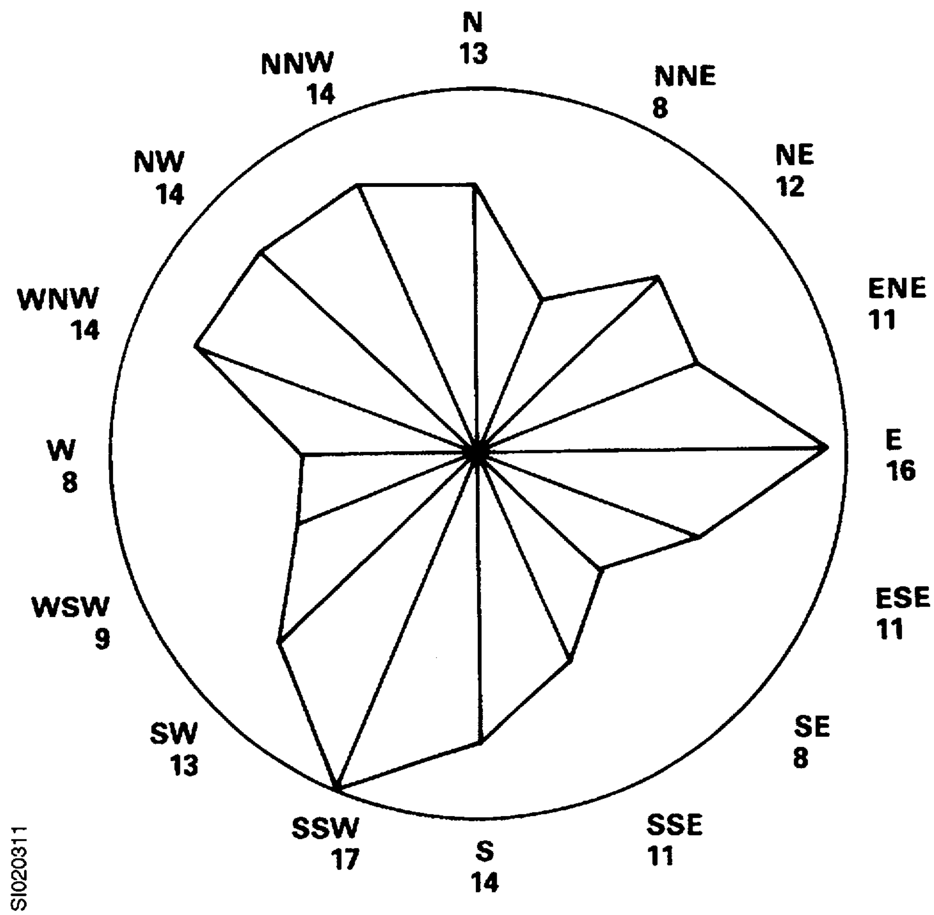


Figure 2.3-12
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL;
SEASON = SUMMER

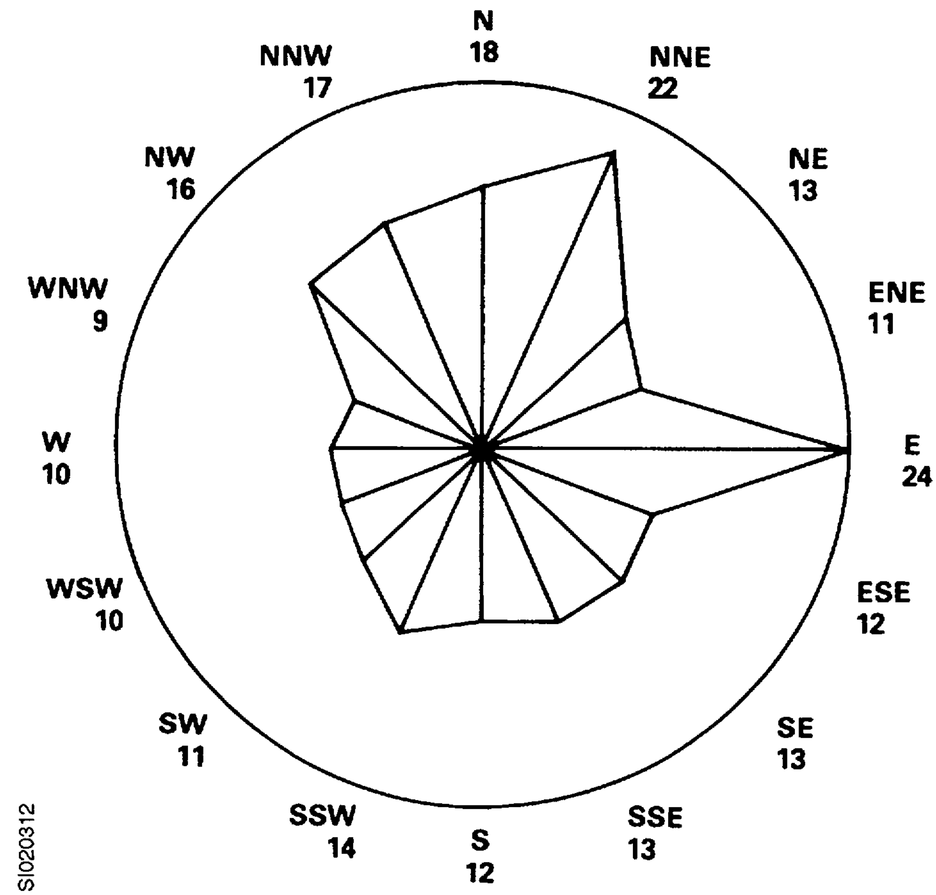


Figure 2.3-13
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL;
SEASON = WINTER

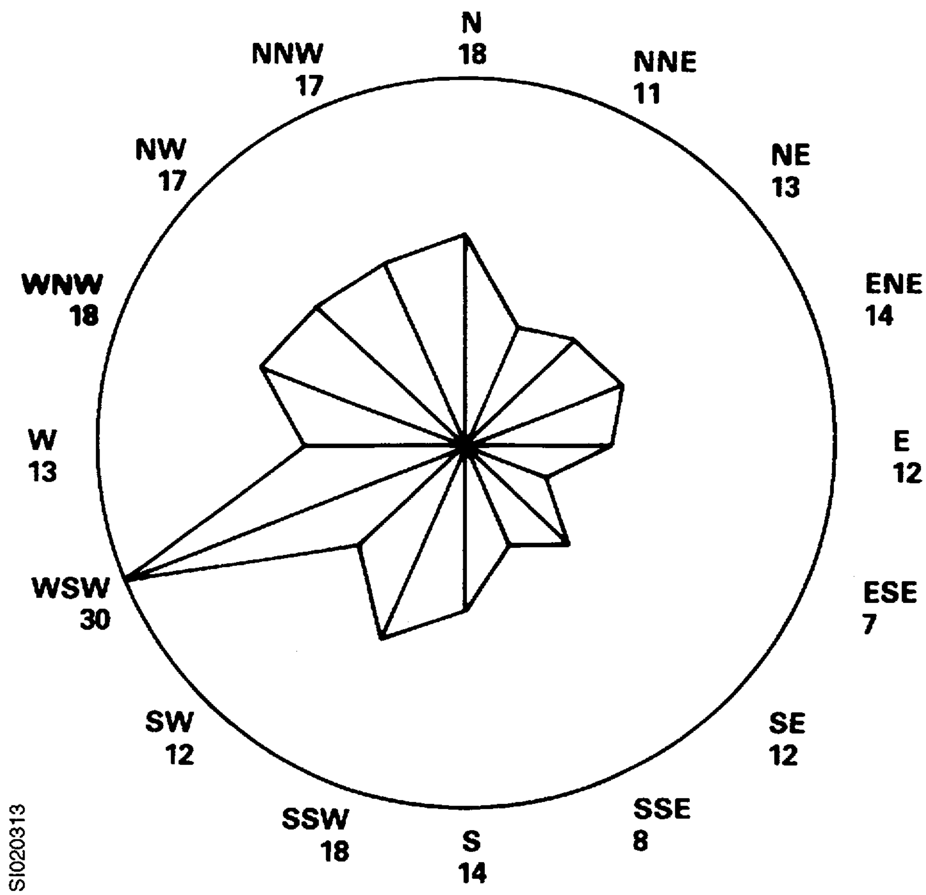


Figure 2.3-14
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL;
SEASON = FALL

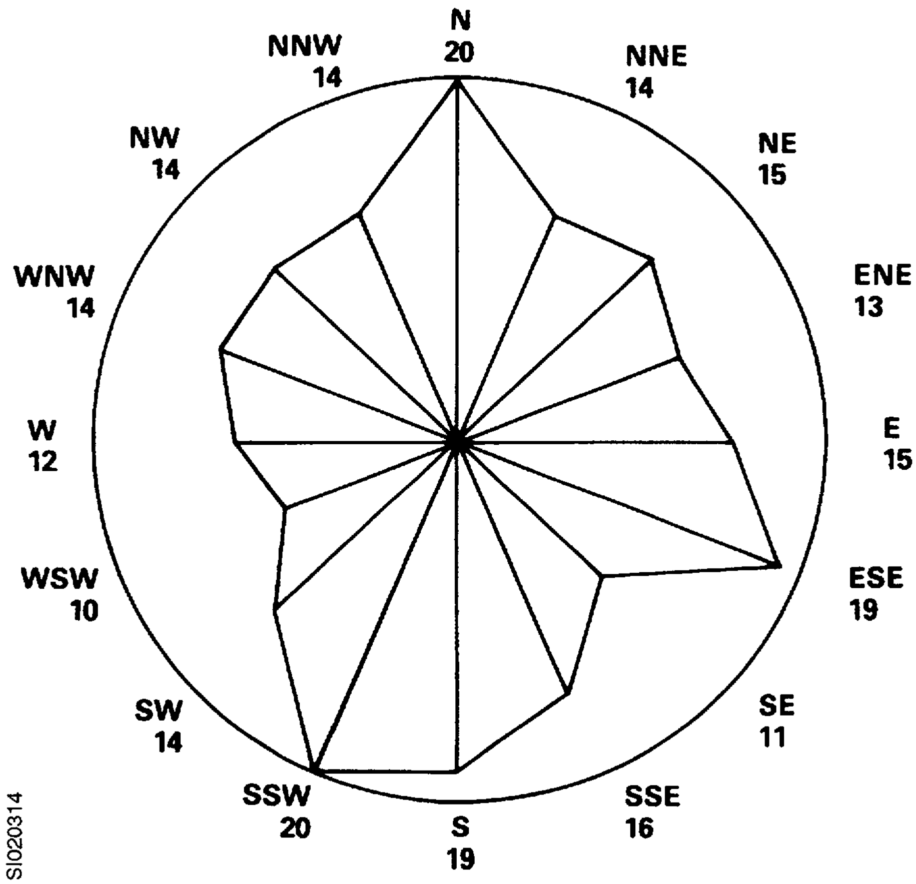


Figure 2.3-15
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL; OVERALL

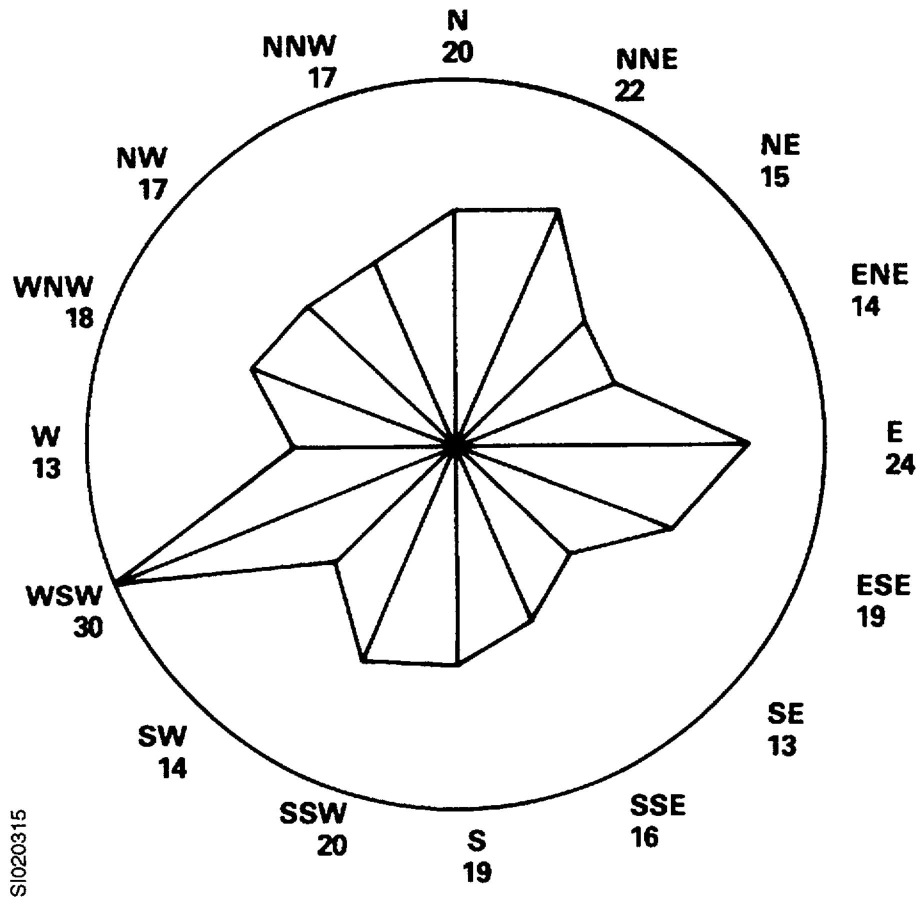


Figure 2.3-16
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL;
SEASON = SPRING

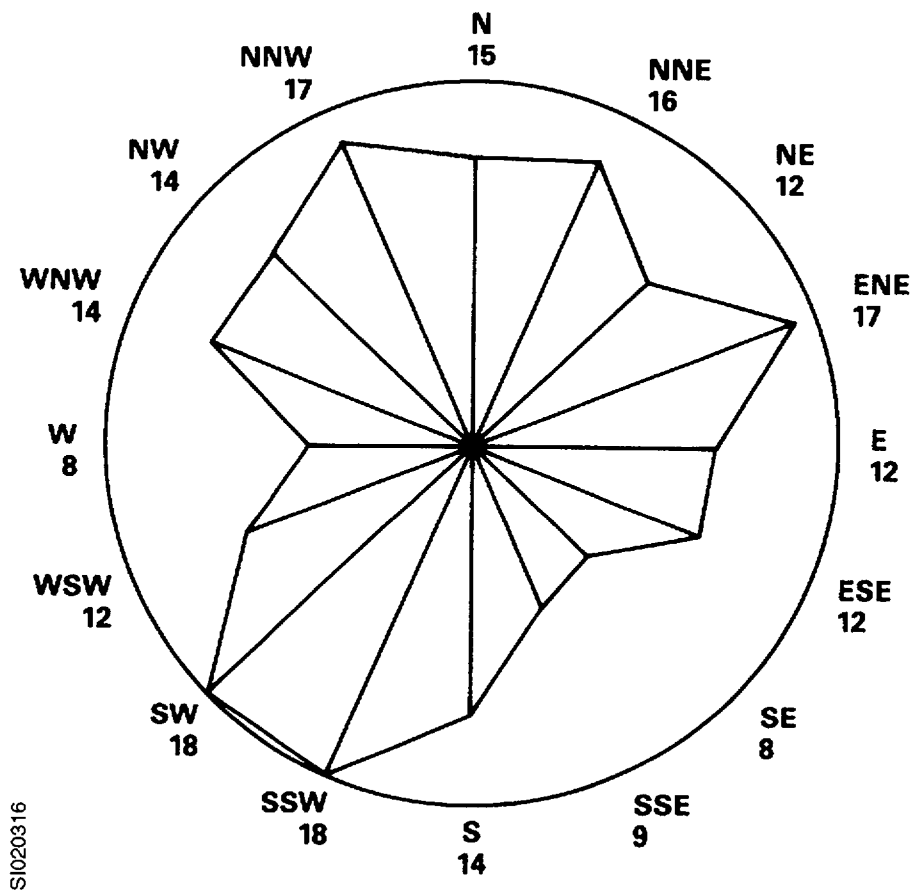


Figure 2.3-17
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL;
SEASON = SUMMER

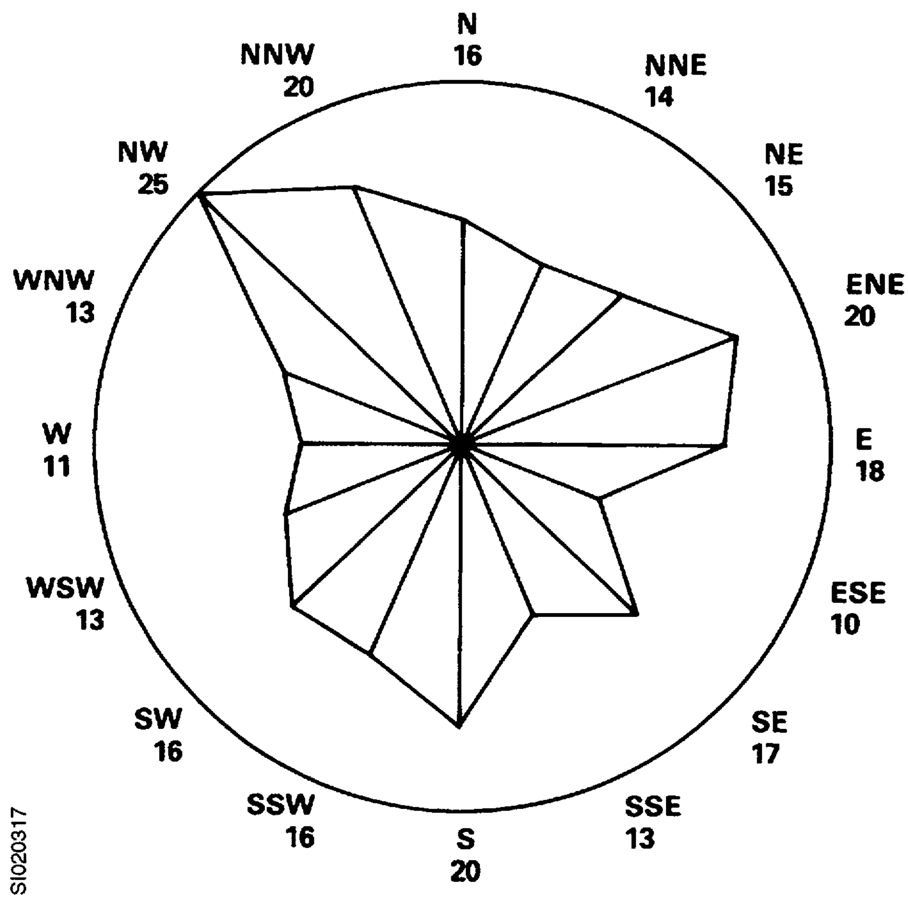


Figure 2.3-18
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL;
SEASON = FALL

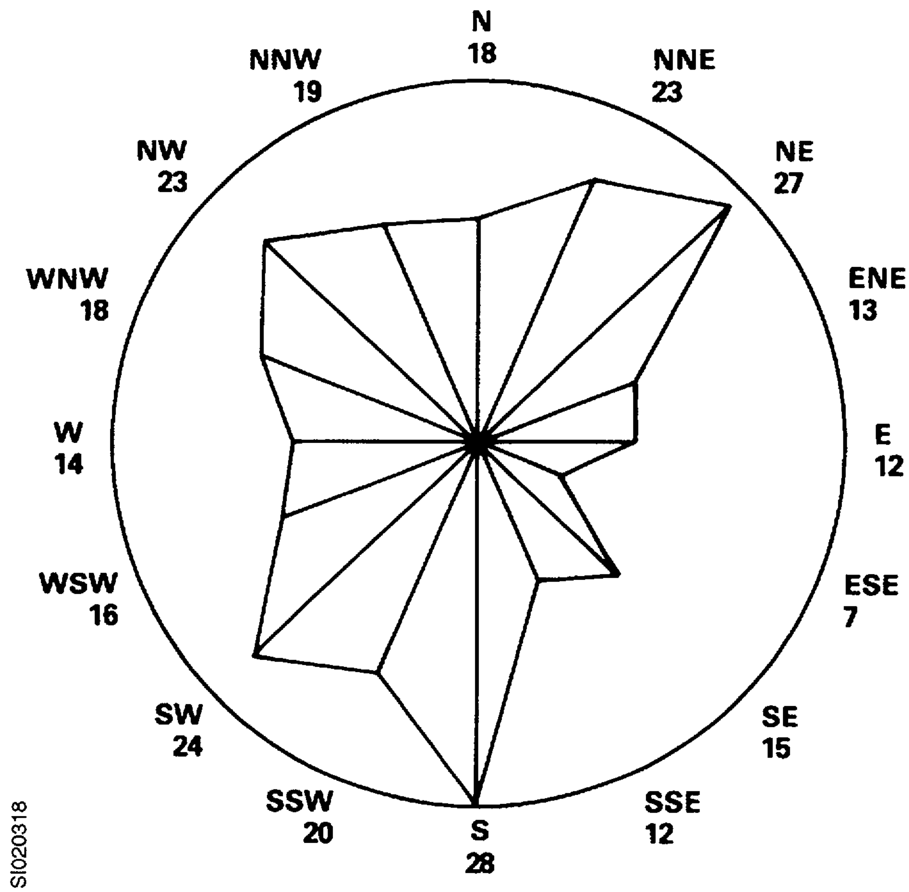


Figure 2.3-19
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL; SEASON = WINTER

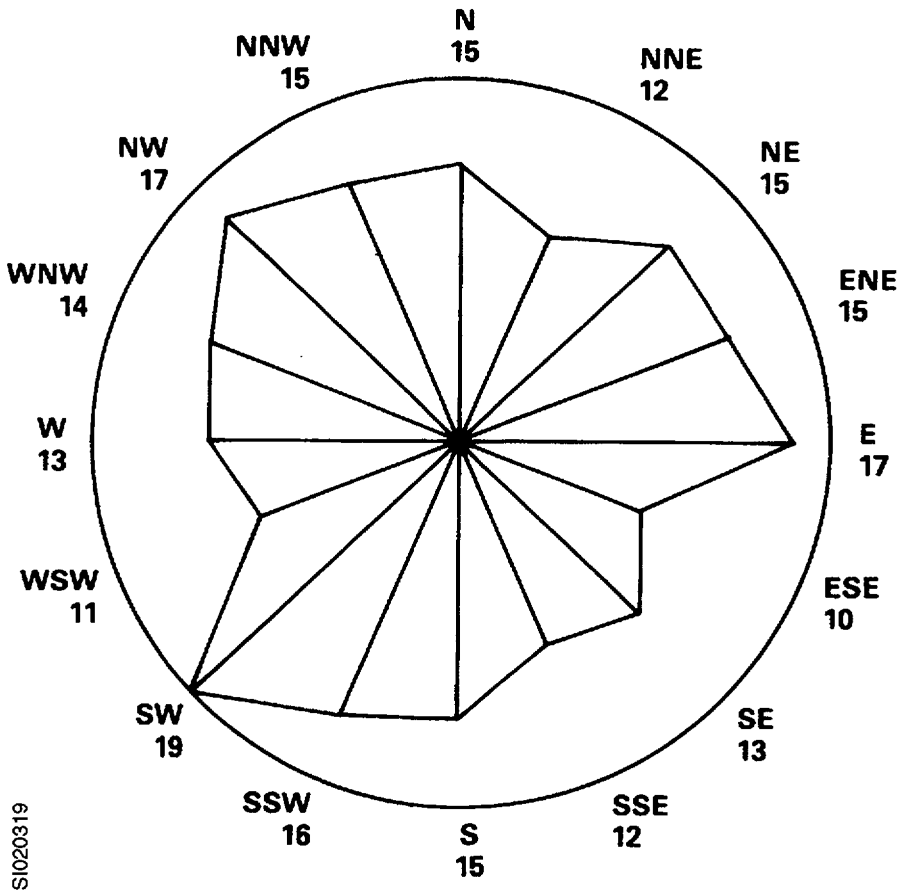


Figure 2.3-20
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL; OVERALL

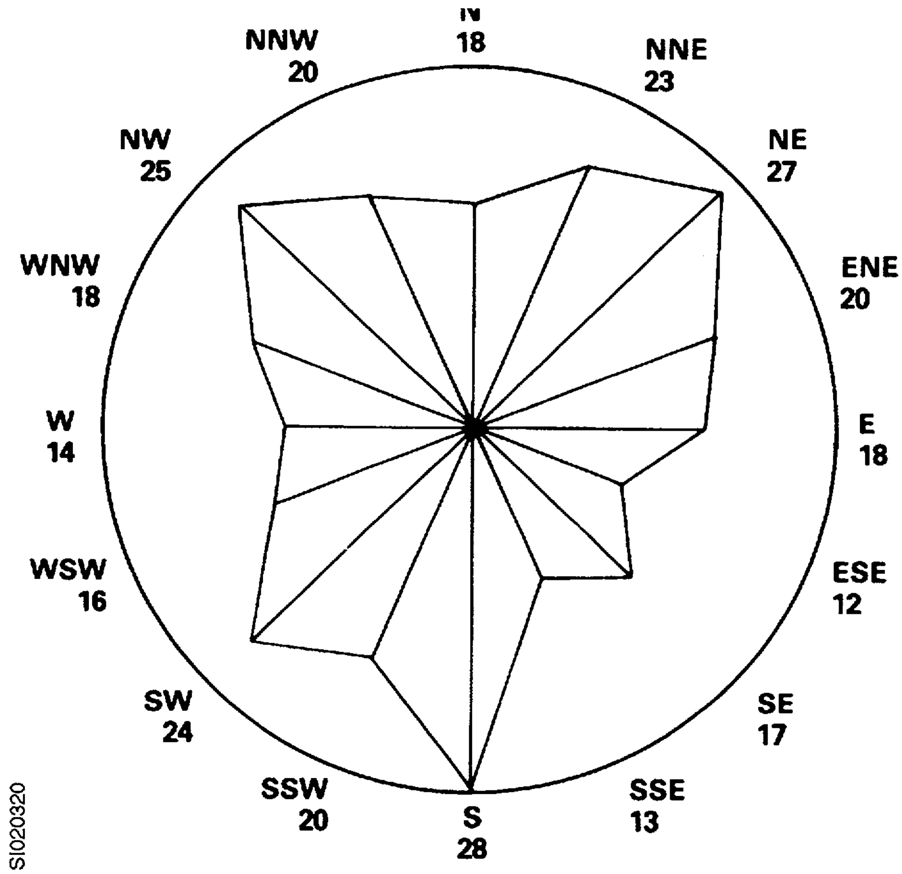


Figure 2.3-21
SURRY POWER STATION; TOPOGRAPHIC CROSS SECTIONS; (0-5 MILES FROM SURRY POWER STATION)

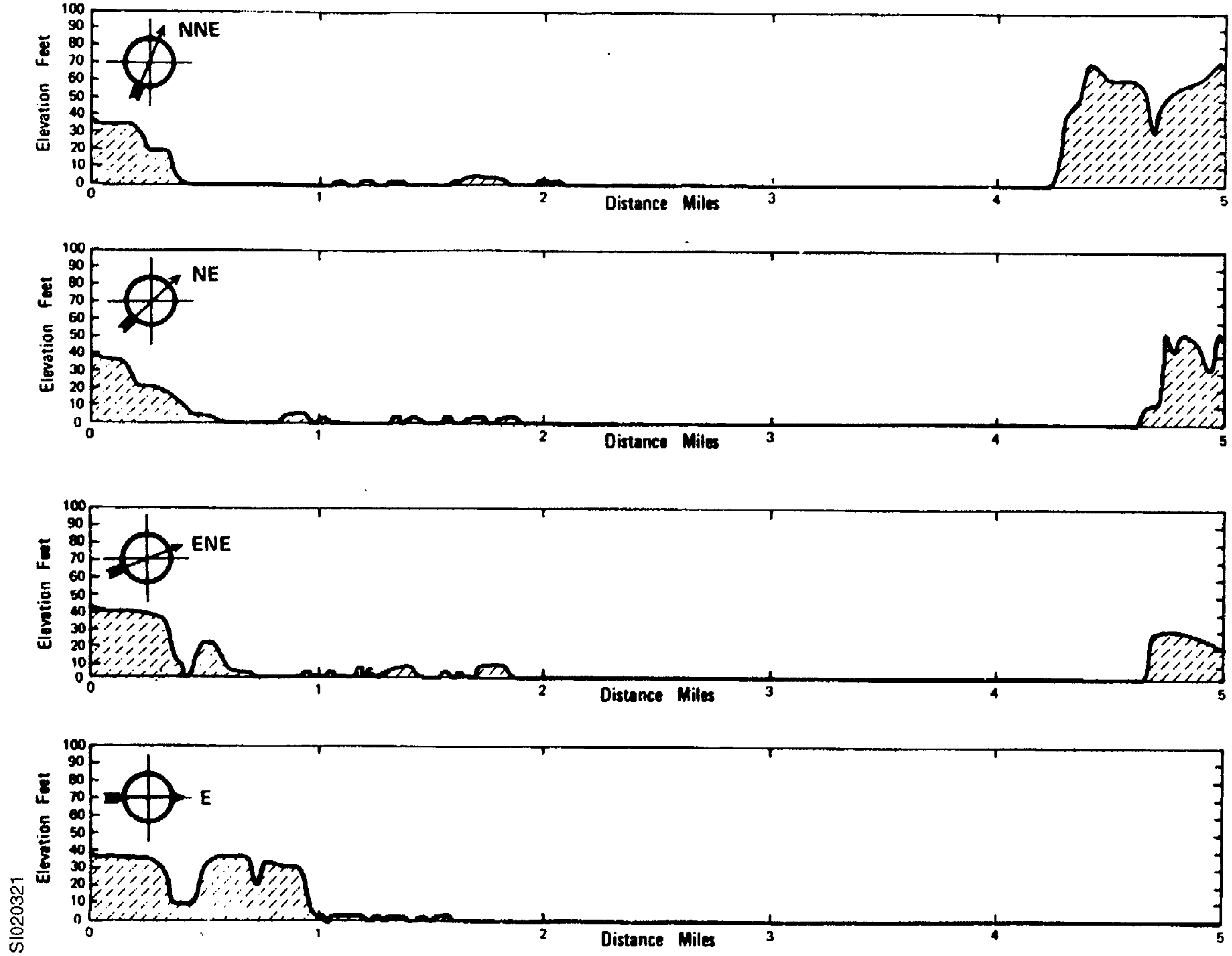


Figure 2.3-22
SURRY POWER STATION; TOPOGRAPHIC CROSS SECTIONS; (0-5 MILES FROM SURRY POWER STATION)

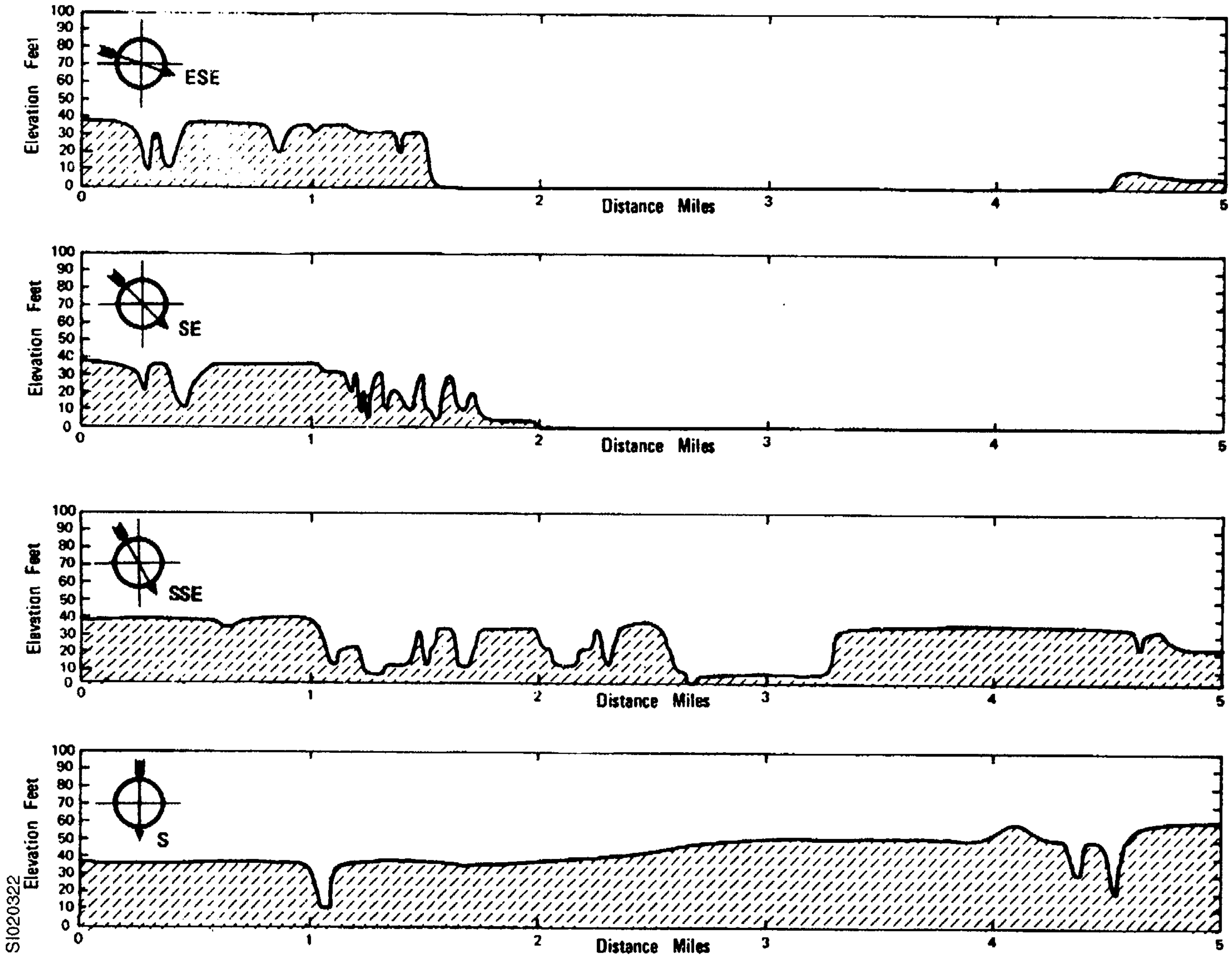


Figure 2.3-23
SURRY POWER STATION; TOPOGRAPHIC CROSS SECTIONS; (0-5 MILES FROM SURRY POWER STATION)

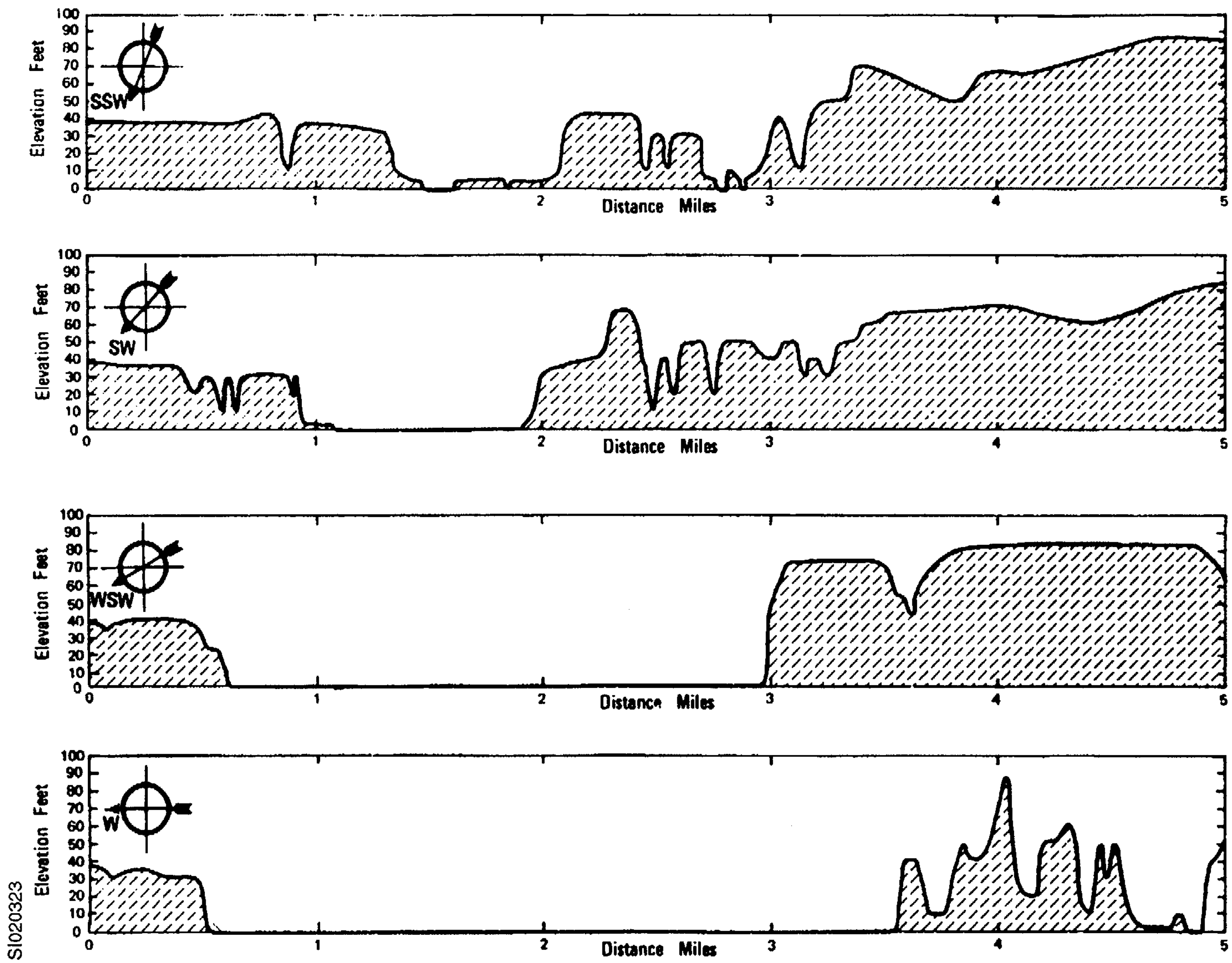


Figure 2.3-24
SURRY POWER STATION; TOPOGRAPHIC CROSS SECTIONS; (0-5 MILES FROM SURRY POWER STATION)

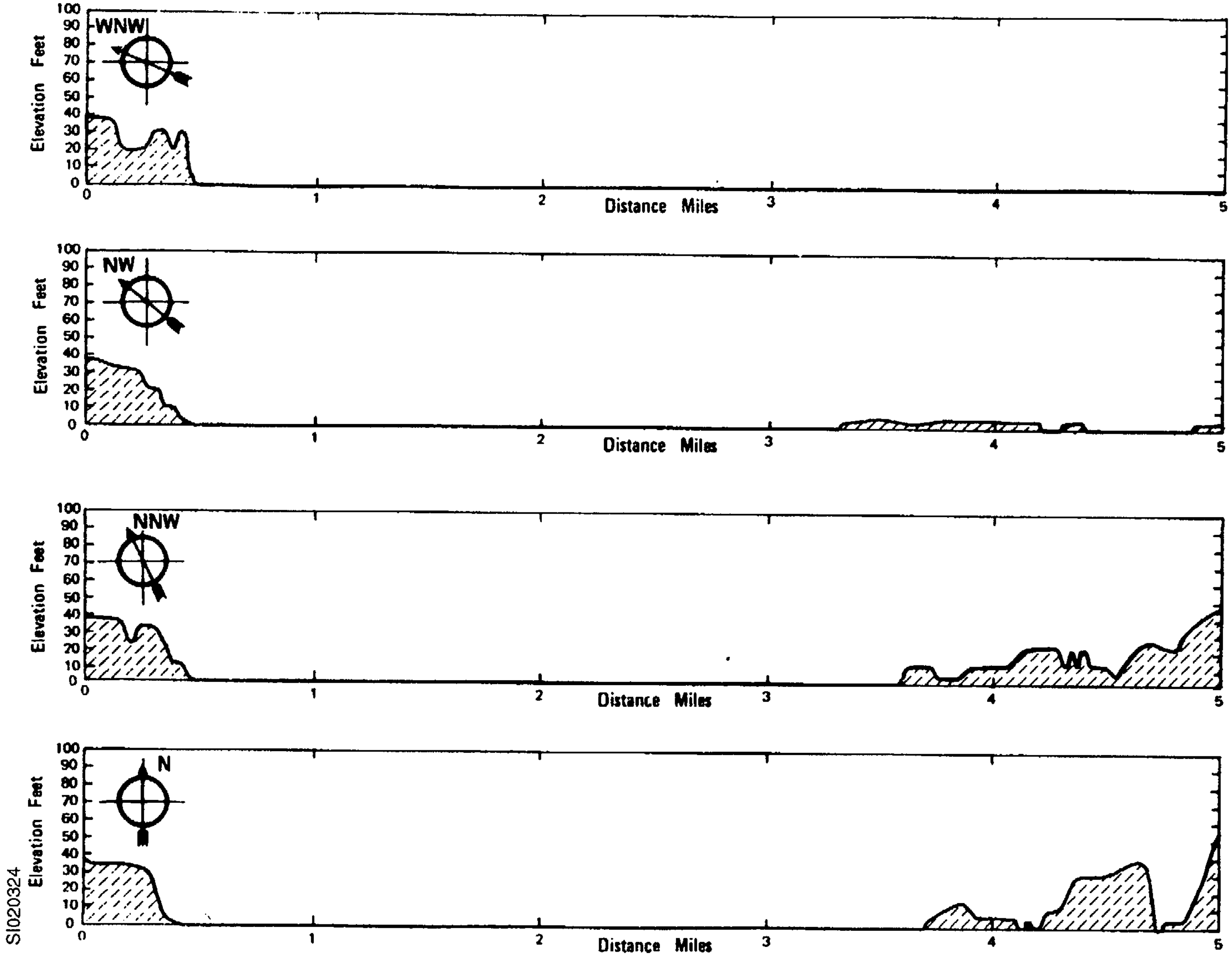


Figure 2.3-25
GENERAL TOPOGRAPHY; (5 MILES RADIUS OF THE SURRY POWER STATION)

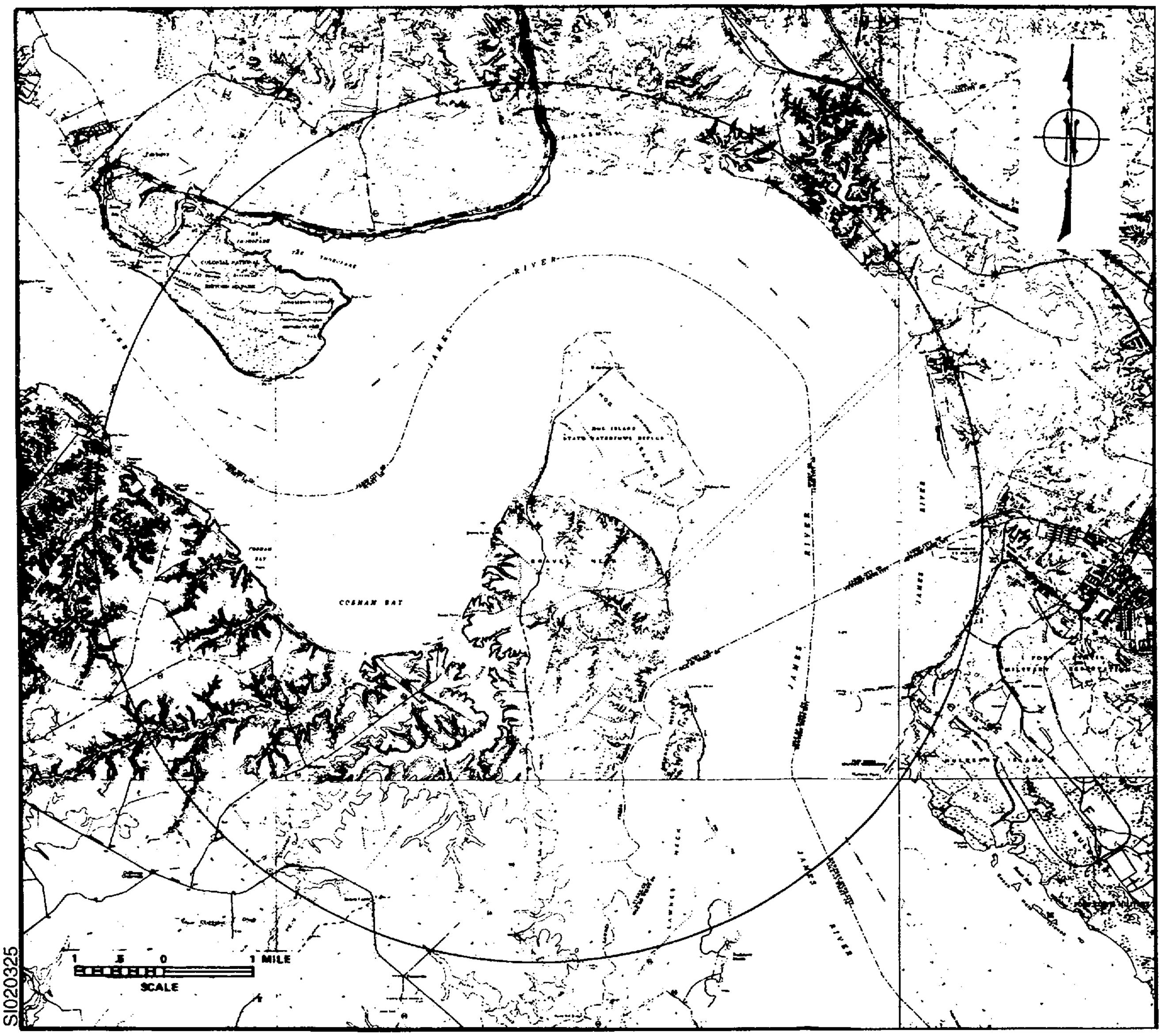


Figure 2.3-26
GENERAL TOPOGRAPHY; (50 MILES RADIUS OF THE SURRY POWER STATION)

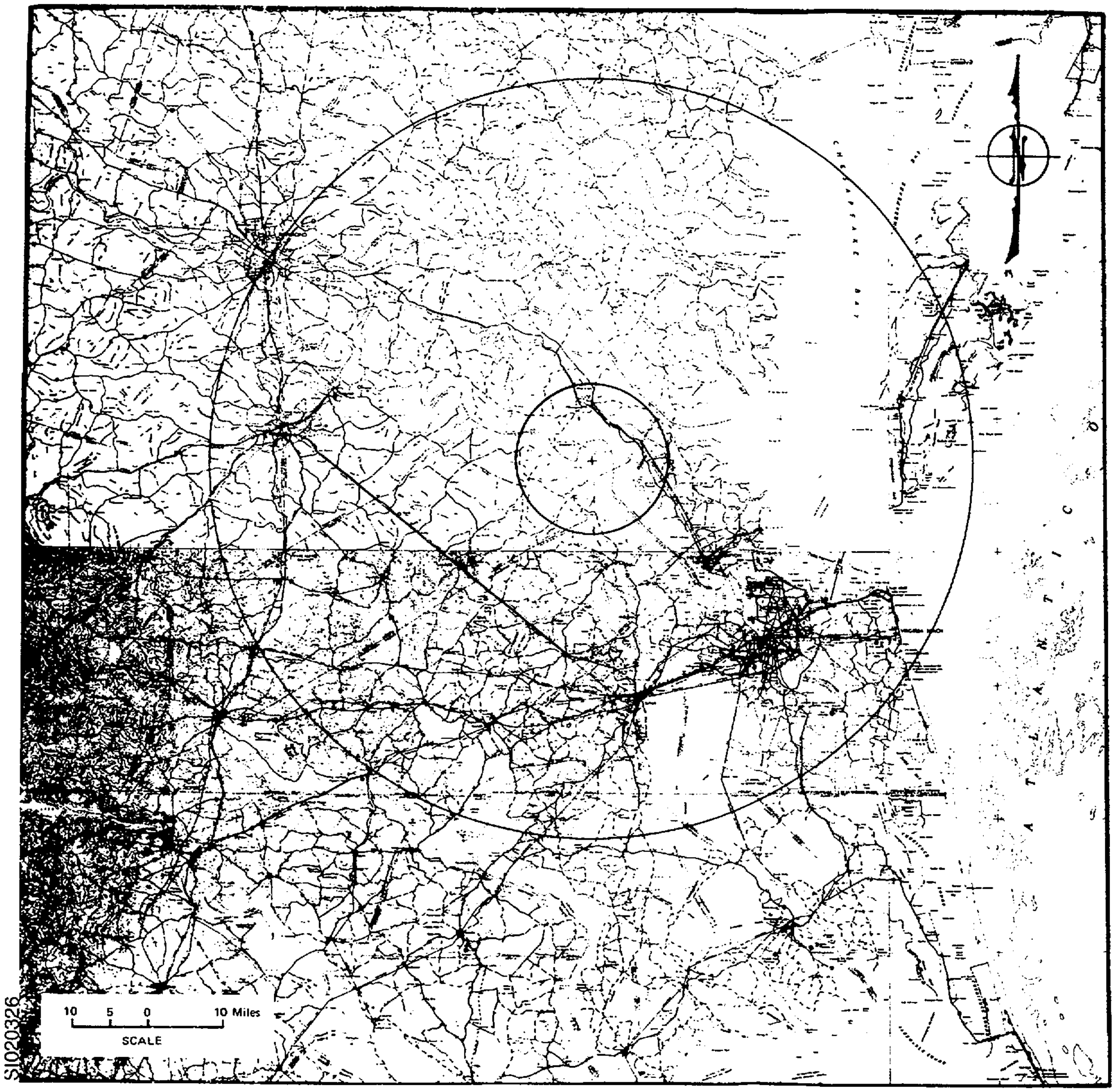


Figure 2.3-27
LOCATIONS OF METEOROLOGICAL TOWERS
SURRY POWER STATION

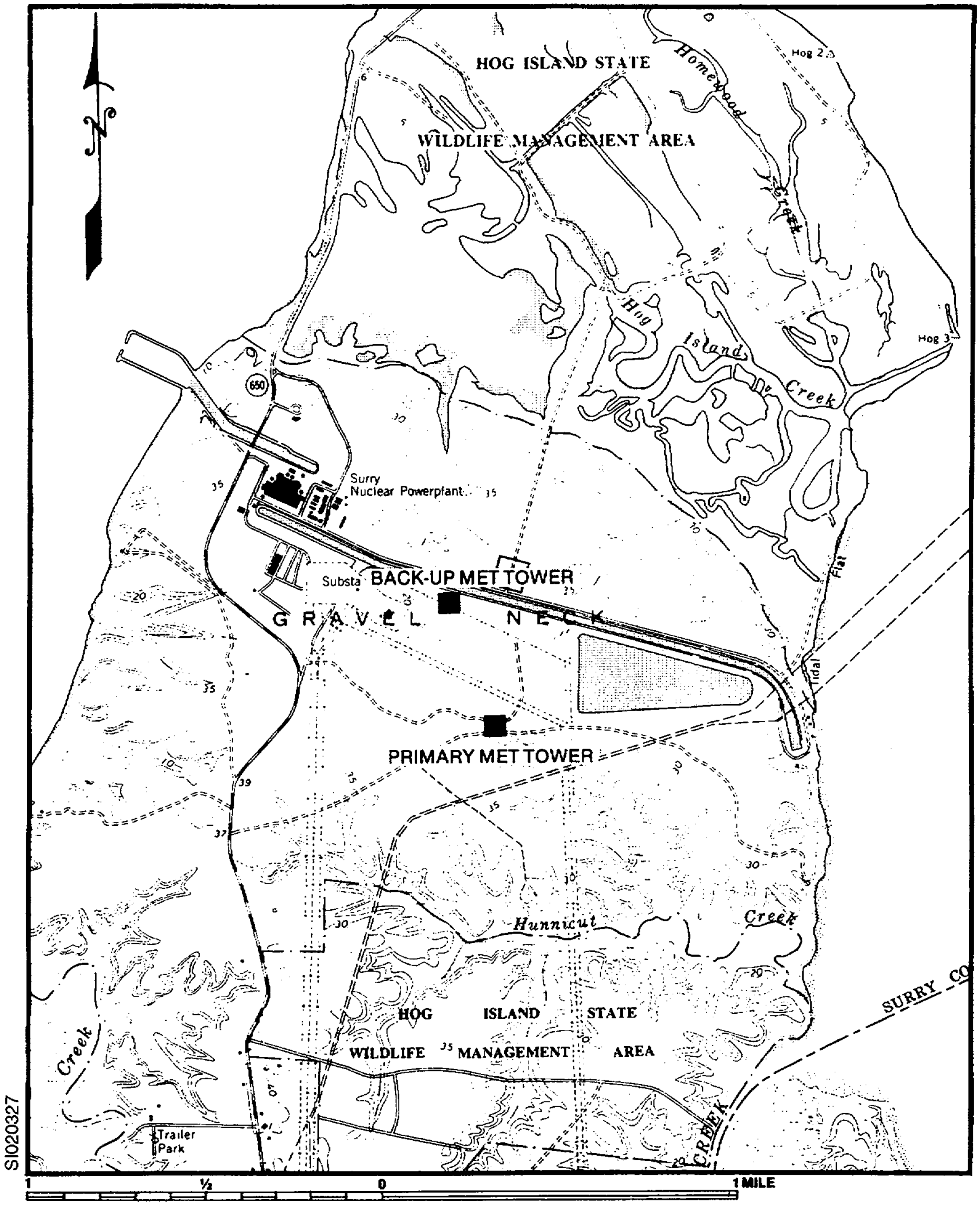
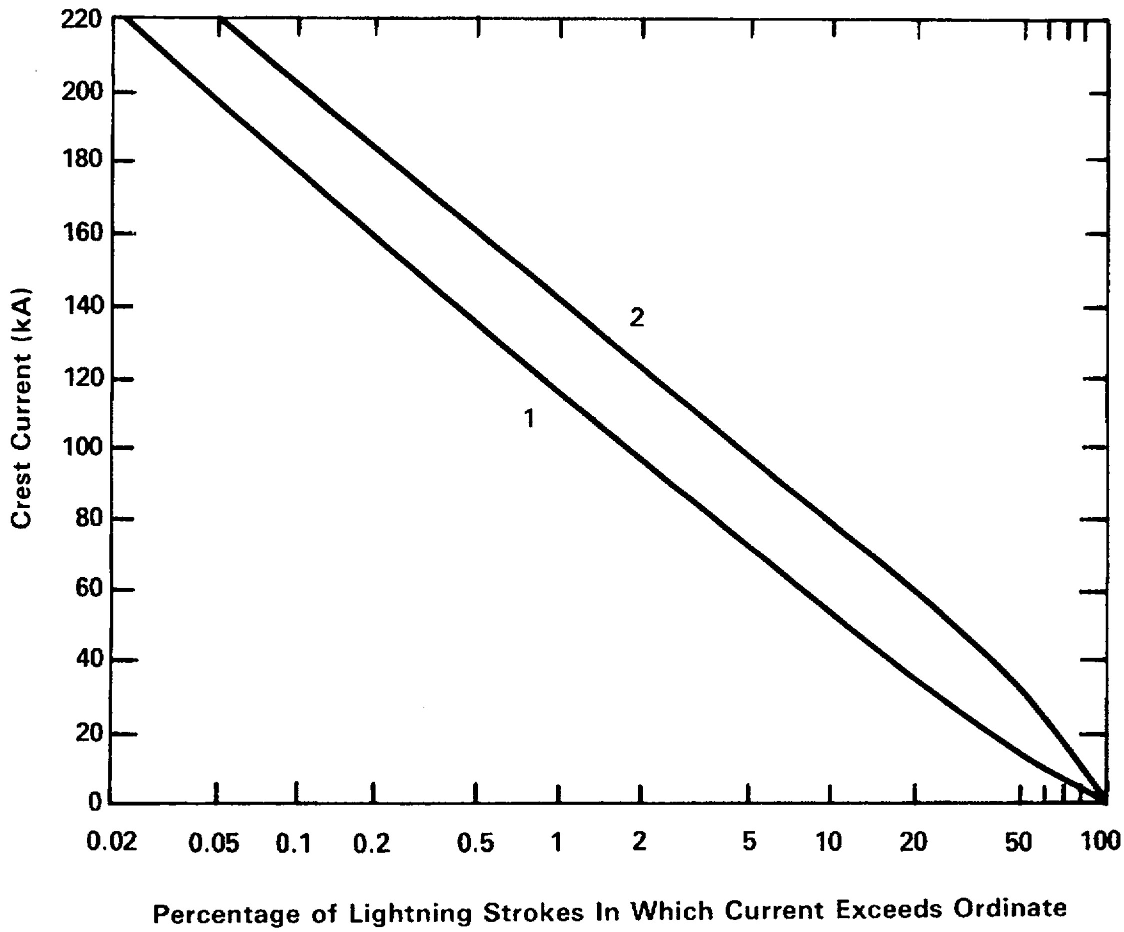


Figure 2.3-28
DISTRIBUTION OF CREST CURRENTS IN LIGHTNING STROKES (REF. 28)



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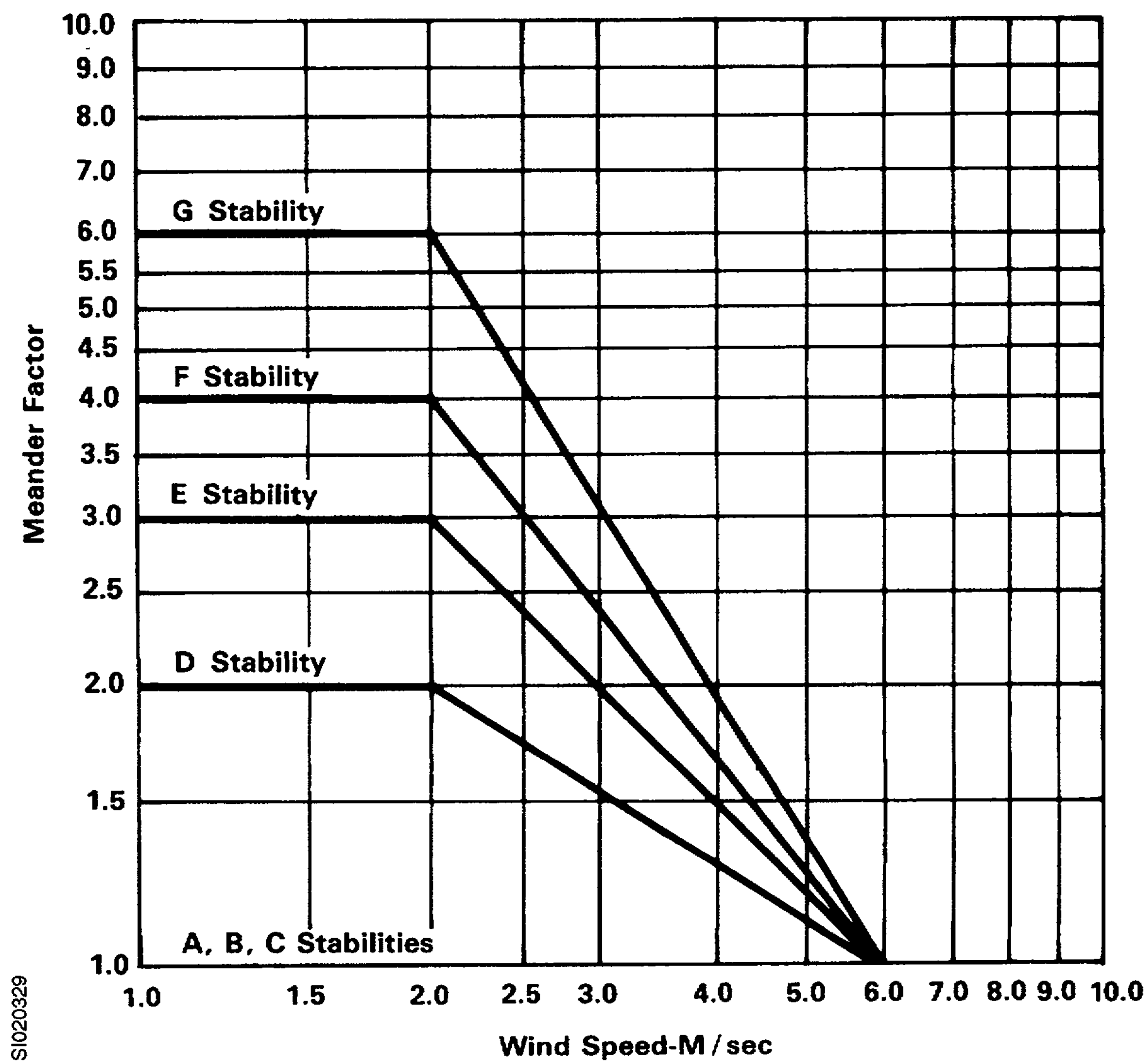
Curve 1: currents in strokes to transmission line ground structures; based on 4410 measurements, 2721 in the United States and 1689 in Europe.

Curve 2: currents in strokes to buried structures, derived from Curve 1.

Figure 2.3-29
MEANDER FACTOR VERSUS WIND SPEED



2.4 SURFACE HYDROLOGY

The data and analyses in this section were obtained from the material presented in the PSAR for the Surry Power Station Units 3 and 4 and the FSAR for Surry Power Station Units 1 and 2. In addition, hydrologic data for the period from 1971 to 1981 were also reviewed. No severe event occurred which would affect the maximum flood level at the site as described in the FSAR and PSAR.

2.4.1 Hydrologic Description

2.4.1.1 Site and Structures

The Surry ISFSI is located within the Surry site in Surry County, Virginia. The site comprises 840 acres on Gravel Neck peninsula, which is bordered by the James River to the east, west, and north, as shown on Figure 2.4-1. The Hog Island State Waterfowl Refuge is located immediately north of the site. The site is about 40 miles west of the Atlantic Ocean.

The site grade for the ISFSI is at 35 feet msl at Hampton Roads, Virginia. The grade for the slabs will be approximately 36 feet msl. The surrounding surface slopes down to the river to the north and is bordered by the cooling canal dike to the south. Site grade is well above the maximum flood level, including wave runup, as discussed in Section 2.4.5.

2.4.1.2 Hydrosphere

Regional topography and characteristics are shown on Figure 2.4-2. The general hydrologic characteristics of the area, as stated in the PSAR, are as follows:

Much of the region is characterized by marshes, extensive swamps, small streams, and pocosins. Water tables are very near the surface throughout the entire area, accounting for the large amount of surface waters. Drainage throughout the area is toward Hampton Roads, near the mouth of Chesapeake Bay, and on to the Atlantic Ocean.

The James River is formed by the junction of the Cowpasture and Jackson Rivers in Botetourt County, Virginia, and flows easterly 340 miles before emptying into Hampton Roads at Newport News, Virginia.

The flow of water in the James River at the site is composed of three components:

1. Fresh water discharge from the James River watershed.
2. Flow due to the oscillatory ebb and flood of the tide.
3. Flow due to the circulation pattern caused by intrusion of saline water within the estuary.

The drainage area of the James River above the station site is 9517 square miles. The drainage area above the nearest gage on the main stem of the James River near Richmond is 6757 square miles. An additional 1638 square miles of drainage area on tributaries between Richmond and the plant site is gaged, leaving 1122 square miles ungaged. Discharge records for

the gaged tributaries below Richmond were used to estimate the discharge from the ungaged areas, and the total mean monthly discharge for each month of the period October 1934 to September 1971 was computed by summing the discharges from the gaged and ungaged watershed areas. These data are shown in Table 2.4-1.

The 85-mile stretch of the James River between Richmond and the mouth of the river is subjected to tidal motion and is hence a tidal estuary. The location of the site is in the transition region between the fresh water tidal river and the saline waters of the estuary proper. At a river discharge of about 10,000 cfs, the upstream portion of the site is in the fresh water river and the salinity at the downstream side of the site is about 1 part per thousand. For river discharges less than 10,000 cfs (a condition occurring approximately 60 percent of the time), the water on both the upstream and downstream sides of the site will have varying concentrations of ocean-derived salts, dependent on river discharge.

The tide in the James River is a semidiurnal tide, with two high waters and two low water's each lunar day of 24.84 hours. The oscillatory ebb and flood of this tide constitute the dominant motion in the waterway in the vicinity of the site. The net downstream flow required to discharge the fresh water seaward through any waterway cross section represents but a small fraction of the tidal flows.

The United States Coast and Geodetic Survey (USC&GS) tidal current tables (Reference 1) show that the ebb current is longer and stronger than the flood current at the site. The average of maximum ebb currents is 1.3 knots (2.2 feet per second) and the average of maximum flood currents is 1.1 knots (1.9 feet per second). During spring tides, the ebb currents reach a maximum of 1.9 knots (3.2 feet per second) and the flood currents a maximum of 1.6 knots (2.8 feet per second). During the typical tide period of 12 hours and 25 minutes, the current on the average will ebb for 7 hours and 5 minutes and flood for 5 hours and 20 minutes. It should be noted that the data used to compile the USC&GS tables are based on near surface observations made during periods of normal river discharge, and therefore, do not reflect meteorological effects. The predominance of ebb flow over flood flow will decrease with decreasing river discharge.

Within the estuary proper, the salinity decreases in a more or less uniform manner from the mouth toward the head and at any location increases with depth. Superimposed upon the oscillatory tide, there is a net nontidal circulation in which the upper, less saline layers of water move seaward, while the deeper, more saline layers of water move up the estuary. The net nontidal seaward direction flow is stronger and, in the vicinity of the site, extends to greater depths on the southern side of the estuary (looking downstream) then on the northern side. At times, the boundary between these two counterflows becomes strongly sloped so that the seaward flow extends to all depths on the south side of the estuary and the flow direction up the estuary occurs from bottom to surface on the north side of the estuary.

The volume rate of flow associated with this net nontidal circulation pattern, while small compared to the oscillatory tidal flows, is several times larger than the volume rate of river

discharge. In general, the higher the salinity the larger the ratio of the volume rate of seaward flow in the surface layers to the fresh water discharge. Consequently, since the salinity at any given location increases with decreasing river discharge, the volume rate of flow associated with the net nontidal circulation does not decrease with respect to the river discharge.

There are no known or planned river control structures on the James River. Several small impoundments on tributaries in the upper reaches do exist, however, their size and location would preclude any effect or danger to the safety related structures at the station.

There are no known municipal users of the James River water from the city of Hopewell downstream. The reason for this is that the middle reaches of the river are relatively underdeveloped and the river becomes increasingly saline as one travels downstream thereby precluding its use as a source of municipal water. Likewise, there are no known irrigation diversions.

Industrial users of significance in the area at the present time are limited to the Dow Badische Company which discharges process water into Skiffes Creek, a tributary of the James River, across the river from the station intakes and the Newport News Shipbuilding and Dry Dock Company which withdraws 17 million gallons per day from the river. The city of Newport News withdraws 27 million gallons per day from the Chickahominy River, an upstream tributary of the James.

A compilation of surface water users is contained in Section 2.1.3 of the Environmental Report. Section 2.5 of this SAR contains a compilation of ground water users.

2.4.2 Floods

2.4.2.1 Flood History

The sources of flooding in the James River at the site are (1) flood discharges due to watershed runoff and (2) surge due to severe storms. Since there is no gaging station located near the site, historical records of peak water level and discharge at the site are unavailable. However, peak discharges have been estimated for the James River at the site as described in the PSAR. Additionally, the predicted maximum storm surge due to a probable maximum hurricane (PMH) at the site is described in Section 2.4.5.

As described in the PSAR for Units 3 and 4, river discharge data for the period of record from 1935 to 1971 were collected and analyzed (Table 2.4-1). Statistical analysis of these data was performed and the results are given in Table 2.4-2. Flood discharges for the various recurrence intervals for the James River near Richmond, Virginia, are presented in Table 2.4-3.

The peak flood discharge at Richmond, Virginia during the period from 1935 to 1979 occurred in June 1972 due to the excessive rainfall during Hurricane Agnes. Flood levels reported for Richmond were 4 to 5 feet higher than those recorded during the previous flood of record.

However, due to the wide flood plain at the site, the rise above normal water levels was relatively minor even during this severe flood.

2.4.2.2 Flood Design Considerations

The ISFSI is located at elevation 35 feet msl which is entirely above the maximum flood level of 28.2 feet msl. The level was calculated based on the storm surge due to a PMH at the site plus coincident wave runup. This analysis is described in Section 2.4.5.

2.4.2.3 Effects of Local Intense Precipitation

The ISFSI is at a higher grade than the surrounding area as shown on Figure 2.4-3. Runoff from local intense precipitation will travel by overland flow away from the ISFSI and drain to the James River via two natural creeks located to the east and to the west of the ISFSI. Swales will be provided, as necessary, to direct runoff towards the natural drainage pattern. Thus, the effect of local intense precipitation will not cause flooding at the ISFSI.

Snow and ice loads are precluded at the ISFSI because there are no roofs associated with the installation where snow and ice may accumulate.

2.4.3 Probable Maximum Flood on Streams and Rivers

Based on information presented in the FSAR and the PSAR, The probable maximum flood on the James River at the site, as defined by the Corps of Engineers, will not produce the highest flood elevations at the site. This condition is applicable to the ISFSI since it is located near the site of the proposed Units 3 and 4 at a grade of 35 feet msl.

2.4.4 Potential Dam Failures (Seismically Induced)

As stated in the PSAR, "there are no dams existing or proposed on the James River whose failure would have any measurable effect on safety related systems and facilities at the station." Thus, the ISFSI is unaffected by flood levels due to seismically induced dam failures.

2.4.5 Probable Maximum Surge and Seiche Flooding

An analysis of the PMH at the power station site is presented in the FSAR and PSAR. This analysis is summarized in the following sections.

2.4.5.1 Probable Maximum Surge and Associated Meteorological Parameters

The PMH was chosen as the most severe meteorological event at the site. The analysis to predict the magnitude of hurricane surge in the James River near the site during the PMH was

performed using methods and data contained in HUR 7-97 (Reference 2). PMH characteristics for latitude 37 are summarized as follows:

Central pressure index, inches Hg	26.97
Radius of maximum winds, nautical miles	35
Forward speed of translation, knots	22
Maximum wind speed, mph	135.4

Using these parameters the maximum water level in the James River at the site during the PMH was calculated to be 22.3 feet msl (Section 2.4.5.3).

2.4.5.2 **Surge and Seiche History**

The site is located approximately 32 nautical miles upstream of the confluence of the James and York Rivers and approximately 40 nautical miles from the mouth of Chesapeake Bay where it enters the Atlantic Ocean.

The highest water level recorded at Norfolk, Virginia in 100 years of record occurred in August 1933 and reached 8.6 feet msl.

Table 2.4-4 shows the estimated tidal recurrence interval at Old Point Comfort, near the mouth of the James River.

Based on a review of data for the period from 1971 to the present, there were no significant high water levels due to storm surge in this area. The two most severe storms, Hurricane Agnes in 1972 and Hurricane David in 1979, had both been classified tropical storms by the time they reached Virginia. Neither of these two hurricanes produced a large storm surge at the Virginia coast.

2.4.5.3 **Surge and Seiche Sources**

Open coast surge during the PMH was calculated at the entrance to the Chesapeake Bay using methods based on the Bathystropic Storm Tide theory as described in References 3 and 4. The components of the maximum still water level based on this calculation are shown in Table 2.4-5.

The storm surge was then routed through the Chesapeake Bay and on up the James River to the site using methods presented in Reference 2. The maximum calculated storm surge elevation at the power station is 22.3 feet msl.

2.4.5.4 Wave Action

Wave heights, periods, and lengths during the PMH were calculated using methods presented in Reference 5. The data used and calculated wave parameters are as follows:

Fetch, nm	3.0
Wind Speed, mph	120.5
Depth, ft	46.6
Wave Height, ft	9.7
Wave Length, ft	159.0
Wave Period, sec	5.6

2.4.5.5 Resonance

The ISFSI is not located adjacent to the James River and there is no other body of water which may experience high water levels due to resonance. Thus, resonance effects are not applicable to this installation.

2.4.5.6 Runup

Wave runup was calculated using the methods in Reference 5 for a 1V on 5H slope. Values of 8.24 feet for smooth slopes and 3.60 feet for rubble slopes were calculated. Since the slopes of the James River in this area consist of surfaces having a roughness between those of smooth and rubble, an average value of runup of 5.9 feet was taken. Consequently, the maximum runup elevation is 28.2 feet msl, consisting of a 22.3 feet msl still water level and 5.9 feet runup. This level is well below the ISFSI grade of 35 feet msl.

2.4.5.7 Protective Structures

Since the ISFSI grade is above the maximum flood level, no special protective structures are required.

2.4.6 Probable Maximum Tsunami Flooding

Based on information given in the PSAR, the site is protected from the effects of tsunami which might strike the coast. Thus, the ISFSI is similarly protected from flooding due to the tsunami.

2.4.7 Ice Flooding

It is highly unlikely that the formation of ice on the James River would obstruct the flow and cause flooding, due to the salinity of the river below the site. Thus, ice flooding is precluded as a source of flooding at the site.

2.4.8 Flooding Protection Requirements

The ISFSI is situated well above the maximum water level in the James River during a PMH with associated wind-wave activity. Flooding from onsite water supplies is precluded since those water levels are below the ISFSI grade. Runoff from local intense precipitation will drain away from the ISFSI via two natural creeks situated to the east and west of the installation. Hence, flood protection for the ISFSI is not required.

2.4.9 Environmental Acceptance of Effluents

There are no liquid releases that could result from operation of the Surry ISFSI. Therefore, this section is not applicable.

2.4.10 References

1. Tidal Current Tables - Atlantic Coast of North America, Published yearly by U.S. Department of Commerce, Coast and Geodetic Survey.
2. Interim Report, *Meteorological Characteristics of the Probable Maximum Hurricane, Atlantic and Gulf Coasts of the United States,* HUR 7-97, Hydrometeorological Branch, Weather Bureau.
3. Bretschneider, C. L. and J. I. Collings, *Prediction of Hurricane Surge, An Investigation for Corpus Christi, Texas and Vicinity,* NESCO Technical Report No. SN-120, prepared by National Engineering Science Co. for U.S. Army Engineering District, Galveston, Texas, 1963.
4. Marinos, George and Jerry W. Woodward, Estimation of Hurricane Surge Hydrographs, *Journal of Waterways and Harbors Division,* ASCE, Vol. 94, No. WW2, May 1968, pp 189-215.
5. *Shore Protection Planning and Design Technical Report No. 4,* U.S. Army Coastal Engineering Research Center, Dept. of the Army Corps of Engineers, U.S. Government Printing Office, Washington, D.C., Third Edition, 1966.
6. State Water Control Board, Commonwealth of Virginia, *Flood Frequency Data for the James River Near Richmond, Virginia,* Gage No. 20375, 1935-1979.

Table 2.4-1 (SHEET 1 OF 2)

MEAN MONTHLY DISCHARGE IN CFS - JAMES RIVER AT STATION SITE

FOR WATER YEARS 1935 THROUGH 1971

(i.e., October 1934 through September 1971)

Note: Total drainage area is 9517 square miles, of which 8395 square miles is gaged. Figures in this table include estimates of the runoff for the 1122 square miles of ungaged drainage area.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	YEAR (AVG.)
1935	5191	5011	20,951	22,488	14,827	20,490	32,045	8304	7830	6402	5298	19,092	13,965
1936	3145	8324	10,336	39,778	25,806	34,620	20,763	6702	4631	2849	3154	2157	13,504
1937	5711	2765	9137	36,185	19,862	10,693	27,926	13,040	6674	5289	9281	10,836	13,331
1938	24,819	11,887	8764	12,364	9991	13,118	9179	6437	15,797	17,190	12,997	3581	12,217
1939	2914	4934	9071	8997	26,181	19,751	10,359	5953	4666	7200	9128	3005	9247
1940	3096	4911	3552	5544	18,319	9215	18,959	10,018	16,688	7203	34,397	7616	11,559
1941	3447	7722	7832	11,332	6493	9135	22,105	3919	3527	8708	1971	1258	6537
1942	857	1415	3828	4510	6329	9306	5227	13,840	8358	3896	15,167	4836	6501
1943	18,256	7319	12,771	14,106	21,118	17,614	14,073	11,788	7860	6649	2073	1508	11,221
1944	1436	2971	2659	6547	10,068	25,264	14,366	9823	3221	2312	2972	18,310	8053
1945	7251	4645	9886	13,750	12,804	12,297	8909	10,432	4178	10,654	4616	12,058	9280
1946	4294	5330	14,988	19,225	18,498	13,666	10,892	19,707	8209	6974	3846	2744	10,676
1947	2890	3455	4224	17,046	6243	15,376	13,026	6250	5107	4614	2686	3883	7082
1948	4804	14,363	6476	9311	21,776	21,299	25,582	14,626	7700	4667	12,522	3051	12,124
1949	7967	13,880	34,608	26,306	19,211	16,643	17,181	15,402	8626	13,777	9774	6254	15,814
1950	4734	13,681	8509	7858	17,805	13,292	7655	15,239	8790	6295	3895	13,268	10,012
1951	5073	4843	17,373	7512	17,023	15,945	21,682	8258	13,726	5190	3246	2419	10,165
1952	1827	5862	14,255	20,225	19,364	26,030	18,012	14,376	4884	4090	5870	6439	11,760
1953	2759	10,568	8983	16,907	17,642	24,795	14,829	10,005	5264	2842	1753	1618	9785

Table 2.4-1 (SHEET 2 OF 2)
MEAN MONTHLY DISCHARGE IN CFS - JAMES RIVER AT STATION SITE
FOR WATER YEARS 1935 THROUGH 1971
(i.e., October 1934 through September 1971)

Note: Total drainage area is 9517 square miles, of which 8395 square miles is gaged. Figures in this table include estimates of the runoff for the 1122 square miles of ungaged drainage area.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	YEAR (AVG.)
1954	1483	2203	5868	9705	7580	15,852	10,258	10,487	4231	2631	1486	954	6066
1955	5197	6395	9880	8058	12,374	25,728	12,307	5252	4733	3335	20,886	4665	9996
1956	5551	3459	2867	2992	11,632	10,921	11,667	4617	4176	3175	2259	2260	5342
1957	4270	8815	7461	7928	22,606	16,307	18,739	6662	6310	2116	1591	5050	8872
1958	4659	8761	17,261	16,549	17,213	20,480	26,168	20,890	6557	4537	6597	2652	12,675
1959	2897	2949	6019	9769	6379	8496	18,616	6081	7729	4543	3874	2791	6665
1960	10,816	9065	11,290	10,307	23,161	17,069	25,301	14,660	7471	2971	4371	6735	11,870
1961	3169	3113	3700	5533	21,475	16,639	19,391	14,579	10,072	4955	4776	4125	9194
1962	15,220	7049	20,882	19,484	15,443	32,186	22,042	9135	9339	6809	3624	2621	13,677
1963	2552	8733	5498	13,541	9076	31,513	6740	4762	4410	1690	1139	1037	7567
1964	1133	2662	4340	14,509	16,992	15,649	9580	5522	2179	2071	1421	1630	6437
1965	2834	3106	6777	11,066	18,268	18,779	11,588	6452	3123	2521	1492	1433	7223
1966	2136	1687	1592	2233	15,165	11,597	4677	9696	3184	911	1350	3857	4840
1967	8731	4397	6400	11,895	10,158	22,175	5977	8725	4058	2543	6881	2446	7866
1968	3454	2952	14,853	13,486	9779	14,602	6415	7101	6025	2268	1990	1091	6963
1969	2549	5139	3594	6928	8806	14,861	7638	5152	5021	8309	25,543	3777	8109
1970	3148	3048	7199	14,249	15,710	9503	14,935	7435	2309	2725	2497	1073	6986
1971	1211	11,674	6339	10,268	23,950	13,404	12,290	18,062	19,724	3884	4366	5001	10,847

(Source: Surry PSAR)

Table 2.4-2
DURATION DATA
MONTHLY MEAN DISCHARGE - FRESH WATER
JAMES RIVER AT SURRY SITE

Mean Discharge cfs	Percent of Months Mean Discharge is Equalled or Exceeded
857	100
2660	90
4370	75
7860	50
14,366	25
20,225	10

Mean of mean monthly discharges - 9952 cfs
Maximum mean monthly discharges - 39,778 cfs, January, 1936
(Source: Surry PSAR)

Table 2.4-3
MAGNITUDE AND FREQUENCY OF FLOOD DISCHARGES
ON THE JAMES RIVER NEAR RICHMOND, VA.
(FOR THE PERIOD OF RECORD 1935-1979)

Recurrence Interval, (Years)	Discharge cfs
1.1	38,900
2	71,400
5	118,000
10	159,000
20	206,000
50	284,000
100	355,000

(Source: Reference 6)

Table 2.4-4
ESTIMATED TIDAL RECURRENCE INTERVAL AT OLD POINT COMFORT

Recurrence Interval, Years	Maximum Tide Level, feet msl
1	3.9
5	5.1
10	5.8
25	6.9
50	7.8
100	8.5

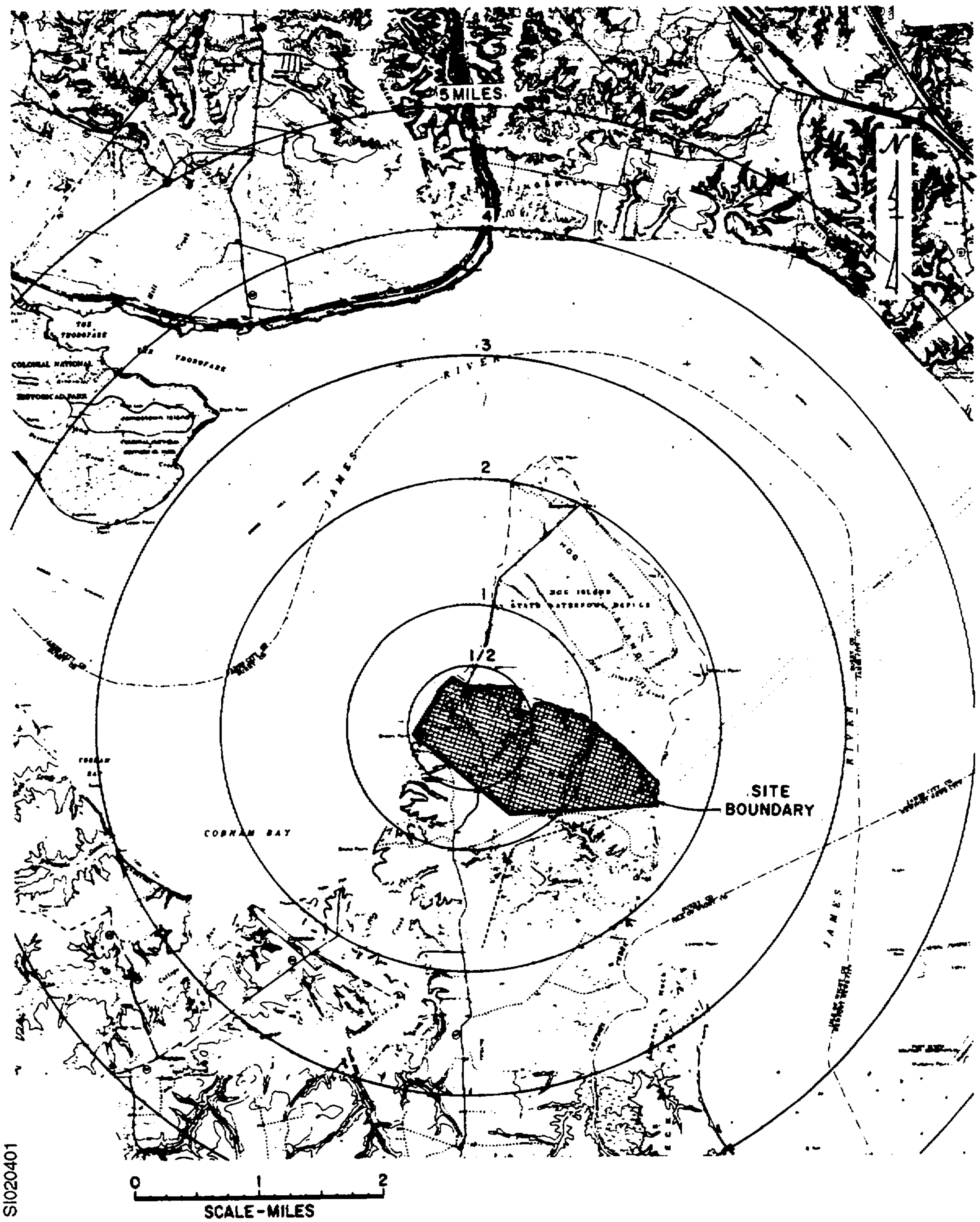
(Source: Surry PSAR)

Table 2.4-5
COMPONENTS OF MAXIMUM STILL WATER LEVEL

	Surge, feet
Atmospheric pressure reduction	2.72
Alongshore component	13.27
Onshore component	4.24
Open coast surge (Subtotal)	20.33
Astronomical tide	3.40
Initial rise	0.50
Open coast still water level	24.23
	22.93 msl

(Source: Surry PSAR)

Figure 2.4-1
LOCAL TOPOGRAPHY



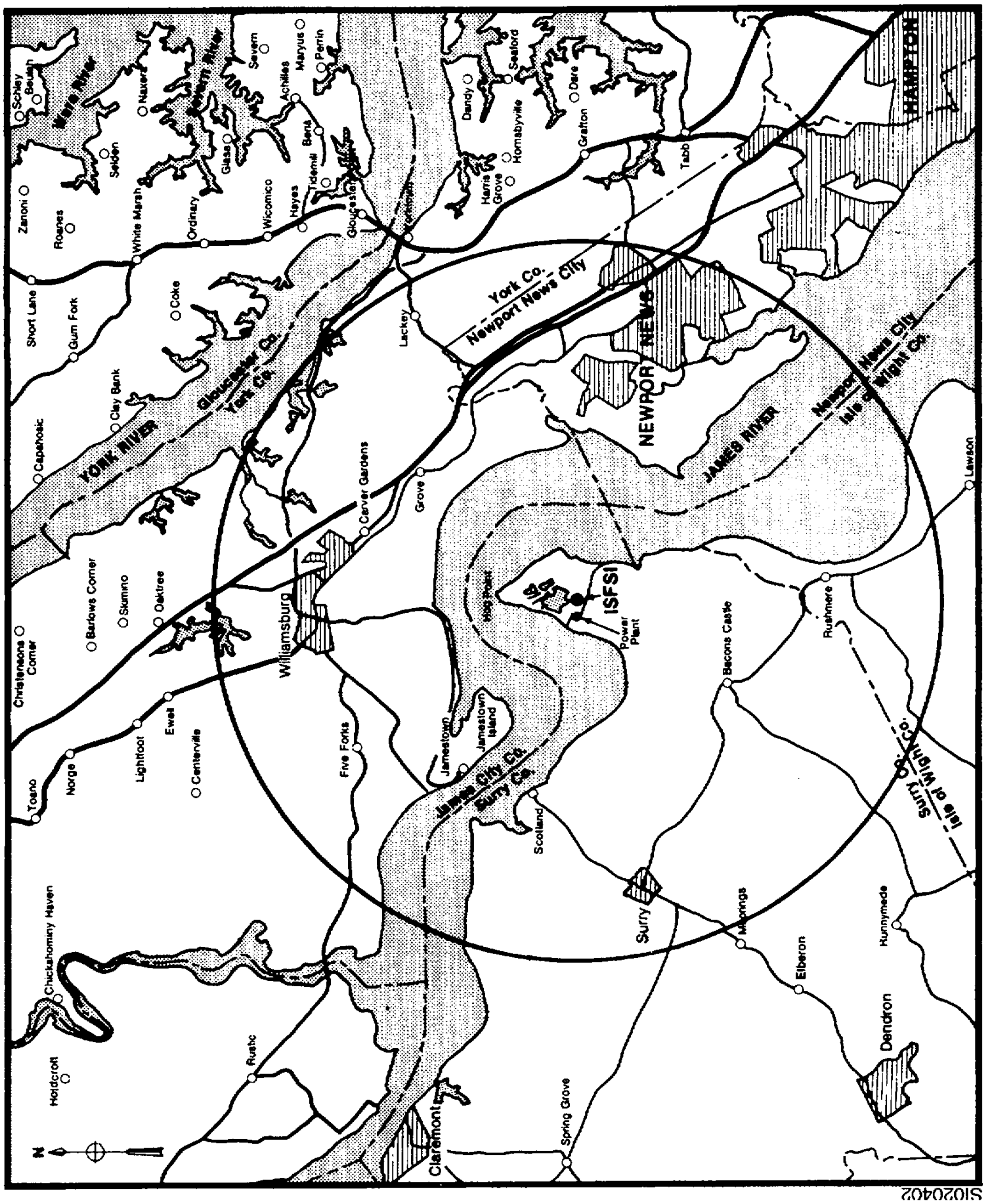


Figure 2.4-2
REGIONAL TOPOGRAPHY

2.5 SUBSURFACE HYDROLOGY

2.5.1 Regional and Site Characteristics

The hydrologic boundaries of the Surry site proper are the James River on the east and west, Hog Island Creek to the north, and Chippokes and Hunnicut Creeks about 1 mile to the south.

Precipitation data pertaining to the site are contained in Section 2.3. A water budget analysis indicates in general that, of the total precipitation, about one-third of the precipitation runs off and the remaining two-thirds is lost through evapotranspiration. Low soil permeabilities preclude any significant ground water recharge from local precipitation.

The soils in the site area, as described in Section 2.6, consist of a series (50 to 80-feet thick) of lenticularly interbedded fine sands, clays, and silts. These clay and silt members are essentially impermeable and the sand member showed field permeabilities on the order of 1×10^{-4} cm per sec. Eleven shallow wells within a 5-mile radius of the site obtain small supplies of water for domestic purposes from these sands.

The above deposits are underlain by 240 to 270 feet of tough impermeable clay containing only occasional and limited sand members. At a depth of about 320 feet below the surface, Eocene and older sediments are encountered. The sand members of these sediments are excellent aquifers, with many domestic wells and some industrial wells in the area obtaining water supplies from this source. In general, yields range from 15 to 50 gpm; however, a well 799 feet deep at Bacon's Castle, about 5-miles to the south, yielded under test 940 gpm with only 20.25 feet of drawdown.

In addition to the 340-foot-deep well on the State Waterfowl Refuge, which existed prior to station construction, there are five operating water wells on the site property that were constructed to serve several purposes. These wells are about 400 feet deep and obtain water from the Eocene sediments. Two of these wells yield 200 gpm each and are for makeup and domestic uses at the station. A separate well having a 120 gpm pump supplies the Training Center.

The closest offsite deep wells are located on the State Waterfowl Refuge about 1 mile north of the site and at Drewry Point, approximately 0.6 miles southwest. Both wells are approximately 340 feet deep and have a yield of about 35 gpm. The well at Drewry Point is not in full time use since it serves a vacation cottage.

The closest shallow well in use is about 50 feet deep and is located 2.3 miles south of Surry Power Station Units 1 and 2. It supplies domestic water to a private residence. There is an abandoned shallow well near the south property line.

The hydraulic gradient is north, east, and west toward the James River. Both the deep well at Drewry Point and the shallow well south of the site are upgradient from the site. The deep well on the State Waterfowl Refuge is downgradient from the site; however, it is not affected by water flow from the site. Based on the results of borings, the general geology of the area, and the

location of the site, the coefficient of permeability of the soil mass in a horizontal direction is estimated to be several orders of magnitude greater than in the vertical direction. Water that does enter the soil will move laterally to the east, north, or west and discharge to the James River.

Water quality analyses at Surry Power Station Units 1 and 2 show a chloride concentration ranging from 33 to 49 ppm. In general, the quality of water from the lower aquifers is good except very near the coast or where the potentiometric levels have dropped significantly below mean seal level.

Due to the isolated location of the plant site (James River on north, east, and west sides, and a game refuge on the south site), no substantial industrial or residential development is anticipated in the immediate vicinity of the plant site. Therefore, no additional demand of a substantial nature upon the ground water supply is expected.

No significant use of ground water is anticipated during the operation of the Surry ISFSI.

Ground water is also discussed in Sections 2.6.1.9 and 2.6.4.6 of this SAR.

2.5.2 Containment Transport Analysis

The nature of the material stored (spent fuel rod assemblies) and the method of storage (dry storage casks) preclude the possibility of a liquid containment spill. Therefore, discussion of potential contamination of the ground water is not applicable.

2.6 GEOLOGY AND SEISMOLOGY

2.6.1 Basic Geologic and Seismic Information

The data presented herein are compiled from the Surry Power Station Units 3 and 4 PSAR (Reference 1), and the Surry Power Station, Units 1 and 2 FSAR (Reference 2).

The Surry site is located upon Gravel Neck, a land peninsula form surrounded by a large U-shaped bend in the James River, and is located approximately 5 miles north-northeast of Bacon's Castle, Virginia. The site location is illustrated from a regional setting on Figure 2.6-1 and is seen in greater detail on Figure 2.6-2. The peninsula at the location of the site is approximately 2 miles wide and consists of a relatively uniform land surface at about elevation +30 msl with occasional incised erosional stream features about 10 to 15 feet deep. The site lies within a gradually subsiding area of the Coastal Plain physiographic province. The region is characterized by estuaries in a drowned coastline resulting from sediment load and the post-glacial rise of sea level.

The subsurface profile within the site area consists of a series of soil deposits containing marine and continental sediments which are approximately 1300 feet deep and overlying crystalline bedrock. The upper portion of these soil deposits, extending from ground surface to approximately elevation -8, are Pleistocene sediments and consist of contemporaneously bedded sands, silts, and clays. A buried erosional feature at approximately elevation -8 forms the upper

boundary of the Miocene formation, a sandy clay material deposited in marine waters and consolidated under stresses which exceed those imposed by the existing site overburden. The Miocene sandy clays are in turn underlain by deep deposits of dense sand and stiff clay overlying crystalline and sedimentary rock.

The site is in an area of sparse seismic activity of small intensity. The largest historic earthquake near the site was the 1875 earthquake, which had an intensity of VI to VII Modified Mecalli (MM) near Richmond, 50 miles from the site. Evaluation of the effect of this event and other distant events, such as the Charleston, South Carolina earthquakes of 1886 and the Giles County, Virginia events of 1897, indicates a maximum potential earthquake of intensity VI MM at the site.

2.6.1.1 Site Geomorphology

The proposed site is located on Gravel Neck, 5 miles north-northeast of Bacon's Castle, Surry County, Virginia. The site is located in the Coastal Plain Physiographic province approximately halfway between the Atlantic Ocean and the fall zone (see Figure 2.6-1).

In Virginia, the Coastal Plain has a stair-step character composed of a series of plains that are successively lower from west to east and are separated from one another by scarps. In the site vicinity, four plains are recognized. From the highest to the lowest they are the 120-foot plain, 90-foot plain, 70-foot plain, and 45-foot plain. Also, three prominent scarps are present. They are the Surry scarp, the Peary scarp, and the Chippokes scarp.

The site area (Gravel Neck) shown on Figure 2.6-2 is located on the 45-foot plain which is bounded to the west, north, and east by the James River and to the south by the Chippokes scarp. The site area is flat and featureless with an average elevation of about 30 feet above mean sea level. In the immediate site area, there are no surface features indicative of actual or potential localized subsidence of landsliding. There is no history of surface mining, withdrawal of large quantities of fluids such as petroleum, or other activity by man which would cause settlement or ground disturbance. Heavy vegetation covers most of the site.

There is no hazard of surface faulting at this site. There are no slopes either natural or man-made which would affect installation safety. There are no soluble rocks, such as limestone or gypsum, under or near the site which would influence site stability.

The most abundantly exposed formation at the site is the Norfolk formation of Pleistocene age. The Norfolk formation was deposited upon an erosional surface of the Yorktown formation during the late-Pleistocene age when the sea level rose to approximately elevation 45 feet. At the end of the Pleistocene age the sea receded. Erosion of the Norfolk sediments is continuing today in the site area. It is accompanied by deposition of recent alluvial deposits in stream valleys, marshes, and lagoons.

The clays and sands of the Norfolk formation of Pleistocene age are fluvial and estuary deposits consisting of highly plastic clays, medium to fine sands, silty sands, clayey sands, sandy gravel, and medium sand. This formation is described in detail in Section 2.6.1.2.2.2.

2.6.1.2 **Geologic History**

2.6.1.2.1 Basic Geologic History

Although the complex evolutionary history of the Appalachian Highlands and that of the Coastal Plain is not completely understood, investigations by numerous geologists allow the following account of the basic geologic history of the central Appalachian region. Table 2.6-1, summarizes the major orogenic events, lists their area of influence, and comments on the character of the event.

Precambrian

Intense metamorphic deformation occurred in the Precambrian age from 1100 to 800 million years ago (Grenville orogeny). Sedimentary and igneous rocks were metamorphosed to form the metamorphic crystalline rocks now known as the basement. These basement rocks are exposed today in the Blue Ridge province and Baltimore gneiss domes.

The Grenville orogeny was followed by a period in late-Precambrian time characterized by subaerial erosion that apparently stripped away most superficial structures. This tectonically inactive period was followed by orogenic movements.

The Avalonian orogeny occurred in very late-Precambrian time, 600 to 580 million years ago. This period of deformation was marked by very large and thick accumulations of clastic sediment and volcanics accompanied, if not caused, by sharp local uplifts and downwarps. The nature of these uplifts, whether they were folds, fault blocks, or islands remains obscure. This period of intense tectonic activity marks the beginning of the differentiation of the Appalachian region from the rest of North America.

Early-Paleozoic Era

The Avalonian orogeny was followed by the subaqueous deposition of thick carbonate and mud sequences, with some volcanics at the end of Cambrian and start of Ordovician time. In middle-Ordovician time, about 450 to 500 million years ago, the thick sequency of late-Precambrian and early-Paleozoic sediments was metamorphosed, deformed, and intruded by intense igneous activity. This period of deformation was called the Taconic orogeny and was the most intense tectonic event of the central Appalachian region.

A second orogeny, known as the Acadian orogeny, occurred during the Paleozoic age, about 360 to 400 million years ago. It was accompanied by regional metamorphism and granitic intrusion. Although very intense in the northern Appalachians, its effect in the central Appalachians is not well established.

Late Paleozoic Era

While the Piedmont and Blue Ridge provinces were undergoing metamorphism and igneous intrusion during the early- and mid-Paleozoic ages, the Valley and Ridge and Appalachian Plateau provinces were receiving sediments. At the end of the Paleozoic era, about 230 to 260 million years ago, the entire sedimentary sequency of the Valley and Ridge was folded and faulted producing the present mountainous terrain. This period of deformation is known as the Allegheny orogeny. It was long considered the main Appalachian orogeny; however, it is now evident that it was only one event at the end of a series of deformations throughout the Paleozoic. Its effect in the Piedmont and Coastal Plain must have been nominal. There is no evidence to date showing any marked tectonic activity in these provinces from the Appalachian events.

Early Mesozoic Era

The Late Triassic period, 190 to 200 million years ago, marked the last orogenic episode of the Appalachian region. Large regional arching was accompanied by development of downfaulted basins which were contemporaneously filled with Triassic continental sediments and lava flows. Accompanying the regional arching was the development of dike swarms. In the region of study, dikes trend mostly northwest which is transverse to regional structural trends. The dike activity may have lasted as late as the Jurassic period.

The eastern most margin of the crystalline rocks of the Piedmont province was downwarped during Mesozoic time with accompanying uplift and arching of the western Piedmont and Blue Ridge provinces. The result was an accelerated erosion of the western areas and deposition of the eroded material on the downwarping eastern portion. Uplift and relative subsidence was most rapid during Cretaceous and Miocene times.

In the site area, the first sediments deposited on top of the crystalline bedrock were a mixture of terrestrial, deltaic, and shallow marine sediments of Early Cretaceous age. By Late Cretaceous time, a shallow sea covered the site area and stayed in the area until late-Miocene time. During this time interval, a thick sequence of marine sediments was deposited which are the Mattaponi, Aquia, Nanjemoy, Chickahominy, Calvert, St. Mary's, and Yorktown formations.

The oldest unit encountered in the borings at the site is the Yorktown formation. Regionally it consists of a sand facies and silt-clay facies. The sand facies is the result of terrestrial stream deposits in a shallow marine environment. The silty and clayey sequences are the result of estuary and lagoon environments. In the borings at the site, only the silt-clay facies were encountered.

In late-Miocene and early-Pliocene time, 11 million years ago, the sea level receded which exposed the upper beds of the Yorktown formation to erosion. Extensive erosion occurred, followed by a period of deposition of the Sedley and Bacon's Castle formations. They consist of Pliocene sediments of fluvial and estuarine origin.

During late-Pliocene and early-Pleistocene times, 2 million years ago, extensive erosion occurred which removed much, or in some places all, of the Bacon's Castle and Sedley formations. Subsequently, the sea encroached on the land to about elevation +100 and deposited estuarine and littoral (beach) sediments of the Windsor formation.

During mid-Pleistocene time, the sea receded in stages leaving steplike plains and scarps at each intermediate stage. Erosion was extensive and in the site area all of the Windsor formation and parts of the Yorktown formation were removed. The present valley of the James River was established during this time.

In late-Pleistocene time, the sea level rose for the last time to about elevation +45 accompanied by the deposition of clayey sands of the Norfolk formation in marshes and nearshore marine environments.

From the end of the Pleistocene time to the present, the sea has receded and the erosion of Norfolk sediments is continuing today in the site area. It is accompanied by deposition of recent alluvial deposits in stream valleys, marshes, and lagoons.

2.6.1.2.2 Stratigraphy

2.6.1.2.2.1 *Regional Stratigraphy*

The distribution of the major geologic units in the region is shown on Figure 2.6-3. The units within the site area and the Coastal Plain are discussed in this section.

In the site area, the Coastal Plain is composed of a mixed sequence of marine and nonmarine formations. These sediments thicken progressively to the east, away from the fall zone. They form a wedge-shaped mass resting on the crystalline bedrock of what was the eastern portion of Piedmont province about 140 million years ago, (see Figure 2.6-4).

This sequence of sediments has been derived from the erosion, transport, and deposition of the soil and rock from the provinces of the Appalachian Highlands. Examination of individual layers reveals several depositional and stratigraphic features:

1. Most strata display a thickening eastward away from the fall zone.
2. Rapid vertical and lateral variation in lithology and texture.
3. Decreasing dip with progressively younger formations.

A summary of the geologic character, lithology, age, relative stratigraphic position, origin, and areal distribution of each stratigraphic unit is given in the stratigraphic column shown on Figures 2.6-5 and 2.6-6.

Generally, the Coastal Plain sediments consist of an early sequence of continental deposits of fluvial or near-shore deposition which are overlain by a thick sequence of marine sediments.

These sediments are of Late Cretaceous through Miocene age. These deposits are overlain by a thin sequence of intermixed marine and continental deposits which are of Pliocene to Recent age.

The first continental deposits are of the Potomac group, Late Jurassic to Late Cretaceous age, consisting of sand, gravel, and clay beds. The marine sequence, from the oldest to the youngest, consists of the Mattaponi, Aquai, Nanjemoy, Chickahominy, Calvert, St. Mary's, and Yorktown formations. They consist of marine clays, marls, glauconitic or quartz sands, shells, and occasional thin limestones. The last intermixed sequences of Pliocene to Recent age consist of Sedley, Bacon's Castle, Windsor, Norfolk formations, and Recent alluvium. This sequence is characterized by sands, silts, gravels, and clay of continental or shallow marine origin. Also discussed as part of Figure 2.6-5 are the regional ground water characteristics of each unit. Ground water conditions are discussed in Section 2.5.

2.6.1.2.2.2 *Site Stratigraphy*

Details of the subsurface geology were determined from 52 test borings and 10 piezometer installations drilled for Units 3 and 4 (Reference 2), borings drilled for Units 1 and 2 (Reference 1), and 9 borings and 1 piezometer drilled at the ISFSI location.

The distribution of the sedimentary units is shown on the map of site geology, Figure 2.6-7. The sediments in the upper 60 to 85 feet consist of Pleistocene age deposits and some thin Recent alluvial deposits. The Pleistocene sediments are principally of the Norfolk formation and consist of fluvial and estuarine deposits. The subsurface stratification is shown in figures provided under Section 2.6.4.2, of this SAR and is summarized as follows: Generally the Norfolk formation sediments consist of a surface layer extending from the ground surface to about elevation +21, and consist of a highly-plastic, very stiff, light gray mottled with red brown clay. In narrow stream gullies and in river flood plains, this layer is capped by a thin zone of alluvial deposits consisting of sands, organic silts, and clays. Such alluvial deposits comprise the surface soils of the entire Hog Island area just north of the site.

Below the upper plastic clay is a sequence of light-gray and brown, medium-dense, fine sand and silty-fine sands with occasional lenses of soft-gray clay (Boring B-3). This sequence averages 10 feet in thickness and extends to approximately elevation +10.

Below the silty sand is a layer of light-brown, loose- to medium-dense, medium- to coarse-grained sand and fine gravel. This zone is approximately 10 feet thick and extends to approximately elevation 0 feet.

The next layer encountered in 7 of the 9 borings for the ISFSI was a brown, brownish-gray, or reddish-brown fine silty sand to sandy clay.

This appears to be a remnant of the Sedley formation or Bacon's Castle formation and varies in thickness from 1 to 8 feet. These sediments represent the lower most Pliocene deposits in the area which are at elevation 0 to -8 feet.

The top of the Miocene sediments (Yorktown formation) is at about elevation -8 feet. The Yorktown formation at the site, consists of a moderate- to highly-plastic, stiff to medium, grayish-green, silty clay, and at times slightly sandy, glauconitic, calcareous, and containing shells. The Yorktown formation is the deepest formation penetrated by borings at the site. Regionally the Yorktown is about 150 to 200 feet thick. The extent of the Yorktown is not known at the site; however, at least 100 feet of Yorktown deposits were penetrated by the borings at the site.

The Yorktown is underlain by the St. Mary's and Calvert formations, also of Miocene age. The three formations comprise the Chesapeake group and are estimated to be about 240 feet thick in the site area.

Underlying the Miocene formations, at an estimated depth of 320 feet, are older Eocene, Paleocene, and Cretaceous sediments which are described in the columnar section, Figure 2.6-5. Thicknesses of these older sediments are estimated to be about 45, 55, and 800 feet, respectively.

The ground water conditions in the surface formations at the site and relative effects of the proposed facility are discussed in detail in Section 2.6.4.6.

2.6.1.2.3 Structural Geology

There is no evidence of structural deformation at the site. The only structural feature in the vicinity of the site indicative of folding or faulting is south east of Yorktown, Virginia where the Yorktown formation shows a reversal of regional dip. This condition is thought to be a result of differential compaction of underlying units in response to surface loading.

The structural geology of the site and surrounding region is discussed in detail in Section 2.6.1.3.

2.6.1.2.4 Tectonics

The tectonics of the region are largely dependent on the study of the Appalachian Highlands, especially that of the Blue Ridge and Piedmont provinces. The appearance of the Coastal Plain is a relatively recent event and is related to the late tectonic history of the Piedmont. Therefore, the Coastal Plain tectonics will be introduced after a basic discussion of the early tectonics of the Appalachian Highlands which form the structural basis for the region. The tectonic features of the region are shown on Figure 2.6-8.

The Appalachian Highlands form a continuous mountain chain extending the length of the eastern North American shoreline from central Alabama to Newfoundland. The tectonic trends (fold axis, faults, foliation, structural pattern, igneous intrusives, etc.) or the Highlands, though locally irregular, generally are remarkably even. They are parallel to one another, and parallel to the general northeast-southwest trend of the mountain chain. Taken broadly, the chain is a series of arcs convex to the northwest. The central arc extends from New York City to southern Virginia (approximatley 400 miles), and delineates the region known as the central Appalachians. Most of

the site region is within this area. To the south is another arc which extends from southern Virginia to central Alabama (approximately 500 miles), and delineates the region known as the southern Appalachians. It includes the most southern parts of the site region.

One of the most prominent structural features of the region is the western edge of the Blue Ridge province, known as the tectonic front (Reference 3). It marks the boundary between the highly deformed and metamorphosed crystalline rocks of the Blue Ridge and Piedmont provinces to the east and the unmetamorphosed sedimentary rocks of the Valley and Ridge and Appalachian Plateau provinces to the west. Through most of central and northern Virginia there is no marked evidence of major faulting along the front. South of about latitude 36°N the front is continuously faulted for the entire length of the southern Appalachians, 500 miles. From latitude 36° to the Roanoke area the faulting is high-angle reverse. South of Roanoke it abruptly changes character to systems or low angle thrust sheets. Some of these thrust faults have throws as great as 10 miles to the northwest. The closest approach of this faulted front to the site is 130 miles to the west.

Immediately northwest of the tectonic front is the Valley and Ridge province and the Appalachian Plateau. These are separated by the Allegheny front, which marks the sharp transition between the intensely folded and faulted rocks of the Valley and Ridge and the gently folded, and only locally faulted plateau rocks. The Allegheny front is approximately 200 miles from the site area.

Within the central Appalachian region, the Valley and Ridge province is structurally dominated by large, parallel, northeast-southwest trending fold systems rather than by faults as in the southern Appalachians. The main fold belts are the Massanutten synclinorium, Shenandoah synclinorium, and Nittany anticlinorium, approximately 140, 165, and 180 miles northwest of the site area, respectively. Two major fault zones also traverse the Valley and Ridge province in this area, the Staunton fault and the Little North Mountain fault. The Staunton fault is approximately 145 miles west-northwest of the site area and trends northeast to southwest, parallel with the regional structural fabric. It is a high angle reverse fault along its 95-mile length through the central Applachians. Near Roanoke, it joins with the Catawba-Pulaski fault system which are low angle thrust faults. Further northwest, about 150 miles from the site, is the Little North Mountain fault zone. This zone trends parallel to regional structure for a total length of about 190 miles and is a high angle reverse fault, dipping southeast at its surface exposures. The deep seated tectonic nature of the faults and folds and their relationship to the Blue Ridge (Reference 3) is an item of much controversy among leading scholars of the subject. Presently there are two main schools of thought termed "thin-skinned" and "thick-skinned" tectonics. Harris (Reference 4), described the schools of thought in the following paragraphs.

> "The thick-skinned school of thought, which is the more traditional concept, reasons that all folds and faults extend into basement and their existence depends on support from basement. It postulates that major deformation during the Appalachian orogeny occurred mainly in the basement and the sediments simply mimic those structures."

> "The thin-skinned school of thought, which was largely developed by geologists concerned with the southern Appalachians, reasons that the Valley and Ridge structures are features marginal to the main area of deformation and were produced by tangential forces acting from southeast only upon the sedimentary prism. These forces produced huge bedding plane thrust plates with miles of displacement without involvement of the basement. Movements of these sheets toward the northwest produced a series of intricate thrust faults and rootless folds."

All of the above mentioned tectonic features of the Valley and Ridge Province, regardless of their tectonic origin, date back to Paleozoic age with the most intense activity during the Allegheny orogeny, 230 to 260 million years ago. No active surface faulting is known in this area.

East of the tectonic front are the Blue Ridge and Piedmont provinces. The Blue Ridge province has been structurally folded and faulted into a complex anticlinorium. Through the area of study it is composed of metarmorphosed Precambrian age, 1100 million-year-old gneiss with some small areas of younger Precambrian or Cambrian schists. Small faults are common throughout the anticlinorium. However, as shown on Figure 2.6-8, there is one large fault zone about 55 miles long trending northeast, parallel with the regional structure, just west of Charlottesville, Virginia. The faulting is high angle reverse. It is about 120 miles northwest of the site. All of the above mentioned tectonic features of the Blue Ridge are of Paleozoic age, with the most intense activity during the Taconic orogeny, 450 to 500 million years ago. No active surface faulting is known in this area.

Further east is the Piedmont province. It is primarily composed of early to mid-Paleozoic sedimentary and igneous rocks that have been metamorphosed into schist, gneiss, and granitic gneisses. Within the older crystalline rocks are basins of unmetamorphosed sediments of Triassic age, 180+ million years old.

The boundary between the older Precambrian rocks of the Blue Ridge and the Piedmont does not appear to contain major faulting within the study area. In southern Virginia this transition is marked by a major fold belt known as the James River synclinorium which is faulted along the northwest. The synclinorium is 110 miles west of the site.

In Northern Virginia, the eastern Blue Ridge boundary is slowly approached by the western border fault system of the Culpeper Triassic Basin until, near the Maryland border, it intersects the Blue Ridge basement rock complex. This Triassic basin border fault, as well as all other known Triassic basin border faults, is a high angle normal fault.

It is downfaulted on the east side with a vertical displacement of about 10,000 feet, a magnitude common to most large triassic fault basins. The fault is part of a system that extends a distance of about 125 miles to the northeast and joints the Gettysburg and Newark-Delaware basin system, which are out of the area of study. It is about 110 miles northwest of the site. Other

Triassic faults and associated sedimentary basins, which are of common origin and character, located within the study area are:

1. A Triassic basin just south of Charlottesville, Virginia, approximately 110 miles west of the site. It is about 25 miles long and faulted on both the east and west sides.
2. Dan River basin, approximately 120 miles west of the site. It is about 110 miles long and faulted on the west side.
3. Central Triassic faulting, located south of Arvonia syncline approximately 95 miles west of the site. The faulting extends intermittently for 70 miles along a northeast trend. The small basins formed are faulted on the west side.
4. Richmond basin, approximately 55 miles west of site. It is the closest known faulting to the site area. The basin trends north-northeast and away from the site area. It appears to be about 65 miles long and faulted on both the east and west sides.
5. Deep River-Durham basin approximately 120 miles southwest of the site area. It is faulted primarily on the east side for about 160 miles.
6. Recent aeromagnetic data indicate the possibility of additional Triassic basin faulting east of the Baltimore area as shown on Figure 2.6-8.

Other Piedmont tectonic structures are of Paleozoic age, most of which are contemporaneous with the intense metamorphic and tectonic activity related to the Taconic and Acadian orogenies of 450 and 360 million years ago. The major fold belts include the James River synclinorium, previously mentioned, the Hardware anticline, the Arvonia-Columbia-Quantico syncline trend, the Virginia synclinorium and the Wake-Warren anticlinorium, about 110 miles west, 105 miles northwest, 90 miles northwest, and 80 miles southwest of the site, respectively. Faulting, though common on a localized scale throughout the Piedmont, is not prominent on a regional scale. Aeromagnetic data (Reference 5) indicate a major Paleozoic age lineament through central Virginia. It trends northeast across the State of Virginia and is about 100 miles northwest of the site. The lineament has not been identified by field mapping, but is inferred to be a metamorphosed and recrystallized fault trend (Reference 6).

Additional Paleozoic faulting is associated with the northwest side of the James River synclinorium, about 120 miles west of the site and two faults associated with the Baltimore, Maryland, area 140 miles north of the site. The James River synclinorium faults are westerly thrust faults, about 50 miles long, trending northeast. The Baltimore area faults trend northeast to north, are normal faults, and extent for a length of about 10 miles.

East of the Piedmont is the Atlantic Coastal Plain. The Coastal Plain is essentially an irregular, thick, dissected, eastward facing wedge of unconsolidated to semiconsolidated sediments. The basement of this wedge consists of Paleozoic-age Piedmont-type rocks. They are largely igneous and low- to high-grade metamorphic rocks.

Recent deep drilling and geophysical data have revealed the underlying Coastal Plain basement to be regionally downwarped into a series of depositional basins formed by a series of arches and troughs parallel and at angles to the Appalachian trend (Reference 7). The site area lies in the vaguely defined basin area known as the Chesapeake-Delaware embayment. From analysis of the stratigraphic record of the Coastal Plain, large regional uplift of the Piedmont area and relative downwarping of Coastal Plain took place in early Cretaceous and Miocene time, 135 and 25 million years ago, respectively. Some minor uplift occurred during the Late Cretaceous and early-Teritary times. Since the Pliocene age, 11 million years ago, the region has been relatively stable, experiencing only minor and uniform regional subsidence in the site area and gradual regional uplift of the southern Appalachians. Present subsidence data indicate the southern Appalachians to be gradually rising, at a rate of 0 to 15 millimeters per year, the central Appalachians to be stable, and the central Coastal Plain gradually subsiding at a rate of 1 to 5 millimeters per year (Reference 8).

The mechanism of subsidence of the Coastal Plain has been thought to be the regional response to gravity loading from the deposition of sediments derived from the regional arching of the Piedmont and Blue Ridge provinces. A different mechanism suggested by Brown (Reference 9) attributes subsidence to a lateral north-south compressional force, instead of gravity. The mechanisms primary movements are lateral with secondary vertical movements postulated to account for subsidence observed in the Coastal Plain. Brown's model suggests large lateral movements and periodic realignment of the resultant stress field, producing folds, faults and flexures which would be periodically reactivated. The primary directions of flexures are northeast to southwest, northwest to southeast, and north to south. The analysis within this report is in agreement with the gravity subsidence as the primary mechanism and questions the validity of the compressional force mechanism. The large lateral north-south compressional force as shown by Brown would have to be active throughout the Appalachian provinces; yet, in these provinces, where the geologic features are exposed, no such mechanism can be observed. Therefore, the validity of such a mechanism isolated and acting in the rocks of the Coastal Plain is highly questionable.

Within the region of study, surface geologic mapping, subsurface drilling, and geophysical techniques have shown no regional folding or faulting within the Coastal Plain sediments. Rogers and Spencer (Reference 10) in a discussion of the structural setting of Princess Anne County, Virginia, proposed the existence of a hinge line (fault) marking the western edge of a proposed Triassic basin underlying Cheasapeake Bay. This feature is referred to as the Norfolk hinge.

Rogers and Spencer cited data from Cederstrom (References 11 & 12) Peterson (Reference 13), and Ewing et al. (Reference 14). Rogers and Spencers' evidence for the hinge line came principally from a geologic cross section incorporating well log data from Sedley, Fort Eustis, and Point Comfort, Virginia, and seismic data from Cape Henry, Virginia. Fort Eustis, Point Comfort, and Cape Henry all lie in a straight line while the Sedley data is projected about 30 miles north onto that line, possibly introducing some error.

Rogers and Spencer (Reference 10) made considerable mention of the 1950 work of Spangler and Peterson (Reference 13) but they failed to adopt the Fort Eustis basement depth of -1550 feet proposed by Spangler and Peterson; instead, they used -1250 feet. Had they used Spangler and Peterson's rock depth they would have obtained a relatively uninterrupted sloping bedrock surface. Investigations since 1950 (References 15 & 16) have confirmed the uninterrupted nature of the basement rock. Figure 2.6-9 shows the basement rock slope contours and does not indicate a hinge under Chesapeake Bay. Recent work by Teifke (Reference 17) and a recently drilled well in Hampton, Virginia (Reference 18) further confirm this conclusion.

Some local minor folding of Cretaceous beds has been observed near Washington, D.C. and along the upper parts of the Chesapeake Bay (Reference 19). Also localized post-Triassic faulting has been postulated (References 11, 19, 20 & 21). Their locations are listed below:

1. Lebanon Church on U.S. Highway 250, south of Greenwood, Virginia.
2. Near Washington, D.C.
3. Drewry's Bluff on James River, Virginia.
4. U.S. Route 1 near Quantico, Virginia.
5. A total of 4 miles north-northwest of Petersburg, Virginia.
6. Near Sandy Point, Maryland.
7. Southeast of Route 5, vicinity of Brandywine, Maryland.
8. Southeast side of upper Chesapeake Bay, Maryland.

Locations 3 and 5 are closest to the site. Drewry's Bluff is about 44 miles from the Surry Power Station. It is on the west bank of the James River approximately 6 miles south of Richmond, Virginia. The bluff sediments are in the Patuxent formation of Lower Cretaceous age. The fault has received little attention in the literature, referenced only by Cederstrom (References 11, 12 & 22). Of these only Reference 12 presents a description and a photograph of the feature. The feature is described as a reverse fault. The photograph (plate 6B of Reference 12) shows a displacement of about 0.5 to 1.0 feet. No mention is given of the orientation, extent, or exact location. A field survey performed during the investigations for Units 3 and 4 failed to locate the feature.

A careful survey of recent aeromagnetic data (Aeromagnetic Map of Southeastern Virginia, 1972) did not reveal any lineations in the vicinity of Drewry's Bluff, thus further precluding the possibility that the fault has any lateral or vertical importance.

The Drewry's Bluff fault could be the result of differential compaction or of intramass movement within a large gravity slide during or shortly after deposition. The small displacement and the minor extent of this feature made a tectonic explanation improbable.

The Petersburg Virginia fault is also referenced by Cederstrom (Reference 12). This is the only known reference to the feature. The fault is described as being "near the base of the Chesapeake sediments, 4 miles north-northeast of Petersburg." This would place the feature in the Calvert formation (Geologic Map of Virginia, 1963) at a location halfway between Jefferson Park, Virginia and the Appomattox River. The Calvert formation is upper Eocene to Miocene in age. Cederstrom states "a small fault... trending northwest and dipping 55° southwest." No photograph is presented nor is the extent, type of movement, or exact location of the feature presented. A careful survey of recent aeromagnetic data (Aeromagnetic Map of Southeastern Virginia, 1972) did not reveal any lineations in the vicinity of this reported fault.

The context of the reference suggests that the fault is similar to that at Drewry's Bluff and the possible explanations of this feature might also involve differential compaction or intramass movements within a large gravity slide during or shortly after deposition. The apparent small magnitude and minor extend of this feature makes a tectonic explanation improbable.

The origin of these localized features could be related to localized tectonic adjustments to regional uplift, or to surface manifestation of deeper differential compaction, or to gravity slides contemporary with, or shortly after, deposition. There is no known correlation of these features within any major zone of deformation or with any major earthquake epicenteral trend.

2.6.1.3 **Structural Geology**

The site area lies on the southern flank of the Chesapeake-Delaware embayment, a depositional basin that has been downwarping and receiving sediments since Late Jurassic time, approximately 140 million years ago. Present regional subsidence in the site area has been measured to be about 1 to 5 millimeters per year (Reference 8). The resulting dip of the sedimentary units is oceanward, toward the east. The dip of the Late Tertiary units (Yorktown) in the site area is 2 to 7 feet per mile, southeast (Reference 23).

The bedrock structural contours on Figure 2.6-9 show no disturbance. The sample applies for the isopach contours on Figures 2.6-10 through 2.6-20. The figures cover a range in time from Cretaceous through Pleistocene. No abrupt thickening nor asymmetric isopach contour patterns are present as would be expected for fault type subsidence. Rather, large gradually varying isopach patterns are evident. These may be formed by gradual regional downwarping, differential compaction, erosion or as a function of distance from the sediment source (deposition). The isopach centers vary in location with geological time and are not correlative with any localized structural effect.

Except for an area near Yorktown, Virginia, the site area and vicinity is devoid of any structural features indicative of folding or faulting. Southeast of Yorktown, Virginia the beds of the Yorktown formation (Miocene age, 25 to 11 million years old) show a reversal of the regional dip. The beds dip 8 to 55 feet per mile, northwest. The reversal area was once believed to be of tectonic origin. However, as a result of more recent studies by Johnson, 1972 (Reference 23), the warping appears to be contemporaneous with Miocene deposition and the result of differential

compaction of underlying units in response to surface loading. The northwest tilting had ceased prior to Pleistocene deposition, 2 million years ago. The overlying Pleistocene sediments show no dip reversal and conform with the regional trends.

In the immediate site, area surface inspection and subsurface investigations show no evidence of structural deformation. The borings indicate no offsets or folding of strata. There is no surface or subsurface evidence of prior landslides, cratering or fissures that may be indicative of prior intense earthquake effects. The specific geotechnical properties of the materials at the site, their stability, and their feasibility for use as foundation materials for the proposed facility are discussed in Section 2.6.4.

A fault referred to as the Hampton Roads fault was postulated by Cederstrom in 1945 (Reference 11) in order to explain what appeared to be abrupt thickening of Eocene deposits on the north side of the James River. A total of 12 years later Cederstrom revised his assessment of the thickness of the Eocene sediments and concluded that what thickness differential there was could be described as moderate and not indicative of faulting (Reference 24).

The same postulated fault was again investigated by Rogers and Spencer in 1971 (Reference 25). Their evidence for faulting was based upon chloride content of ground water, pieziometric levels, and reversal in dip of strata based upon electric logs of drilled wells.

Rogers and Spencer's interpretations were examined in detail by Stone and Webster in response to an NRC question on the Surry Units 3 and 4 PSAR. They concluded that the evidence presented by Rogers and Spencer did not support the postulated fault. The complete response is presented in Appendix 2A in this SAR.

Gravity and magnetic data reveal a possible Triassic basin east of Richmond as well as a large mafic intrusive to the east of this basin. As can be seen on Figures 2.6-21 and 2.6-22 the trend of the geophysical data in the Coastal Plain parallels the known geologic structural trend of the region west of the fall zone (Johnson).

Aeromagnetic data (Reference 26) for the Coastal Plain indicates that an area east of Richmond shows low magnetic relief (see Figure 2.6-21). A similar lack of magnetic relief occurs over the known Richmond Triassic basin and the New Jersey basins to the north. In the area east of Richmond the data indicate an area of Triassic rocks. Other aeromagnetic data for the area have been investigated, and the maps have shown the same feature.

Gravity data for the Coastal Plain show several gravity lows which correlate closely with known and inferred Triassic units. An area with lower gravity values appears east of Richmond and may be indicative of Triassic sediments, Figure 2.6-22.

A seismic refraction traverse was made across the Coastal Plain, from Petersburg onto the continental shelf, in 1935 (Reference 27) (Figure 2.6-23). At the Damp Lee and Youngbloods store stations, a velocity of 12,850 feet per second was obtained, far below the expected normal

velocity for crystalline rocks (17,100 feet per second). Miller (Reference 28) suggested that this velocity of 12,850 feet per second is too high for Cretaceous and Tertiary deposits, and is probably indicative of Triassic (Newark) rocks.

Deep well data from the area just east of Richmond confirm that there are older than Cretaceous sediments concealed beneath the Coastal Plain sediments. Richmond lies on crystalline rock, but wells at King George, Bowling Green, Manquin, and Wells W-1291, W616, and W2071 (Figure 2.6-24) encounter sediments which have been interpreted as Triassic by the Virginia Division of Mineral Resources. The well at Manquin continues through the Triassic for 1760 feet, where it bottoms in crystalline rocks.

From the available geophysical and well data, boundaries for this basin can be inferred (Figure 2.6-24). The closest approach to the site is approximately 32 miles.

To the east of the area just described is a linear feature which is distinctive as both a magnetic and gravity high. This stringline anomaly appears about 30 miles to the west of the site (Figure 2.6-21) as a strong magnetic high. Buried Triassic dikes have been postulated as a source for this anomaly (References 29 & 30).

A gravity high (Reference 31) (Figure 2.6-22) lies over this area and corresponds with the magnetic anomaly. Johnson (Reference 32) suggests that this is probably due to high density mafic rocks.

No deep wells have been drilled in this area to support the geophysical data presented above.

The extent of this feature can be seen in Figure 2.6-22. The closest approach to the site is about 25 miles, and the anomaly extends from Sussex, north to the state boundary.

East of this high to the coast is an area which is relatively featureless magnetically. The intensity of magnetic features may diminish slightly as the sediment thickness increases. However, seismic evidence (Reference 27) along a line from the Petersburg area to Cape Henry (Figure 2.6-23) confirms the magnetics and indicates that the basement is a featureless surface of relatively high and constant bedrock velocities indicating a lack of tectonic structure.

Gravity studies by Woolard (Reference 32) and Johnson (Reference 33) also indicate a rather featureless area with values decreasing to the east. No large anomalies occur in the gravity data.

The seismic refraction data previously cited show bedrock velocities east of the mafic high that are indicative of crystalline rock. Deep well data support this with two exceptions: the wells at West Point and Oak Hall (Figure 2.6-24). Logs from these wells indicate older than Cretaceous sediments. These sediments have been classified as Triassic (Reference 33), but may also correspond with the Jurassic and Cretaceous Unit H of Brown, Miller, and Swain (Reference 34). The indicated lack of structure from geophysical studies suggests that if these sediments are

indeed Triassic, they are not present in a downfaulted basin, but are erosional remnants of previous onlapped sediments.

As discussed above, the gravity and magnetic data show no structure in the vicinity of this site.

2.6.1.4 **Site Geologic Map**

A site geologic map is shown as Figure 2.6-7.

2.6.1.5 **Results of Subsurface Investigation**

A description of the results of the subsurface investigation is given in Section 2.6.4.2.

2.6.1.6 **Geologic Profiles**

A description of the engineering characteristics of the subsurface materials is given in Section 2.6.4.2.

2.6.1.7 **Excavation and Backfills**

A description of the excavation and backfilling is discussed in Section 2.6.4.5.

2.6.1.8 **Geologic Features that Could Affect Dry Cask ISFSI Structures**

As stated in Sections 2.6.1.1, 2.6.1.2, 2.6.1.3, and 2.6.4.1, there are no local geologic features that could affect the ISFSI structure. There is no surficial or subsurface evidence of any structural deformation (folding, faulting, etc.). No evidence of landslides, cratering, or fissures has been recognized. There are no slopes in the vicinity that could pose a risk to installation safety. The site is essentially featureless. There are no soluble rocks such as limestone or gypsum under or near the site which would influence site stability.

2.6.1.9 **Site Ground Water Conditions**

The principal aquifers in the site area are the Pleistocene sands and the Cretaceous and Eocene sands. They are isolated from one another by the Miocene clays and show no evidence of being hydraulically connected (Reference 2).

The Pleistocene sands within the site are isolated from those outside the site area by the James River, the Chippokes Creek, and the Hunicutt Creek. The potentiometric level within the Pleistocene sands is apparently not under tidal influence, so the water level in the Pleistocene sand reflects rainfall and infiltration in the site vicinity. Infiltration occurs where the Pleistocene sands are located at or near the ground surface, and where erosion along stream channels has exposed the sands allowing recharge to occur.

Potentiometric levels within the deeper aquifer (Cretaceous and Eocene) may be influenced by recharge where these beds are exposed (along the fall zone) and also may be affected by pumping. This is the more productive of the two principal aquifers.

Site ground water conditions are also discussed in Sections 2.5 and 2.6.4.6.

2.6.1.9.1 Ground Water Levels

Ground water levels in the Pleistocene sand in the vicinity of the Units 1 and 2 site were approximately +0 to +13 feet in 1972/73 (Table 2.6-2), and at the Units 3 and 4 site were approximately +15 feet in 1972/73 (Table 2.6-3). The ground water level in the area of the proposed ISFSI is approximate +10 feet (1982).

The potentiometric level within the lower aquifer (Cretaceous and Eocene) was not measured but is estimated to be approximately -10 feet.

2.6.1.9.2 Permeability Measurements

Insitu permeability tests were performed in the 10 piezometers and Boring 201 (for Surry Power Station Units 3 and 4 Geotechnical Report). Results of the falling head permeability tests are presented in Table 2.6-4. The data show that the hydraulic conductivity of the Pleistocene deposits is low, ranging from 0.001 feet per day to 19 feet per day with horizontal hydraulic conductivities generally higher than the vertical. Lowest hydraulic conductivity values are probably representative of silty or clayey zones whereas highest values are representative of the coarser sands. Measured hydraulic conductivity values appear somewhat lower than those based on correlations with effective grain size. This could be the result of silt-size particles clogging the pores and progressively decreasing the measured values. The hydraulic conductivity values in either case are quite low.

2.6.1.10 **Geophysical Survey**

Seismic velocity investigations in the form of cross hole surveys were performed at the Surry Power Station Units 3 and 4 site adjacent to the ISFSI site. They are included in Appendix 2B.

2.6.1.11 **Soil Properties**

Discussion of soil properties and laboratory test results is included in Section 2.6.4.2.

2.6.1.12 **Analysis Techniques**

Analysis techniques and factors of safety used for foundation materials are discussed in Section 2.6.4.12.

2.6.2 Vibratory Ground Motion

The ISFSI is adjacent to the Surry Power Station. A detailed characterization of the regional seismicity through the early 1970s is contained in the Surry Power Station Units 1 and 2 Updated FSAR and the PSAR for the once-considered Surry Units 3 and 4. It is the earthquake characterization of the PSAR for Units 3 and 4, updated to include earthquakes occurring after 1973, that is the basis for the ISFSI vibratory ground motion section. The principal area of

coverage is within 200 miles of the site. A few very large historical earthquakes at greater distances are also considered. The earthquakes discussed under this criterion are adequate to allow specification of the Design Earthquake (DE) for the ISFSI. As discussed further in Section 2.6.2.5, this DE is based on a conservative generalization of earthquakes that have led to the maximum historic site intensity.

2.6.2.1 Engineering Properties of Materials for Seismic Wave Propagation and Soil Structure Interaction

The static and dynamic engineering properties of materials underlying the site are presented in Sections 2.6.4.2 and 2.6.4.4.

2.6.2.2 Earthquake History

The site is located in a region of moderate historic earthquake activity. The record of earthquake occurrence dates to the mid-18th century. Since then the region has had a well distributed population so that it is probable that a record exists of any earthquake of intensity V (MM) or greater. All intensity values in this report refer to the Modified Mercalli (MM) scale as abridged in 1956 by Richter and shown as Table 2.6-5.

Since the mid-18th century there have been just over 40 earthquakes of intensity V (MM) or greater reported within a 200 mile radius of the site. The largest of these are of epicentral intensity VII (MM). The effect at the Surry site from these shocks and that of the more distant larger shocks has been nominal. There has been no resultant structural damage at the site and the associated acceleration is estimated to have been less than 0.05g.

Listed in Table 2.6-6 and shown in Figure 2.6-25 are all known earthquakes with epicentral locations within a 50-mile radius of the site and all earthquakes of intensity V (MM) or greater with epicentral locations within 200 miles of the site. There are no known epicentral locations within a 30-mile radius of the site. Discussed in greater detail in the following paragraphs are all the historical earthquakes of the region that are believed to have been felt at the site (Reference 34).

February 21, 1774

A rather strong shock was felt throughout most of Virginia and parts of North Carolina. Although there are no reports of damage, the fact that the shock was sharply felt at Westover, Williamsburg, Petersburg, and Fredericksburg would lead one to estimate the intensity at the site of IV (MM). Its epicentral location is thought to be about 20 miles south of Richmond and about 45 to 50 miles west of the site (References 34, 35 & 36).

1811 and 1812

The New Madrid, Missouri earthquakes of December 16, 1811, January 23, and February 7, 1812 were felt throughout the Virginias, and, in fact, most of the eastern two thirds of the United States. The earthquakes were of epicentral intensity XII. Intensities of the earthquakes were

slightly higher at Richmond than at Norfolk. Reports from Richmond for the most severe event indicate that the intensity was between IV and V (MM) while the intensity at Norfolk was no higher than IV (MM). The intensity at the site was probably IV (MM) (Reference 37).

March 9, 1828

The epicenter of this earthquake was located in west central Virginia. The shock was felt over an area of approximately 218,000 square miles. Despite the large area over which the earthquake was felt, the epicentral intensity is estimated to be V (MM). The epicentral area was an area of very sparse population at that time. The probable intensity of this earthquake at the site was III (MM) (Reference 38).

August 27, 1833

The epicenter of this earthquake of epicentral intensity VI was between Charlottesville and Richmond, Virginia. Although no damage was reported, the earthquake was more strongly felt in Richmond than the New Madrid earthquakes, indicating a probable intensity, at Richmond, of V (MM). The shock was also sharply felt at Norfolk, where the intensity was IV (MM). Based on reports at Norfolk and Richmond, the probable intensity of this earthquake at the site was IV to V (MM) (Reference 39).

April 29, 1852

This earthquake, which was felt over an estimated 187,000 square miles, had its epicenter in southwestern Virginia. This earthquake was an intensity VI as evidenced by felled chimneys. The site is near the eastern extremity of the felt area and therefore the intensity was probably no higher than III (MM) (Reference 38).

August 31, 1861

This earthquake of probable epicentral intensity VI (MM) affected a 300,000 square mile area along the Atlantic Coast from Charlestown, South Carolina, to Washington, D.C. Sketchy reports concerning damage from this earthquake can be attributed to the fact that the Civil War had just begun. The epicenter of this earthquake was probably in western North Carolina or in extreme southwestern Virginia. The only significant report of damage came from Wilkesboro, North Carolina, where bricks were shaken from chimneys and clocks were stopped. The site is located near the eastern extremity of the felt area, where a Modified Mercalli intensity of III is probable (Reference 38).

December 22, 1875

The epicenter of this earthquake was located near Richmond, Virginia. This earthquake was felt over all of Virginia, except perhaps the extreme southwestern portion. It had a total felt area of more than 50,000 square miles. Damage in the epicentral region consisted of fallen chimneys, shingles shaken from roofs, lamps, and other articles thrown from shelves, and plaster thrown

from walls. The epicentral intensity of this earthquake was placed at intensity VI to VII (MM). This earthquake was felt at Fortress Monroe and at Norfolk. An intensity of IV (MM) is estimated for the site area (References 36, 39 & 40).

August 31, 1886

The two main shocks of the Charleston, South Carolina, earthquake of epicentral intensity X (MM) were strongly felt in Virginia. Damage, however, was slight, consisting of an occasional collapsed chimney, some fallen plaster, a few broken windows, and some fragile objects being dislodged from shelves. Intensities in Virginia ranged between V and VI (MM). The Rossi-Forel isoseismal line separating intensity V (MM) from intensity VI (MM) passes very close to the site. Comparison of Rossi-Forel and Modified Mercalli Intensity Scales show that the intensity at the site was also V to VI (MM) (Reference 41).

Recent detailed work by Bollinger in 1977 (Reference 57), in which all the original intensity reports of Dutton (Reference 41) are reinterpreted in terms of the Modified Mercalli Intensity Scale and plotted throughout the eastern United States, shows the maximum site intensity from the 1886 Charleston earthquake was V(MM).

May 3 and 31, 1897

The epicenters of these two large earthquakes were located near Pulaski in southwestern Virginia.

The earthquake of May 3, 1897, was felt over an area of 150,000 square miles while the earthquake of May 31, 1897, was felt over an area of about 280,000 square miles. Damage from the May 3, 1897 earthquake was confined to chimneys; the epicentral intensity of this earthquake is listed as a VI (MM). The May 31, 1897, earthquake is listed as intensity VIII (MM). Damage reports consisted of walls of old brick houses cracked, bricks thrown down from chimneys, a few small earth fissures and land slides, and some rocks rolled down mountains. However, a report from Mr. M. R. Campbell says that "the shock of May 31st was probably more severe in and about Pearisburg than at any other point from which I have information. No serious damage was done even here, but old brick houses were badly shaken, and many chimneys were cracked and the topmost bricks hurled to the ground." This report indicates that the intensity of this earthquake might be slightly less than the intensity VIII (MM) listed by United States Coast and Geodetic Survey. The earthquakes were strongly felt at Richmond where windows, pictures, glassware, and the like were shaken with some unstable objects overthrown, indicating an intensity of V to VI (MM). The intensity of this earthquake at the site area may be estimated at intensity V to VI (MM) (References 36, 42 & 43).

April 9, 1918

This earthquake of intensity VI (MM) had its epicenter near Luray, in western Virginia. It was felt over an area of approximately 100,000 square miles. The site is on the extreme eastern

limit of the felt area of this earthquake and therefore probably experienced a Modified Mercalli intensity of III (Reference 44).

2.6.2.3 Zones of Significant Historic Earthquake Activity

Relative to the site, the most significant earthquakes have occurred in three zones:

1897 Giles County, Virginia; intensity VIII (MM) - associated with the Appalachian seismic zone.

1875 Richmond, Virginia; intensity VII (MM) - associated with the Central Virginia seismic zone.

1866 Charleston, South Carolina; intensity X (MM) - associated with the Charleston seismic zone.

Giles County, Virginia

The 1897 Giles County, Virginia, earthquake is part of the Appalachian seismic zone. This zone is characterized by a general northeast-southwest alignment of the epicenters of the larger shocks in the site region. The zone is roughly coincident with tectonic features of the Blue Ridge and the eastern side of the Valley and Ridge provinces. It is indicative of continued deep seated crustal adjustments along zones of intense ancient tectonic deformations. Of the 11 shocks that have been felt in the site area as discussed in Section 2.6.2.2, the following 6 can be attributed to this zone:

1. March 9, 1828, west central Virginia; V (MM)
2. April 29, 1852, southwestern Virginia; VI (MM)
3. August 31, 1861, southwestern Virgina; VI (MM)
4. May 3, 1897, Giles County, Virginia; VI (MM)
5. May 31, 1897, Giles County, Virginia; VIII (MM)
6. April 9, 1918, Luray, Virginia, V to VI (MM)

Richmond, Virginia

The Richmond area is the eastern most extension of the central Virginia seismic zone.

The central Virginia seismic zone is a "relatively narrow, isolated zone of activity, offset from the Appalachian seismic zone and located in the Piedmont province, oblique to the northeast-southwest structural grain." The zone includes an east-west elongate cluster of low to moderate seismic activity. It extends from Richmond, Virginia to the edge of the Blue Ridge province. It covers a relatively small area of about 16,500 square miles (Reference 46).

The historical record of the region attests to the areal extent of the zone as described above. The historical record is over 200 years long within a relatively well populated area. Therefore shocks of intensity V (MM) and greater would have been recorded by the local populace. Bolinger (Reference 46) has worked out the theoretical earthquake recurrence ratio for different levels of earthquake intensity for the eastern United States. For the large earthquake intensities the recurrence rates are VIII (MM) (51 years), and VII (MM) (13 years) and much less for the lower intensities.

Although these types of calculations are highly subjective for the eastern United States, they should be applicable in a qualitative sense. They suggest a fair amount of intensity V (MM) and VI (MM) activity should be present in any seismically active zone over the 200 year history and such is the case in the Piedmont area described as the central Virginia seismic zone. This activity is shown graphically on Figure 2.6-26. However, no activity at all of intensity V (MM) or greater has been observed in the Coastal Plain of southeastern Virginia.

This reasoning indicates that based on earthquake recurrence estimates the seismic zone does not extend into the Coastal Plain.

In addition, the isoseismal plots of historic and recent earthquakes (Figures 2.6-27 and 2.6-28) show either a lobate or an elliptical trend striking north northeast parallel with regional structure. Such elongation may be characteristic of the direction of geologic faulting triggering the earthquake.

Geologic and geophysical evidence reviewed also showed continuity of north northeast trending structures. In particular:

1. Geologic mapping, showing continuous north-northeast stratigraphic trends shown on Figure 2.6-3.
2. Tectonic structure shows no major east-west faults as shown on Figure 2.6-8.
3. Triassic dikes (Reference 47) show continuous north-northeast/north-northwest trends over the entire Virginia Piedmont with no major disruption.
4. Published aeromagnetic maps (Reference 48) shown on Figure 2.6-29 and unpublished maps (Reference 49) available for inspection at the U.S.G.S office in Beltsville, Maryland, also show continuity of north-northeast regional structure.
5. The adjacent Coastal Plain area to the east was also investigated geologically and geophysically and again continuity of north-northeast/south-southwest structures was observed.

The causal mechanism of the central Virginia seismic zone earthquakes has not been well defined. Bollinger (Reference 45) suggests that the strain developed by crustal uplift of the southern Appalachians may be the proximate cause of seismicity in the central Virginia seismic zone and other areas of southeastern U.S. Figures 2.6-30 and 2.6-31 show the pattern of recent

geodetic uplift in the eastern U.S. A hinge line is suggested in northern North Carolina in the Piedmont province relatively close to the central Virginia seismic zone. The hinge in the Coastal Plain is further south, in southern North Carolina.

Of the 11 shocks historically felt in the site area, 3 were related to the central Virginia seismic zone. They are:

1. February 21, 1774, Richmond, Virginia; VI (MM)
2. August 27, 1833, Charlottesville, Virginia; VI (MM)
3. December 22, 1875, Richmond, Virginia; VI to VII (MM)

Charleston, South Carolina

The seismic history of the southeastern United States is dominated by earthquake activity in the Charleston area. Charleston is about 350 miles south of the site and represents the closest zone of major earthquake activity. Of the 850 earthquakes reported for the southeastern United States in the period of 1754 to 1971, 402 have been in the Charleston area. All of these shocks have been localized to a very limited area around Charleston. Geologically, there is no satisfactory explanation for the localized activity nor is there any satisfactory regional geological evidence to include Charleston as part of any regional trend. Based on the character of the historical record alone, the high frequency of shocks consistently within a small area, the Charleston area is treated as a seismotectonic province by itself. The largest shock that occurred here was the shock of August 31, 1886 of epicentral intensity X (MM). It was felt at the site with an intensity V (MM).

Other Earthquake Activity

Some more distant shocks have been felt in the site area. These are the New Madrid, Missouri shocks of 1811 and 1812 of epicentral intensity XII and the Canadian shock of 1870 of epicentral intensity IX. These are not geologically related to the regional geology of the site.

In addition to the activity noted, there is a scatter of small shocks in the region which cannot be related to known geologic structure. None of these shocks have exceeded epicentral intensity V (MM). It is probable that they are related to local minor zones of weakness in the earth's crust or to gradual crustal flexure along hinge zones of crustal uplift and subsidence.

2.6.2.4 Site Acceleration Probability and Building Code Zonation

The Surry Site is in an area of minor expectable earthquake damage and low likely peak acceleration according to all published building codes and all probability acceleration estimates associated with building codes.

According to the 1982 edition of the Uniform Building Code (Reference 58), the site is within Zone 1, a zone characterized as one of minor damage corresponding to intensities V (MM) and VI (MM). The UBC zones are based principally on the known distribution and intensities of

damaging historic earthquakes generalized somewhat to take into account geological considerations.

An early evaluation of probabilistic acceleration for the United States by Algermissen and Perkings in 1976 (Reference 59), which was based on a conservative generalization of historic earthquake activity, shows the 500-year acceleration at the Surry Site (that acceleration with a 10 percent chance of occurring during a 50-year period) to be 0.04g neglecting site specific foundation condition effects.

A slightly modified version of the Algermissen and Perkins (1976) map was subsequently derived by Donovan, et al. in 1978 (Reference 60). The isoacceleration contours of this later map were subsequently adopted by both the American National Standards Institute in 1982 (Reference 61) and, after some further modification to consider political boundaries, by the Applied Technology Council (Reference 50).

The Donovan, et al map shows the site to be one for which the 500-year acceleration is just below 0.05g. ANSI Standard A58.1-1982 (Reference 61) places the site within Zone 0, one for which no damage from earthquakes is expected. The zonation maps published by the Applied Technology Council (NBS Special Publication 510) (Reference 50) show the Surry site to be in a map zone 2 for both coefficients A_v and A_a. Table 1-B of the same publication assigns zone 2 an A_a coefficient and an A_v coefficient value of 0.05. The value of A_a may be used as the numerical equivalent to the effective peak acceleration (EPA) when the EPA is expressed as a decimal fraction of the acceleration of gravity. The Surry site would then have a g value of 0.05.

The Applied Technology Council provisions also address foundation conditions. In general, the high frequency design reponses indicated by the Code are the same for rock, stiff-soil, and deep cohesionless soil sistes. For sites with soft to medium clay foundations, a reduction factor of 0.8 is used for all seismic zones. For periods greater than about 0.4 second, responses on deep cohesionless soil foundations begin to exceed those on rock or stiff soils. For periods greater than about 0.6 second, soft to medium clay foundation responses begin to exceed those of all other foundation types.

2.6.2.5 **Design Earthquakes**

Section 72.66(b) of 10 CFR Part 72 requires that, for determining the seismic design level of the Surry Site ISFSI, a site-specific investigation be performed to establish site suitability commensurate with the specific requirements of the ISFSI.

The Surry ISFSI consists of only two basic elements: The SSSCs and the concrete slabs on which they rest. As discussed in the reports describing the SSSCs, the casks have been designed and tested to withstand, without loss of integrity, loads exceeding any possible seismic design condition. Due to the inherent safety of the SSSCs, the concrete slabs are not important to safety.

For this reason, the approach has been taken that a conservative estimate of proper design is one determined by use of a building code-type seismic design level. As discussed in

Section 2.6.2.4, this level of design may be generally related to a peak ground surface acceleration with a 10-percent chance of occurring in a 50-year period, or to a generalized site intensity which can, in turn, be related to a peak ground surface acceleration.

Site-specific modifications of ground motion, to take into account possible differences between the foundation conditions at the site and those implicit in both the probabilistic acceleration and the intensity versus acceleration surface design motion characterizations, are not usually considered in building code-type design, and have not been considered here.

The studies referenced in Section 2.6.2.4 show that the site probabilistic acceleration is 0.05g or less and that the site historic intensity is VI (MM) or less. This intensity can be related to a peak horizontal acceleration of 0.066g (Trifunac and Brady 1975) (Reference 51). A conservative value of 0.07g is adopted for the Surry ISFSI.

2.6.3 Surface Faulting

The ISFSI need not be designed for surface faulting. As previously stated in Section 2.6.1.3, there is no evidence of surface faulting at or near the proposed site nor are there any known active faults within 5 miles of the site that could cause surface faulting. In addition, all evidence about the sediments overlying the crystalline bedrock indicates that they are undeformed. These sediments range in age from Recent to Cretaceous.

2.6.3.1 Evidence of Fault Offset

There is no evidence of fault offset at or near the ground surface at or near the Surry site.

2.6.3.2 Identification of Active Faults

Within 5 miles of the site, there is no evidence of active faults and no evidence of faults 1000 feet long.

2.6.4 Stability of Subsurface Materials

The stability of subsurface materials is discussed in Sections 2.6.4.7 and 2.6.4.8.

2.6.4.1 Geologic Features

As discussed under Section 2.6.1.3, there are no geologic features, such as cavernous or karst terrains, calcareous or soluble deposits, tectonic depressions or regional warping, deformational or shear zones, unrelieved residual stresses, or mineral extractions associated with the site which would cause collapse or instability of the subsurface materials on the site.

Man-made activities related to the withdrawal of fluids from the ground beneath the site are related only to the pumping of water from wells, as discussed in Section 2.5. Neither the location nor quantity of ground water removed can be postulated to cause collapse of the ground. The removal of ground water from existing wells, 400 feet deep, on the site property for power station makeup and for domestic uses, as noted in Section 2.5, would not cause sufficient change in

localized ground water gradients to affect the stability or cause excessive settlement of the ISFSI foundations.

2.6.4.2 **Properties of Underlying Materials**

An investigation was made to determine the properties of the underlying materials at the site of the ISFSI. The investigation included drilling nine test borings and installing one observation well. The maximum depth of the borings was 100.5 feet. A detailed description of the investigation, laboratory testing, and analyses is presented in a report by Bechtel Associates Professional Corporation (Virginia) (Reference 52). Complete boring logs identifying all samples and indicating penetration resistance values are shown on Figures 2.6-32 to 2.6-42. Figure 2.6-43 shows the location of the borings and observation well.

Laboratory testing of the recovered samples included Atterberg limits, determination of natural moisture contents and unit weights, grain size determinations, unconfined compression tests, unconsolidated undrained triaxial compression tests, consolidated undrained triaxial compression tests, and one dimensional consolidation tests. Table 2.6-7 contains a summary of the classification testing results. Figures 2.6-44 to 2.6-47 show the results of the strength and consolidation tests. Table 2.6-8 summarizes the static engineering properties of the soil profile as determined from the laboratory testing and subsurface investigation.

Figures 2.6-48, 2.6-49, and 2.6-50 show the soil profiles in the ISFSI area, interpreted from the sample borings and laboratory test results. In general, the soil profile can be divided into upper near-surface Pleistocene sediments and underlying Miocene sediments. The geologic contact between the Pleistocene and Miocene is shown on the soil profiles. The foundation slab for the ISFSI will be founded on structural backfill within the Pleistocene deposits.

2.6.4.2.1 Pleistocene Sediments

The Pleistocene sediments can be subdivided into three layers. The upper-most layer, ranging in thickness from 12 to 15 feet, is a dark brown to gray silty clay (CH-CL) to clayey silt (MH-ML). Standard penetration values ranged from 5 to 13 with an average value of 9. The undrained cohesive shear strength of the layer based on field and laboratory testing was determined to be 1100 psf. The consolidation testing indicated the clay layer was preconsolidated to at least 1.5 ksf, with a compression index of 0.066, a recompression index of 0.009, and a coefficient of consolidation of 0.060 square foot per day.

The middle-Pleistocene layer is a reddish-brown silty-fine sand (SM) to tan fine sand (SP) ranging in thickness from 5 feet at Boring B-9 to nearly 12 feet at the remaining borings. Standard penetration values ranged from 9 to 32 with an average value of 19. The angle of internal friction used in the analysis was conservatively taken to be 32 degrees.

The lowest layer in the Pleistocene is a tan medium to coarse sand with some fine gravel (SP). The division between this coarse material and the overlying fine sand usually occurs at the water table. Standard penetration values of this layer ranged from 5 to 43 with an average value

of 14. The high N-values were most likely caused by the presence of gravel in the tip of the split-spoon sampler. The angle of internal friction used in the analysis was conservatively taken to be 30 degrees. It is estimated, using Gibbs and Holtz[53] correlations that the average relative density of this sand layer is 50 percent. The liquefaction potential evaluation of this layer is discussed in Section 2.6.4.8.

2.6.4.2.2 Miocene Sediments

The Miocene sediments were encountered at an average depth of 35 to 40 feet before existing grade. The uppermost Miocene deposit consists of a greenish gray silty fine sand (SM) to a fine sandy silt varying in thickness from 25 feet at Boring B-3 to 45 feet at Boring B-6. The standard penetration values ranged from 4 to 14 with an average of 8. The laboratory tests indicate that this layer is almost nonplastic and has an undrained cohesive shear strength of 400 psf and an angle of internal friction of 17 degrees.

The deepest deposit encountered in the borings is the Miocene clay. This layer extends from the bottom of the Miocene silty-fine sand to a depth of over 100 feet. The standard penetration values of the greenish-gray clay ranged generally from 6 to 32 with an average value of 12. Some very high N-values obtained (>20) were associated with cemented shell zones within the clay deposits. The undrained cohesive shear strength of the Miocene clay based on laboratory tests was determined to be 1500 psf.

The liquefaction potential evaluation of the Miocene sediments is discussed in Section 2.6.4.8.

2.6.4.2.3 Structural Backfill

Structural backfill will be composed of well-graded, durable granular material compacted to a high percentage of its maximum dry density. The material will be tested prior to placement to ensure that it meets these requirements. For analysis, an angle of internal friction for the fill was conservatively taken to be 35 degrees.

2.6.4.2.4 Dynamic Engineering Properties

No new dynamic testing was performed during the investigation for the ISFSI. Appendix 2B contains a report of the dynamic soil properties of the various soil layers at the Surry site, as determined during the investigation for Surry Power Station Units 3 and 4.

2.6.4.3 **Plot Plan**

A plot plan of the nine borings drilled and the single observation well installed is shown on Figure 2.6-43. The subsurface profiles are shown on Figures 2.6-48, 2.6-49, and 2.6-50.

2.6.4.4 **Soil and Rock Characteristics**

The soil and rock characteristics are discussed in Section 2.6.4.2.

2.6.4.5 Excavation and Backfilling

The proposed excavation plan for each facility is shown on Figure 2.6-51. The excavated material will be spoiled. The backfill will be select granular material with less than 10 percent passing the No. 200 sieve. The fill material will be from an offsite borrow area.

The fill material will be tested prior to delivery to the site to ensure the gradation meets the requirements of the technical specification and to determine the maximum dry density according to ASTM D 1557. The borrow material will be frequently tested during placement to verify gradation and establish maximum dry density values with which to compare field density tests.

The backfill under the structures will be compacted to a high percentage of maximum dry density according to ASTM D 1557. Testing will be required on a routine basis according to the technical specification to ensure adequate compaction is achieved. The lift thickness and compactive effort will be adjusted in the field to maintain the required compaction.

2.6.4.6 Ground Water Conditions

At the ISFSI site, static water levels were observed in the nine bore holes and the one observation well. The location of the borings and the well are shown on Figure 2.6-43. The static water level was at approximate elevation +10 feet. The water level in the observation well is currently being monitored and will continue to be monitored until the construction phase of the project begins. An as-built sketch of the observation well installed at the ISFSI site is shown on Figure 2.6-52.

Fluctuations of 3 feet to 4 feet in piezometric levels were observed during construction of Surry Power Station Units 1 and 2 and were anticipated at the Unit 3 and 4 site; therefore, it is reasonable to expect similar fluctuations at the ISFSI site.

Ground water conditions are also discussed in Sections 2.5 and 2.6.1.9.

2.6.4.7 Response of Soil and Rock to Dynamic Loading

No new dynamic soil testing was performed during the investigation for the ISFSI. Appendix 2B contains a report of the dynamic soil properties of the various soil layers at the Surry site as determined during the investigation for Surry Power Station Units 3 and 4.

It is anticipated that under Design Earthquake (DE) loading conditions, some minor ground subsidence could occur. However, the magnitude of subsidence can be considered insignificant and will have no adverse effect on the structural slab.

A discussion of the response of the soils to dynamic loading with regard to liquefaction potential is presented in Section 2.6.4.8.

2.6.4.8 **Liquefaction Potential**

2.6.4.8.1 General

A liquefaction potential analysis was performed for all soil layers below the water table. The procedures that were used for determining the liquefaction potential were those developed by Seed and Idriss (Reference 54) and Seed, Idriss, and Arango (Reference 55). The procedure consists of evaluating the shear stress ratio necessary to cause liquefaction and comparing it to the shear stress ratio expected to be induced during the DE loading. The DE loading that was used in the analysis has a maximum acceleration at the ground surface of 0.07g and a magnitude of 5 1/2. The water table elevation used in the analysis was conservatively taken to be at El. +15 feet. This elevation was based on the observed elevation at the time of the borings (+10 feet) and the maximum anticipated ground water fluctuations of 3 to 4 feet.

The maximum shear stress ratios expected during the DE were computed by evaluating the total weight of the soil column above a unit area at the designated depth and multiplying that weight by the average anticipated horizontal acceleration. The equivalent uniform horizontal acceleration value is taken to be 65 percent of the maximum in accordance with Seed and Idriss's procedure. Seed and Idriss also recommend incorporating a shear stress reduction factor into the analysis since the flexibility of the soil column results in reduced stresses.

These reduction factors, as a function of depth, are shown in Figure 2.6-53. The resulting equation for calculating the induced stress ratio is as follows:

$$\frac{\tau_h(ave)}{\sigma'_o} = 0.65 a_{max}/g \cdot \sigma_o/\sigma'_o \cdot r_d$$

where, $\frac{\tau_h(ave)}{\sigma'_o}$ = average cyclic shear stress ratio as a result of the earthquake loading

a_{max} = maximum acceleration at the ground surface due to earthquake loading

σ_o = total overburden pressure

σ'_o = effective overburden pressure

r_d = stress reduction factor from Seed and Idriss (Reference 54)

The shear stress ratio (τ/σ'_v) required to cause liquefaction was evaluated for the DE from the normalized penetration values (N-values) and the Seed, Idriss, and Arango correlation of N_1-values and the shear stress ratio to cause liquefaction. These correlations are shown in Figure 2.6-54. The normalized penetration value (N_1), which is adjusted to an effective

overburden pressure of 1 ton per square foot, is determined from the field standard penetration value (N) using the following relationship:

$$N_1 = N \cdot C_N$$

where, N_1 = Normalized standard penetration value at 1 ton per square foot

N = Standard penetration field value

C_N = Standard penetration adjustment factor from Seed, et al. (Reference 55).

The standard penetration adjustment factors as a function of effective overburden pressure are shown in Figure 2.6-55.

The resulting factor of safety against liquefaction is defined as the ratio of the shear stress ratio necessary to cause liquefaction to the shear stress ratio induced by the DE and as defined by the following equation:

$$FS = \frac{(\tau/\sigma'_v)}{\tau_h(ave)/\sigma'_o}$$

Therefore, in order to calculate the factor of safety against liquefaction at any given depth in a sand layer for a known magnitude earthquake, it is necessary to determine the total and effective overburden stresses, the stress reduction factor, and the normalized standard penetration value. The factor of safety against liquefaction, as discussed below, was determined for the two sand layers encountered below the water table.

2.6.4.8.2 Pleistocene Sand

The Pleistocene sand directly below the water table is a tan, medium to coarse sand with some fine gravel. The depth of the layer is generally from 23 feet to 35 feet below existing grade. The factor of safety against liquefaction was calculated for this layer at three depths, i.e., the top, midpoint, and bottom of the layer. The N-value used in the analysis, at all depths, was the lower one-third value for the layer. The resulting factors of safety are shown on Table 2.6-9. The minimum factor of safety for this layer is 2.5.

2.6.4.8.3 Miocene Silty Sand

The Miocene silty sand directly below the Pleistocene sand extends generally to a depth of 75 feet. The factor of safety against liquefaction for this layer was also calculated at three depths using the lower one-third N-value. The resulting factors of safety are shown on Table 2.6-9. The minimum factor of safety for this layer is 1.5.

A second analysis was also performed for this layer incorporating an adjustment factor due to the high silt content of this layer. An adjustment of 7.5 (Seed, et al. (Reference 55) is made on

the N_1 value when the D_{50} is less than 0.15 mm. Using this adjustment factor, the calculated minimum factor of safety is 3.5.

2.6.4.8.4 Miocene Clay

Seed, Idriss, and Arango (Reference 55) have stated that under some conditions a clay can liquefy; however, if the clay has certain physical properties, it can be considered nonliquefiable. These conditions are as follows:

1. If the clay content (percent finer than 0.005 mm) is greater than 20 percent.
2. If the water content is less than 90 percent of the liquid limit.

The test results showed the Miocene clay met both these criteria. In addition, the dynamic stresses induced by the DE in the Miocene clay (as well as the upper clay layer) are considerably less than the shear strength of these layers. Therefore, no reduction of shear strength will result.

2.6.4.9 **Earthquake Design Basis**

The earthquake on which the liquefaction analyses are based is the design earthquake discussed in Section 3.2.3.

2.6.4.10 **Static Analysis**

The dry cask installation will be soil supported and will settle under the loading of the casks. The settlement will be a combination of immediate elastic settlement of the granular backfill and consolidation settlement of the upper clay layer. The total calculated settlement of the slab will be less than 2 inches with most of the settlement due to consolidation of the clay. Differential settlement will be less than 1 inch. Since there are no rigid piping connections from the dry cask facility, the settlement of 2 inches will be within tolerable limits. Bearing capacity analyses indicate a factor of safety of more than 3 against a bearing capacity failure due to cask loading. A summary of the soil properties used in the analysis are shown in Table 2.6-8 with supporting laboratory data shown in Figures 2.6-44 to 2.6-47.

There will be no buried structures for the ISFSI. Therefore, lateral pressures are not considered.

2.6.4.11 **Techniques to Improve Subsurface Conditions**

Analysis has shown that the upper clay layer has an inadequate factor of safety against bearing capacity failure and would settle beyond acceptable limits upon loading if allowed to remain in place. Therefore, the upper 7 feet of the clay layer will be removed and replaced with a well compacted granular structural backfill as described in Section 2.6.4.5. The settlement, due to the cask loading with the 7 feet of structural backfill in place above the remaining clay, will be less than 2 inches, which is within acceptable limits.

2.6.4.12 **Criteria and Design Methods**

The foundation design criteria for the ISFSI consisted of meeting or exceeding the appropriate minimum factors of safety and loading requirements that were established.

2.6.4.12.1 Bearing Capacity

The bearing capacity factor of safety was defined as the ratio of the net ultimate capacity to the net applied foundation bearing pressures. The static factor of safety considered the total dead and live loads acting on the structure. A minimum safety factor of 3.0 was established as the criterion. The dynamic factor of safety considered the total static dead and live loads and the maximum dynamic soil pressures. A minimum value of 2.0 was established as the criterion. The ultimate bearing capacity was determined using conventional bearing capacity equations and bearing capacity factors (Reference 56).

2.6.4.12.2 Foundation Stability

The factor of safety against liquefaction is defined as the ratio of the shear stress to cause liquefaction to the shear stress induced by the earthquake. The minimum factor of safety established against liquefaction is 1.5 for an average N-value.

The minimum factor of safety for slope stability is 1.5 for permanent slopes and 1.2 for temporary slopes. A discussion of the site slope stability is in Section 2.6.5.

2.6.5 Slope Stability

The only slopes that will exist in relationship to the ISFSI will be temporary slopes during the excavation and backfilling operation. The slopes will be entirely in the upper clay layer and cut on a 1.5 H:1.0 V slope. The resulting factor of safety is over 2.0. After completion of the backfilling there will be no natural or man-made slopes that will have a bearing on the ISFSI.

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Table 2.6-1
OROGENIC MOVEMENTS IN THE CENTRAL APPALACHIAN REGION
(REFERENCE 12)

Orogenic Episode and Approximate Time Interval	Known Area of Influence	Maximum Manifestation
Appalachian Movements		
Palisadian		
Late Triassic (Carnian-Norian) 190 to 200 million years	Belt along central axis of already completed mountain chain	Fault troughs, broad warping, basaltic lava, dike swarms.
Allegheny		
Pennsylvania and/or Permian (Westphalian and later) 230 to 260 million years	West side of central and southern Appalachians, southeast side of northern Appalachians perhaps also in Carolinian Piedmont	Strong folding, also middle-grade metamorphism and granite intrusion, at least in southern New England
Acadian		
Devonian, mainly Middle but Episodic into Mississippian (Emsian-Givetian 360 to 400 million years)	Whole of northern Appalachians, except along northwest edge; as far southwest as Pennsylvania	Medium to high grade metamorphism, granite intrusion
Taconic		
Middle (and Late) Ordovician (Caradocian, locally probably older) 450 to 500 million years	General on northwest side of northern Appalachians, local elsewhere; an early phase in Carolinas and Virginia, perhaps general in Piedmont province	Strong angular unconformity, gravity slides, at least low grade metamorphism, granodioritic and ultramafic intrusion
Avalonian		
Latest Precambrian 580 to 600 million years	Southeastern Newfoundland, Cape Breton sland, southern New Brunswick; probably also central and southern Appalachians	Probably some deformation, uplift of sources of coarse arkosic debris, gravity slides
Grenville (pre-Appalachian) movements		
Late Precambrian 800 to 1100 million years	Eastern North America including western part of Appalachian region	High-grade metamorphism, granitic and other intrusion

Table 2.6-2
GROUNDWATER LEVELS
DECEMBER 1972 TO FEBRUARY 1973
UNITS 1 AND 2

Piezometer		Groundwater Elevation (ft) msl		
Number	Tip Elevation (ft)	Minimum	Maximum	Average
C-60	-	9.9	10.9	10.0
P-1A	-10.0	12.8	13.4	13.1
P-1B	-19.0	5.1	7.7	6.4
P-1C	-31.2	5.3	9.0	7.1
P-2A	-8.1	5.4	7.5	6.5
P-2B	-33.5	6.5	8.7	7.6
P-2C	-38.2	5.6	8.8	7.2
P-3B	-51.0	10.5	13.0	11.7
P-3AA	-31.0	0.0	1.2	0.6
P-5B	-37.0	6.4	7.7	7.0
P-6	-12.0	2.2	2.2	2.2
P-7A	-12.0	1.9	2.1	2.0
P-8	-12.0	1.6	2.0	1.8
P-9	-3.0	6.4	7.8	7.1

Table 2.6-3
GROUNDWATER LEVELS
DECEMBER 1972 TO FEBRUARY 1973
UNITS 3 AND 4

Piezometer		Groundwater Elevation (ft) msl		
Number	Tip Elevation (ft) msl	Minimum	Maximum	Average
10A	-0.1	15.7	16.3	16.0
10B	-46.0	14.5	16.3	15.2
11A	-10.6	14.4	16.4	15.8
11B	-31.2	15.6	16.8	15.9
12A	2.0	15.7	17.1	16.3
12B	-43.8	14.7	16.3	15.3
13A	-6.1	12.4	13.9	13.3
13B	-33.8	15.1	16.6	16.1
14A	2.2	12.7	13.7	13.1
14B	-37.0	8.8	9.8	9.1

Table 2.6-4
FIELD PERMEABILITY TEST RESULTS

Boring No.	Elevation(a) msl	Basic Time Lag (min) Horizontal	Basic Time Lag (min) Mean	Permeability (x 10^{-1} ft/day) Vertical	Permeability (x 10^{-1} ft/day) Horizontal	Permeability (x 10^{-1} ft/day) Mean
B-201	10.2	145.0	348.0	5.5	1.6	3.0
B-201	5.2	1.2	37.0	4.2	190.0	28.3
B-201	0.2	164.0	(a)		1.4	
B-201	-9.8	7.0	245.0	0.5	34.0	4.3
B-201	-14.8	(b)	100.0			10.5
B-201	-19.8	12.0	(a)		19.8	
B-201	-29.8	15.8	286.0	0.9	15.0	3.7
B-201	-34.8	21.0	298.0	1.1	11.3	3.5
B-201	-39.8	(a)	592.0			1.8
P-10A	1.5(c)	218.0	(a)		1.0	
P-10B	-44.5	34.0	(a)		8.2	
P-11A	-8.3	(a)	258.0			4.1
P-11B	-33.3	37.4	171.0	7.3	5.2	0.2
P-13A	-4.5	9.1	2500.0	0.01	26.1	0.4
P-14B	-34.3	156.0	(a)		1.5	

(a) Test data not reliable
(b) No determination
(c) Elevation where permeability test was performed

Notes: Permeability values were determined from falling head tests in flush joint casing using clean water. Appropriate boundary conditions and test procedures per Hvorslev, J. M. “Time Lag in the Observation of Ground Water Levels and Pressures,” U. S. Army Waterways Experiment Station, Vicksburg, Miss., 1949.

Table 2.6-5
MODIFIED MERCALLI INTENSITY (DAMAGE) SCALE OF 1931
(Abridged)

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. Considerably 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. (VIII+ to IX- Rossi-Forel Scale.)
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 into the air.

Table 2.6-6 (SHEET 1 OF 6)
SIGNIFICANT EARTHQUAKES [a, b]
ALL EARTHQUAKES WITHIN 50 MILES OF SITE
ALL EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 200 MILES OF SITE [a, b]

Year	Date	Time	Epicentral Intensity	Approximate Location	N Lat	W Long	Perceptible Area (Sq Mi)	Distance From Site
1774	Feb. 21	14:	VI	Va.	37.3	77.4	58,000	43.5
1774	Feb. 22	05:	V-VI	Va.	37.5	77.5		50.8
1802	Aug. 23	05:	V	Richmond, Va.	37.6	77.4		49.3
1807	Apr. 30, May 1	04:00	V	Richmond-Fredericksburg Area				
1811 [a]	Dec. 16	02:00	XII	New Madrid, Mo.	36.6	89.6	2,000,000	705
1812 [a]	Jan. 23		XII	New Madrid, Mo.	36.6	89.6	-	705
1812 [a]	Feb. 7		XII	New Madrid, Mo.	36.6	89.6	-	705
1812	Apr. 22	04:00	IV	Richmond, Va.	37.6	77.4	-	49.3
1816	Dec. 31	13:00	III	Norfolk, Va.	36.8	76.3	-	33.5
1824	Jul. 15	11:20	V	W. Va.-Ohio			63,000	
1826	Aug. 9	21:00	II-III	Richmond, Va.	37.6	77.4	-	49.3
1826	Aug. 10	12:00	II-III	Richmond, Va.	37.6	77.4	-	49.3
1828	Mar. 9	22:00	V	W.-Central Va.			218,000	
1833	Aug. 27	06:00	V	Charlottesville-Richmond, Va.	37.75	78.	61,000	84.3
1852	Apr. 29	13:00	VI	Va.-N.C.-Tenn. (Mt. Rogers in Va.)	36.6	81.6	187,000	270
1852 [a]	Nov. 2	18:35	VI	Eastern Va.	37.75	78.	32,000	84.3
1853	May 2	09:20	V-VI	Va.-W. Va.-Ohio	38.5	79.5	72,000	179
1861	Aug. 31	05:22	VI	S.W. Va.-W. N.C.			300,000	
1870 [a]	Oct. 20	11:25	IX	Canada (Baie St. Paul)	47.4	70.5	1,000,000	780

Table 2.6-6 (SHEET 2 OF 6)
SIGNIFICANT EARTHQUAKES [a, b]
ALL EARTHQUAKES WITHIN 50 MILES OF SITE
ALL EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 200 MILES OF SITE [a, b]

Year	Date	Time	Epicentral Intensity	Approximate Location	N Lat	W Long	Perceptible Area (Sq Mi)	Distance From Site
1871	Oct. 9		VII	Wilmington, Del.	39.75	75.5	-	195
1872	June 4	22:00	III	Chesterfield	37.60	77.4	9000	46.4
1875	Dec. 22		VI	Arvonia, Va.	37.5	77.5	50,000	50.8
1883	Mar. 11	18:57	IV-V	Harford County, Md.	39.5	76.4	-	164.5
1883	Mar. 12	00:	V	Harford County, Md.	39.5	76.5	-	163.7
1885	Jan. 2	21:16	V	Loudon Co. Va.	39.2	77.5	9000	149.5
1885	Aug. 9	23:35	V	Md.-Va. Border Va.	37.7	78.8	29,000	121.5
1886 [a]	Aug. 31	21:51	X	Charleston, S. C.	32.9	80.0	2,000,000	352
1889	Mar. 8	18:40	VI	S. E. Pa.	40.0	76.75	4000	197
1897 [a]	May 3	12:18	VI	Pulaski, Va.	37.1	80.7	150,000	222.5
1897 [a]	May 31	13:58	VIII	Giles County, Va.	37.3	80.7	280,000	222
1897	June 28		V	Roanoke, Va.	37.3	79.9	9500	176.5
1897	Dec. 18	18:45	V	Ashland, Va.	37.7	77.5	10,000	57.2
1906	May 8	12:41	V	Del.	38.7	75.7	400	118.2
1907	Feb. 11	08:22	VI	Arvonia, Va.	37.7	78.3	2000	94.6
1908	Aug. 23	04:30	V	Powhatan, Va.	37.5	77.9	450	71.0
1909	Apr. 2	02:25	V-VI	W. Va.-Va.-Md.-Pa.	39.4	78.0	2500	174.5
1910	May 8	16:10	V	Arvonia, Va.	37.7	78.4	350	99.5
1918	Apr. 9	21:09	V-VI	Luray, Va.	38.7	78.4	100,000	139.0
1918	Apr. 19	11:55	III	Norfolk, Va.	36.9	76.3	-	33.2
1919	Sept. 5	21:46	VI	Front Royal, Va.	38.8	78.2	-	141.0
1921	Aug. 7	01:30	VI	New Canton, Va.	37.8	78.4	2800	100.5

Table 2.6-6 (SHEET 3 OF 6)
SIGNIFICANT EARTHQUAKES [a, b]
ALL EARTHQUAKES WITHIN 50 MILES OF SITE
ALL EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 200 MILES OF SITE [a, b]

Year	Date	Time	Epicentral Intensity	Approximate Location	N Lat	W Long	Perceptible Area (Sq Mi)	Distance From Site
1923	Dec. 31		V	Clarke County, Va. Boyse Section	39.2	78.	-	156.5
1924	Jan. 1		IV-V	Clarke County, Va.	39.2	78.	-	156.5
1924	Dec. 25		V	Roanoke, Va.	37.3	75.9	-	177.0
1925	July 14	16:20	IV	Richmond, Va.	37.6	77.4	-	49.3
1927	June 10	02:16	V	Augusta County Va.	38.	79.	2500	140.0
1928	Oct. 30	06:45	IV	Richmond, Va.	37.5	77.5	3100	50.8
1929	Dec. 25	21:56	VI	Albemarle County, Va.	38.1	78.5	1000	120.0
1932	Jan. 4	23:05	V	Buckingham County, Va.	37.6	78.6	800	110.3
1935	Nov. 1	03:30	V	Elkins, W. Va.	38.9	75.9	-	212.0
1939	Nov. 14	21:54	V	Salem County, N. J.	39.6	75.2	6000	187.2
1940	Mar. 25		V	Shenandoah Valley, Va.	38.9	78.6	400	157.5
1948	Jan. 4		VI	Buckingham, Va.	37.5	78.5	1700	108.3
1949	May 8	06:01	IV-V	Powhatan - Richmond, Va.	37.6	77.9	2700	72.5
1950	Nov. 26	02:45	V	Buckingham County, Va.	37.7	78.4	900	99.5
1951	Mar. 9	02:00		Richmond, Va.	37.6	77.4	-	49.3
1959	Apr. 23	20:58:41	VI	Giles County, Va.	37.5	80.5	3000	210.0
1966	May 31	06:14:02	V	Powhatan, Va.	37.6	78.0	28,000	78.8
1968	Dec. 10	04:12	V	S.E. N.J.	39.7	74.6	-	208.0
1969	Dec. 11	18:44	V	Richmond, Va.	37.8	77.4	6500	61.0
1969	Dec. 11	23:44: 39 2	V	Richmond, Va.	37.8	77.4	3500	61.0

Table 2.6-6 (SHEET 4 OF 6)
SIGNIFICANT EARTHQUAKES [a, b]
ALL EARTHQUAKES WITHIN 50 MILES OF SITE
ALL EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 200 MILES OF SITE [a, b]

Year	Date	Time	Epicentral Intensity	Approximate Location	N Lat	W Long	Perceptible Area (Sq Mi)	Distance From Site
1973	Mar. 1	03:30	V-VI	Delaware County, Pa.	39.8	75.3	-	200
1974	Mar. 23	09:49	-	Shenandoah Valley, Va.	38.92	77.78	-	135.06
1974	Apr. 28	09:19	IV	Wilmington, Del.	39.75	75.5	-	195.0
1974	Nov. 7	16:31	IV	Charlottesville, Va.	37.75	78.20	-	92.45
1977	Feb. 10	19:14	V(VI)	Wilmington, Del.	39.75	75.5	-	195.0
1977	Feb. 27	20:05	V	Charlottesville, Va.	37.90	78.63	-	118.11
1977	Sept. 30	20:53	-	Louisburg, N.C.	36.05	78.35	-	120.46
1978	Feb. 25	03:53	IV	Reidsville, N.C.	36.19	79.30	-	159.98
1978	Apr. 26	19:30	-	Martinsburg, W.Va.	39.63	78.20	-	189.00
1978	Jul. 16	06:40	V	Lancaster, Pa.	39.93	76.34	-	191.85
1978	Oct. 6	19:25	V	York, Pa.	39.97	76.51	-	193.93
1978	Oct. 29	12:22	-	Louisa County, Va.	38.03	78.10	-	97.86
1978	Nov. 15	08:33	-	Richmond, Va.	37.65	77.55	-	58.13
1979	Nov. 6	04:05	-	Cumberland County, Va.	37.44	78.26	-	88.72
1979	Nov. 11	07:22	-	Richmond, Va.	37.72	77.47	-	43.48
1980	Apr. 26	03:60	-	Hanover County, Va.	37.77	77.58	-	64.47
1980	May 18	03:31	-	Powhatan County, Va.	37.58	77.94	-	74.70
1980	May 18	22:34	-	Louisa County, Va.	37.97	78.07	-	94.08
1980	Aug. 4	10:13	-	Louisa County, Va.	38.07	77.76	-	85.85
1980	Sept. 21	10:03	-	Marlinton, W. Va.	38.18	80.07	-	198.04
1980	Sept. 26	01:32	-	Louisa County, Va.	38.07	77.76	-	86.22
1980	Sept. 26	05:04	-	Warrenton, Va.	38.78	77.72	-	124.97

Table 2.6-6 (SHEET 5 OF 6)
SIGNIFICANT EARTHQUAKES [a, b]
ALL EARTHQUAKES WITHIN 50 MILES OF SITE
ALL EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 200 MILES OF SITE [a, b]

Year	Date	Time	Epicentral Intensity	Approximate Location	N Lat	W Long	Perceptible Area (Sq Mi)	Distance From Site
1980	Oct. 11	22:40	-	Louisa County, Va.	38.12	77.81	-	90.22
1980	Oct. 14	01:20	-	Floyd County, Va.	37.08	80.23	-	195.53
1980	Nov. 5	21:48	Felt-	Marlinton, W. Va.	38.18	79.90	-	189.37
1980	Nov. 25	07:44	-	Marlinton, W. Va.	38.10	80.12	-	198.83
1981	Jan. 19	21:54	-	Buckingham County, Va.	37.73	78.44	-	103.95
1981	Jan. 21	16:30	-	Buckingham County, Va.	37.77	78.42	-	103.99
1981	Feb. 11	13:44	IV	Buckingham County, Va.	37.72	78.44	-	103.70
1981	Feb. 11	13:51	III	Buckingham County, Va.	37.75	78.41	-	102.95
1981	Feb. 11	13:52	Felt	Buckingham County, Va.	37.72	78.45	-	104.21
1981	Mar. 20	04:02		Richmond, Va.	37.52	77.68	-	59.96
1981	Apr. 9	07:13		Powhatan County, Va.	37.48	77.82	-	66.12
1981	Apr. 9	07:35		Powhatan County, Va.	37.47	77.87	-	68.51
1981	Apr. 16	13:49	-	Cumberland County, Va.	37.61	78.22	-	89.78
1981	June 6	08:06	-	Bath County, Va.	38.21	79.5	-	170.57
1981	Jul. 30	12:00	-	Louisa County, Va.	38.19	78.09	-	104.50
1981	Oct. 3	09:56	-	Burlington, N.C.	36.01	79.35	-	168.20
1981	Nov. 23	13:15	-	Augusta County, Va.	38.24	79.05	-	149.15
1984	Apr. 23	01:36	-	Lancaster Co., Pa.	39.95	76.32	-	192.50
1984	Aug. 17	18:05	-	Fluvanna Co. Va.	37.87	78.32	-	101.30
1986	Feb. 02	21:50	-	Hanover Co., Va.	37.60	77.39	-	48.20
1986	Dec. 10	11:30	-	Richmond, Va.	37.59	77.47	-	51.00
1990	Jan. 13	20:47	-	Baltimore Co., Md.	39.37	76.85	-	151.70

Table 2.6-6 (SHEET 6 OF 6)
SIGNIFICANT EARTHQUAKES [a, b]
ALL EARTHQUAKES WITHIN 50 MILES OF SITE
ALL EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 200 MILES OF SITE [a, b]

Year	Date	Time	Epicentral Intensity	Approximate Location	N Lat	W Long	Perceptible Area (Sq Mi)	Distance From Site
1991	Mar. 15	06: 54	-	Goochland Co., Va.	37.75	77.91	-	77.40
1993	Mar. 15	04:29	-	Howard Co., Md.	39.20	76.87	-	140.10
1994	Aug. 06	19:54	-	Pamlico Co., N.C.	35.10	76.79	-	142.70
1995	Aug. 03	13:07	-	James City Co., Va.	37.40	76.69	-	15.90

a. Some beyond 200-mile distance, but significant to study.
b. 1774 through 1995.

Table 2.6-7 (SHEET 1 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth / Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
B-1	0'-1.5' / -	Jar	Clayey silt, trace fine sand, with organic matter - tan (ML)	-	-	-	42	33	9	21.0	-	-	-
B-1	7.5'-9' / -	Jar	Silty clay, trace fine sand - brown (CL)	-	-	-	44	23	21	30.0	-	-	-
B-1	19'-20.5' / -	Jar	Fine to coarse sand, trace silt, with gravel - tan (SP-SM)	-	-	-	-	-	-	-	6	-	See Gradation Test Curve
B-1	29'-30.5' / -	Jar	Fine to coarse sand, trace silt, & fine gravel - tan (SP-SM)	-	-	-	-	-	-	-	5	-	See Gradation Test Curve
B-1	34'-35.5' / -	Jar	Fine to medium sand, some silt, with shell fragments - brown (SM)	-	-	-		Nonplastic Fines		24.4	19	-	See Gradation Test Curve
B-1	49'-50.5' / -	Jar	Fine sand, some silt, with shell fragments - gray (SM)	-	-	-		Nonplastic Fines		30.5	29	-	See Gradation Test Curve
B-1	79'-80.5' / -	Jar	Fine silty sand, with shell fragments - dark-gray (SM)	-	-	-		Nonplastic Fines		47.5	-	-	-
B-1	84'-8.5.5' / -	Jar	Clay, trace fine sand - gray (CH)	-	-	-	64	23	41	-	-	-	-

Table 2.6-7 (SHEET 2 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth / Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf		Atterberg Limits			Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
					Wet	Dry	LL	PL	PI				
B-2	2'-4' / -	Tube	Silty clay, trace fine sand - brown & tan (CL)	-	118	89	-	-	-	33.0	-	2.69	See Triaxial and Consolidation Test Curves
B-2	4'-5.5' / -	Jar	Fine silty clayey sand - gray (SC)	-	-	-	43	17	26	27.1	-	-	-
B-2	7'-9' / -	Tube	Silty clay trace fine sand - gray & brown (CL)	-	122	87	-	-	-	31.2	-	2.67	See Triaxial and Consolidation Test Curves
B-2	9'-10.5' / -	Jar	Fine to medium silty clayey sand - brown (SC)	-	-	-	25	17	8	16.5	-	-	-
B-2	49'-50.5' / -	Jar	Fine silty sand, with shell fragments - gray (SM)	-	-	-	Nonplastic Fines			29.3	-	-	-
B-2	52'-54' / -	Tube	Fine silty sand with shell fragments - dark gray (SM)	-	123	93	-	-	-	31.3	-	2.68	See Triaxial and Consolidation Test Curves
B-2U	2'-4' / -	Tube	Clay, trace fine sand - gray & brown (CH)	-	119	88	-	-	-	34.9	-	-	See Triaxial Test Curve
B-2U	7'-9' / -	Tube	Silty clay, some fine sand - gray and brown (CL)	-	119	94	-	-	-	26.2	-	2.62	See Triaxial and Consolidation Test Curves

Table 2.6-7 (SHEET 3 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth / Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
B-2U	12'-14' / -	Tube	Fine to coarse sand, trace silt& fine gravel brown (SP)	-	120	103	-	-	-	15.8	-	-	-
B-3	0.0'-1.5' / -	Jar	Silty clay trace fine sand brown (CL)	-	-	-	24	13	11	21.7	98	-	See Gradation Test Curve
B-3	4'-5.5' / -	Jar	Clay, trace fine sand - gray (CH)	-	-	-	58	20	38	24.3	96	-	See Gradation Test Curve
B-3	14'-15.5' / -	Jar	Fine to coarse sand, trace silt- tan & brown (SP-SM)	-	-	-	-	-	-	-	7	-	See Gradation Test Curve
B-3	24'-25.5' / -	Jar	Clayey silt, trace fine sand, with organic matter & decomposed wood fragments - black (ML)	-	-	-	43	17	26	98.2	-	-	-
B-3	34'-35.5' / -	Jar	Fine sand, some silt - brown (SM)	-	-	-	Nonplastic Fines				18	2.62	See Gradation Test Curve
B-3	44'-45.5' / -	Jar	Fine sand, some silt, with shell fragments - gray (SM)	-	-	-	Nonplastic Fines			31.6	33	2.70	See Gradation Test Curve

Table 2.6-7 (SHEET 4 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
B-3	74'-75.5' -	Jar	Clay, some fine sand, with shell fragments - greenish gray (CH)	-	-	-	57	27	30	44.9	85	2.77	See Gradation Test Curve
B-4	4'-5.5' -	Jar	Clayey silt, trace fine sand - gray (ML.)	-	-	-	36	35	1	25.2	-	-	-
B-4	9'-10.5' -	Jar	Fine silt, some sand with organic matter & shell fragments - gray & brown (ML)	-	-	-	-	-	-	-	69		SeeGradation Test Curve
B-4	14'-15.5' -	Jar	Fine sand, some silt - brown (SM)	-	-	-	-	-	-	-	34	-	SeeGradation Test Curve
B-4	29'-30.5' -	Jar	Fine to coarse sand, trace silt, & fine gravel - tan (SP-SM)	-	-	-	-	-	-	-	5	-	SeeGradation Test Curve
B-4	44'-45.5 -	Jar	Fine sand, some silt, with shell fragments - dark greenish gray (SM)	-	-	-	Nonplastic Fines			29.3	17	-	SeeGradation Test Curve
B-4	84'-85.5' -	Jar	Clayey silt, some fine sand, with shell fragments - dark gray (ML-MH)	-	-	-	50	33	17	34.4	71	-	SeeGradation Test Curve

Table 2.6-7 (SHEET 5 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth / Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
B-5	2.5'-4' -	Jar	Clayey silt, trace fine sand - gray & brown (MH)	-	-	-	52	44	8	29.9	-	-	-
B-5	7.5'-9' -	Jar	Clayey silt, trace fine sand - gray & brown (MH)	-	-	-	65	38	27	36.4	97	-	SeeGradation Test Curve
B-5	14'-15.5' -	Jar	Fine sand, some silt - brown (SM)	-	-	-	-	-	-	-	15	-	SeeGradation Test Curve
B-5	29'-30.5' -	Jar	Fine to coarse sand, some fine gravel, trace silt-brown (SW-SM)	-	-	-	-	-	-	-	5	-	SeeGradation Test Curve
B-5	44'- 45.5' -	Jar	Fine sand, some silt, with shell fragments - gray (SM)	-	-	-		Nonplastic Fines		29.2	13	-	SeeGradation Test Curve
B-5U	1' -3' -	Tube	Clay, trace fine sand - light brown & tan (CH)	-	117	91	-	-	-	29.2	-	2.66	See Triaxial and Consolidation Test Curves
B-5U	4'- 6' -	Tube	Clayey silt, trace fine gray sand - gray & brown (MH)	-	120	98	-	-	-	22.8	-	2.64	See Unconfined Compression & Consolidation Test Curves

Table 2.6-7 (SHEET 6 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth / Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
B-5U	7' - 9' / -	Tube	Silty clay, trace fine sand - gray (CL)	-	114	84	-	-	-	24.1	-	2.55	See Triaxial & Consolidation Test Curves
B-5U	11' -13' / -	Tube	Clayey silt, trace fine to coarse sand - brown & tan (ML)	-	117	89	-	-	-	31.4	-	-	See Unconfined Compression Test Curves
B-6	2.5' -4' / -	Jar	Clayey silt, trace fine sand - brown & gray (MH)	-	-		70	33	37	32.6	-	-	-
B-6	24'- 25.5 / -	Jar	Fine to coarse sand, trace silt & fine gravel - tan (SP-SM)	-	-	-	-	-	-	-	6	-	See Gradation Test Curve
B-6	44' -45.5' / -	Jar	Fine sand, trace silt, with shell fragments (SP-SM)	-	-	-	Nonplastic Fines			30.2	8	-	See Gradation Test Curve
B-6	84' -85.5' / -	Jar	Clayey silt, trace fine sand with shell fragments - dary gray (MH)	-	-	-	84	52	32	49.2	-	-	-
B-7	7.5' -9' / -	Jar	Clayey silt, trace fine sand - gray (MH)	-	-	-	62	50	12	40.6	-	-	-
B-7	29' -30.5' / -	Jar	Fine to coarse sand, trace silt & fine gravel - tan (SP-SM)	-	-	-	-	-	-	-	4	-	Test Gradation Test Curve

Table 2.6-7 (SHEET 7 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth / Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
B-7	44' -45.5' / -	Jar	Fine silty sand, with shell fragments - gray (SM)	-	-	-	Nonplastic Fines			31.0	-	-	-
B-7	84' -85.5' / -	Jar	Clayey silt, some fine sand, with shell fragments - gray (MH)	-	-	-	72	45	27	46.7	-	-	-
B-7	99'-100.5' / -	Jar	Silty clay, some fine sand, with shell fragments - dark greenish gray (CL)	-	-	-	49	23	26	36.0	-	-	-
B-8	2' -4' / -	Tube	Clay, trace fine sand - light brown (CH)	-	115	85	-	-	-	-	-	-	See Triaxial and Consolidation Curves
B-8	4' -5.5' / -	Jar	Clayey silt, trace fine sand - tan & gray (ML)	-	-	-	43	34	9	25.1	-	-	-
B-8	7'-9' / -	Tube	Silty clay, trace fine sand - light gray & brown (CL)	-	120	88	-	-	-	34.0	-	2.82	See Unconfined Compression Test Curves
B-8	9' -10.5' / -	Jar	Clayey silt, trace fine to medium sand - gray & brown (ML)	-	-	-	46	37	9	32.5	-	-	-

Table 2.6-7 (SHEET 8 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
B-8	12'-14' -	Tube	Silty clay some fine sand - light gray & brown (CL)	-	116	87	-	-	-	33.0	-	2.73	See Triaxial and Consolidation Test Curves
B-8	14'-15.5' -	Jar	Fine to medium sand, some silt - brown & gray (SM)	-	-	-	Nonplastic Fines			19.6	-	-	-
B-8	29'-30.5' -	Jar	Fine to coarse sand, trace silt & fine gravel - tan (SW-SM)	-	-	-	-	-	-	-	7	-	See Gradation Test Curve
B-8	42' -44' -	Tube	Fine silty sand, with shell fragments - dark greenish gray (SM)	-	118	89	-	-	-	32.9	-	2.13	See Triaxial and Consolidation Test Curves
B-8	62'-64' -	Tube	Fine silty sand with shell fragments- dark gray (SM)	-	118	88	-	-	-	33.8	-	-	SeeTriaxial-Test Curve
B-8	82'-84' -	Tube	Clay, trace fine sand with shell fragments - dark greenish gray (CH)	-	106	70	-	-	-	51.2	-	2.74	See Triaxial and Consolidation Test Curves
B-8	84'-85.5' -	Jar	Clay, trace fine sand, with shell fragments - dark greenish gray (CH)	-	-	-	60	30	30	44.0	-	-	SeeTriaxial Test Curve

Table 2.6-7 (SHEET 9 OF 9)
SUMMARY OF SOIL LABORATORY TESTS

Boring No.	Sample Depth / Elev	Sample Type	Description of Soil Specimen	Stratum Designation	Natural Density pcf		Atterberg Limits			Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
					Wet	Dry	LL	PL	PI				
B-9	0'-1.5' / -	Jar	Clay, some fine to coarse sand - gray & tan (CH)	-	-	-	57	25	32	42.2	-	-	-
B-9	9'-10.5' / -	Jar	Clay, trace fine sand - gray & tan (CH)	-	-	-	56	29	27	44.5	-	-	-
B-9	44'-45.5' / -	Jar	Fine silty sand, with shell fragments - dark gray (SM)	-	-	-	Nonplastic Fines			30.7	-	-	-
B-9	84'-85.5' / -	Jar	Clay, trace fine sand, dark gray (CH)	-	-	-	73	13	60	48.3	-	-	-

Notes: 1. Soil tests in accordance with applicable ASTM standards.

2. Soil classifications in accordance with unified soil classification system.

3. Key to abbreviations: LL = Liquid Limit, PL = Plastic Limit, PI = Plasticity Index.

4. Soil tests were conducted by L. Carl and J. Hollowell.

Table 2.6-8
SUMMARY OF ENGINEERING PROPERTIES

Layer	Typical Depth (ft)	Total Unit Weight (PCF)	Undrained Shear Strength		Consolidation		
		γ_T -	φ	c (psf)	CR	RR	c_v Ft^2/Day
Structural Backfill	0-7	-125	35°	-	--	--	--
Pleistocene							
Silty Clay							
Clayey Silt	7-12	117	-	1100	0.066	0.009	0.060
Silty Sand							
Fine Sand	12-23	115	32°	-	--	--	--
Medium to Coarse Sand	23-35	110	30°	-	--	--	--
Miocene							
Silty Sand							
Sand Silt	35-75	119	17°	400	--	--	--
Clay	75+	110	-	1500	0.29	0.029	0.004

Table 2.6-9
LIQUEFACTION ANALYSIS SUMMARY[1]

Layer	Depth (Feet)	a_{max}	σ_o (ksf)	σ'_o (ksf)	r_d[2]	$\tau_{h(ave)} / \sigma'_o$	N[3]	C_N[4]	N_1	τ[5] $/ \sigma'_v$	FS
Pleistocene Sand	23	0.07g	2.67	2.42	.95	0.0477	11	.90	9.9	0.150	3.1
	29	0.07g	3.33	2.71	.92	0.0514	11	.84	9.2	0.143	2.8
	35	0.07g	3.99	2.99	.90	0.0546	11	.82	9.0	0.137	2.5
Miocene Silty Sand	35	0.07g	3.99	2.99	.90	0.0546	7	.82	5.7	0.086	1.6
	55	0.07g	6.37	4.12	.70	0.0492	7	.68	4.8	0.073	1.5
	75	0.07g	8.75	5.25	.57	0.0432	7	.58	4.1	0.063	1.5

NOTES:

1. All variables are defined in text.
2. Values are taken from Figure 2.6-53 (below 40 feet are extrapolated average values).
3. The field N-values were taken as the lower 1/3 value for the layer.
4. The C_N values are taken from Figure 2.6-55 using a D_r = 40 to 60 percent.
5. Values are taken from Figure 2.6-54 using an earthquake magnitude of 5 1/2.

Figure 2.6-1
REGIONAL PHYSIOGRAPHY

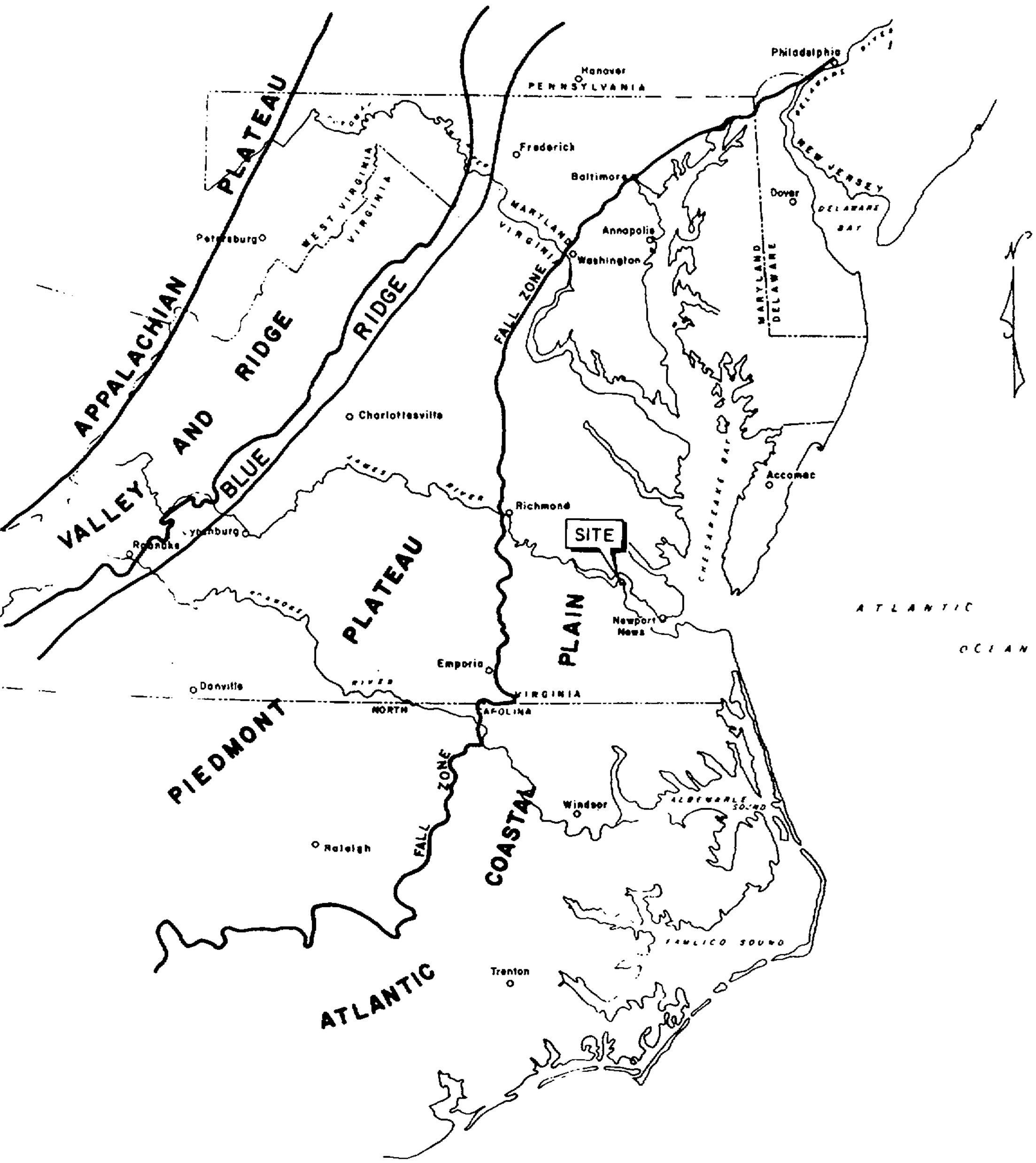

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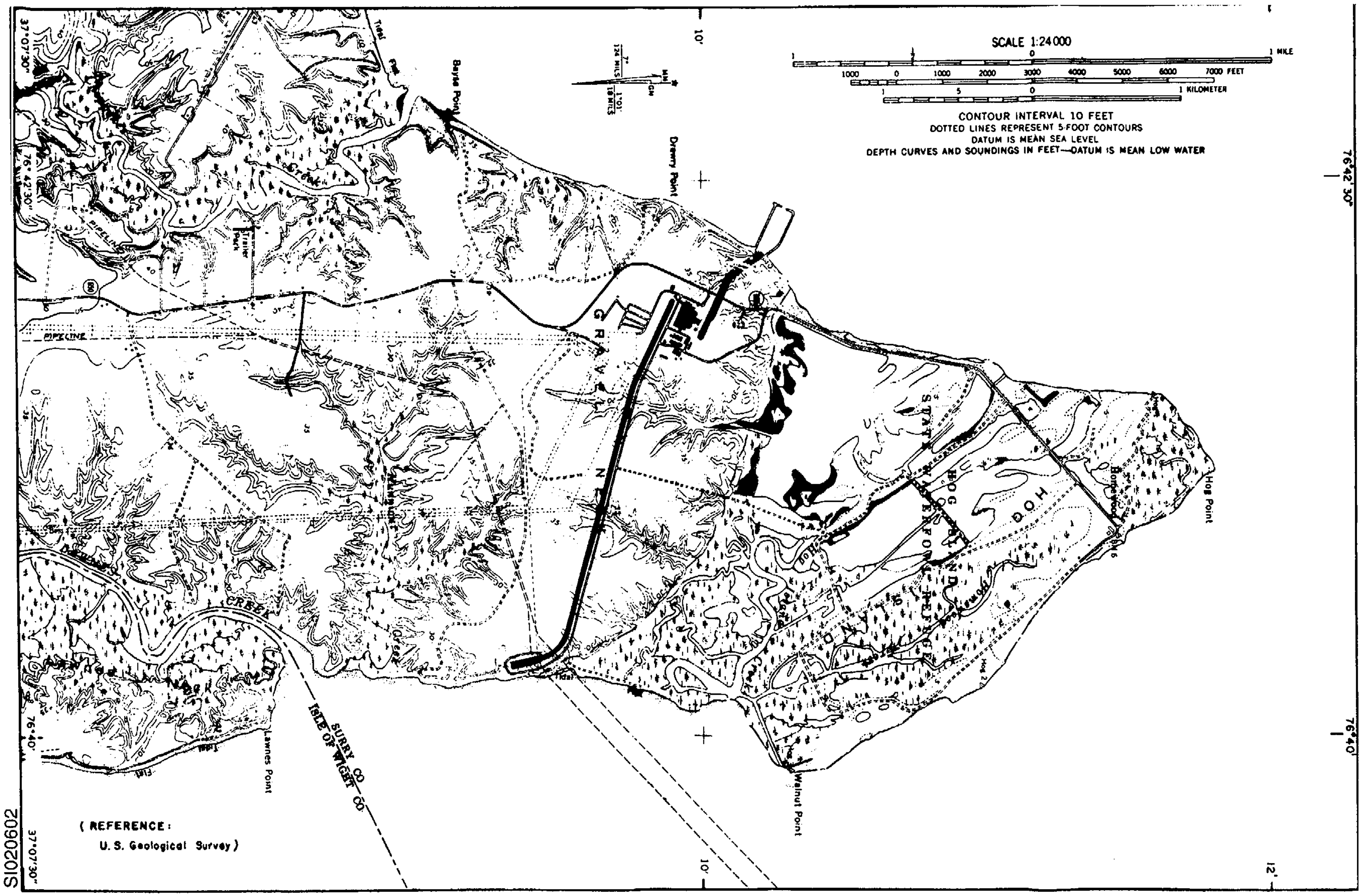
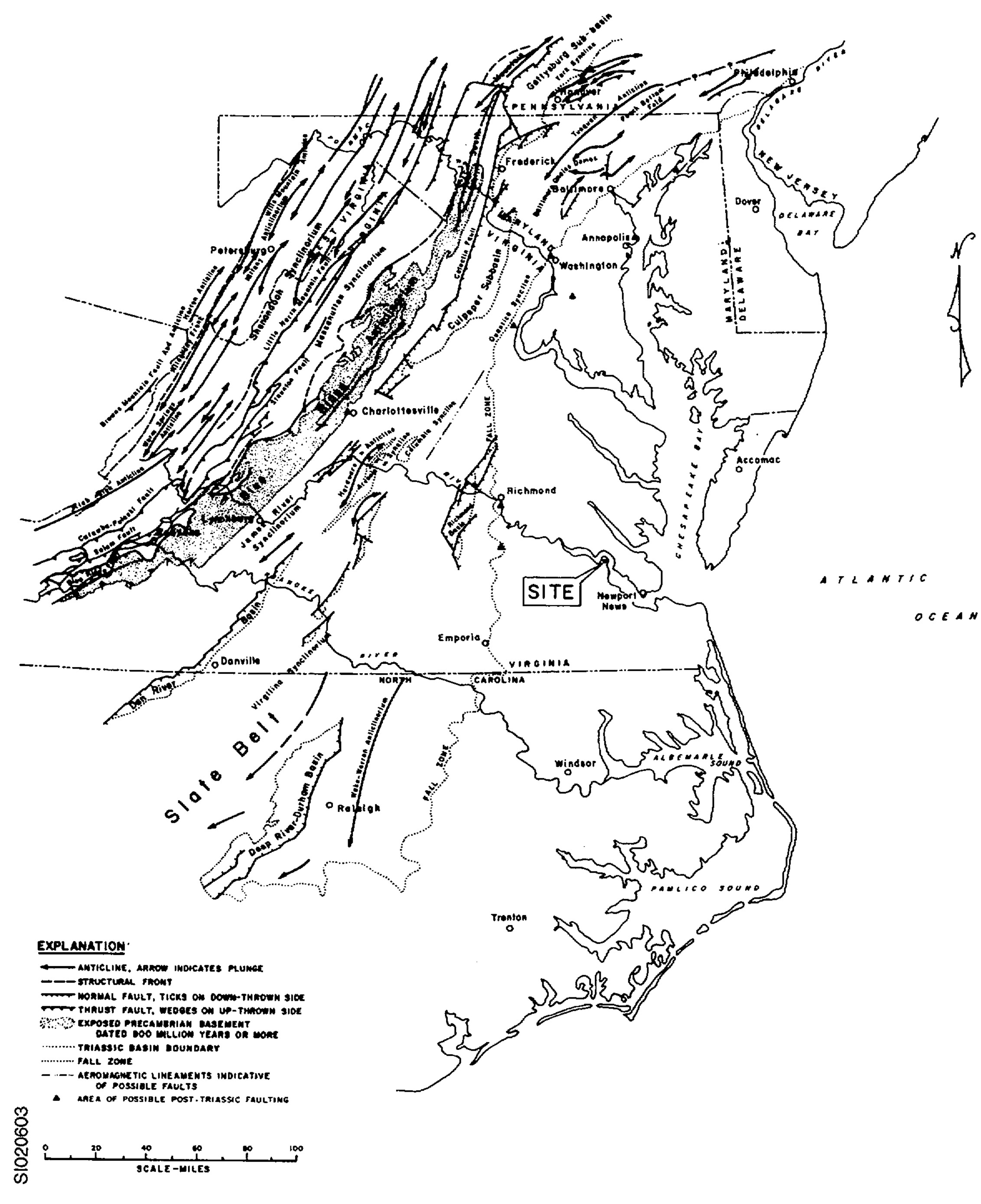
Figure 2.6-2
SITE TOPOGRAPHY



SI020602

Figure 2.6-3
REGIONAL GEOLOGY



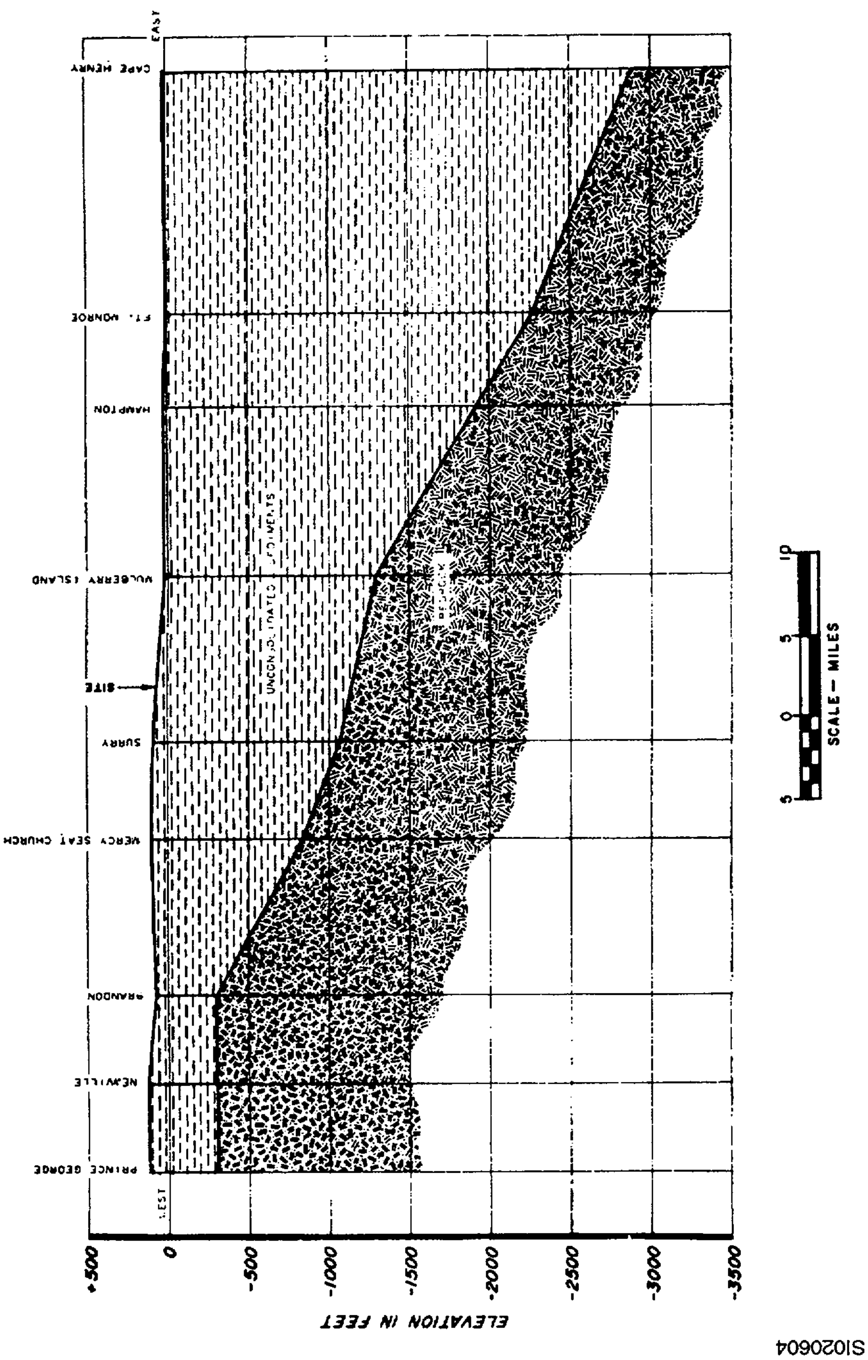
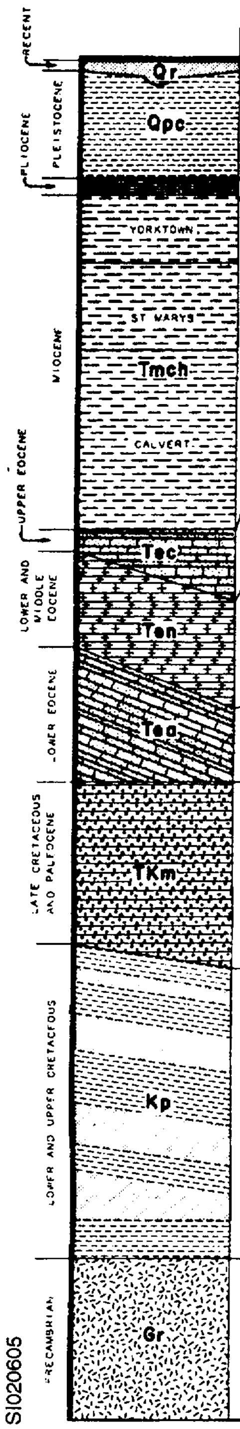


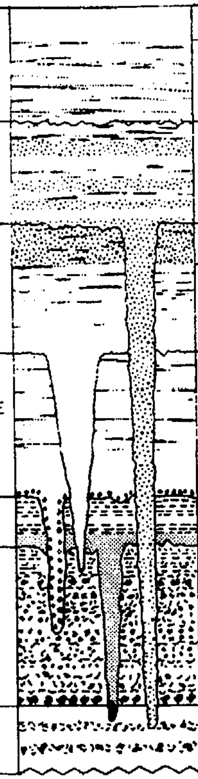
Figure 2.6-4
REGIONAL SUBSURFACE PROFILE

Figure 2.6-5
SITE STRATIGRAPHIC COLUMN



GEOLOGIC AGE AND DESCRIPTION	ORIGIN	DISTRIBUTION	WATER-BEARING PROPERTIES
Recent alluvium, beach and organic sediments such as found on Hog Island Waterfowl Refuge.	Deposited by ocean currents.	Thick deposits present only at Hampton	May yield a little water to shallow wells.
Pleistocene Columbia group. Consists of clays and sands that make up the surficial terraces. Marly strata are present in easternmost terraces only.	The higher westerly terraces are of continental origin, but the lower easterly terraces are of marine origin.	Exposed at the surface throughout the area.	Excellent water-bearing formation for domestic and small industrial supplies.
Bacon's Castle formation and Sedley formation of Pliocene age.	Sediments of Bacon's Castle formation are of fluvial origin. Sedley formation is of marine origin.		
The Chesapeake group of Miocene age consists of shell marl, dark-blue or gray clay, and subordinate sandy strata. The Yorktown formation is sandy and very fossiliferous. The St. Marys formation consists of tough blue or gray clays. The Calvert formation is diatomaceous and sandy but is less fossiliferous than the Yorktown formation.	Deposited in marine waters but may have extended inland some distance west of the present Fall Line.	Exposed in stream beds except at Hampton and lower Warwick, where it is concealed by younger sediments. The Yorktown and St. Marys formations crop out throughout the central and western area and the Calvert formation crops out along the Fall Line.	Yorktown formation yields small quantities of hard water to wells. St. Marys formation is not water-bearing. Calvert formation yields small to moderate supplies of water in many places. At Yorktown and in the lower peninsula area the water may be somewhat brackish.
Upper Eocene Chickahominy formation. Consists of gray marl beds containing glauconite and pyrite. Highly foraminiferal.	Deposited in marine waters.	Known from well cuttings at Yorktown, Camp Peary, Jamestown, Fort Eustis, Newport News, and Fort Monroe. Thins to a vanishing point before approaching the Fall Line.	Not a water-bearing formation at Yorktown. Some thin water-bearing sand beds in central part of the peninsula are probably Chickahominy formation.
Lower and Middle Eocene Nanjemoy formation. Consists of gray marl glauconite and quartz sand, and thin limestone beds.	Deposited in marine waters.	Typical exposure from the Fall Line to Williamsburg, but may be thinner or absent east of Williamsburg. Lower Eocene part of the formation thins to a vanishing point about 20 miles east of the Fall Line. Middle Eocene part may be quite thin in vicinity of Newport News.	Yields ample water for domestic supplies along the lower Chickahominy River and at the head of the York River. Water for industrial use is pumped at West Point.
Lower Eocene Aquia formation. Consists of glauconitic marl and basal quartz sand beds. Maximum thickness about 125 feet.	Deposited in marine waters.	Occurs along the Fall Line. Formation is exposed at the surface near Richmond. No unconformity with underlying Mattaponi formation.	Basal sands yield moderate supplies of water to wells in Hanover, Henrico, and western King William Counties.
Late Cretaceous and Paleocene Mattaponi formation. Consists of mottled clay, glauconitic sand and marl, and thick basal quartz sand.	Deposited in estuaries and bays.	Occurs at depth in central and eastern parts of the Coastal Plain as far west as the Fall Line.	A prolific water-bearing formation tapped by many domestic and a few industrial wells, notable at West Point and Newport News. The formation constitutes a vast reserve of fresh water in the central Coastal Plain. East of Williamsburg, the formation yields brackish water.
Potomac group of lower and Upper Cretaceous sands and clay beds.	Deltaic sediments deposited in fresh to slightly brackish waters.	The formation crops out in the vicinity of Richmond but lies beyond the reach of most wells a short distance east of the Fall Line (See plate 1).	The formation yields water to a few wells near the Fall Line but elsewhere it is not yet reached by wells.
Pre-Cambrian metamorphosed igneous and sedimentary rock. Granite.	Igneous intrusive rocks.	Crops out along the Fall Line except where Triassic units are present. Underlies entire Coastal Plain.	Yields small to moderate supplies of water to wells along or near the Fall Line.

Figure 2.6-6
SITE STRATIGRAPHIC COLUMN OF QUATERNARY AND UPPER MIOCENE FORMATIONS



Epoch	Formation	DESCRIPTION	ORIGIN	DISTRIBUTION	WATER BEARING PROPERTIES	THICKNESS
HOLOCENE	ALLUVIUM	CHIEFLY ORGANIC SILTS AND CLAYS OF SWAMPS AND MARSHES, SOME CHANNEL AND BEACH SANDS	FLUVIAL AND TIDAL-MARSH	ALONG STREAM VALLEYS, TIDAL MARSHES AND CHANNELS, AND BEACH SANDS.	MAY YIELD A LITTLE WATER TO SHALLOW WELLS.	0-50 FT.
PLEISTOCENE	NORFOLK FORMATION	INTERBEDDED SANDS, CLAYS, AND ORGANIC SILTS, AND SANDY GRAVEL	FLUVIAL ESTUARINE	EXPOSED AT THE SURFACE THROUGHOUT THE SITE VICINITY	EXCELLENT WATER-BEARING FORMATION FOR DOMESTIC AND SMALL INDUSTRIAL SUPPLIES	70-80 FT.
PLEISTOCENE	WINDSOR FORMATION	UPPER MEMBER-POORLY SORTED MIXTURE OF SAND, SILT AND CLAY	LITTORAL	NOT FOUND AT THE SITE		0
		LOWER MEMBER-INTERTONGUED SANDS AND CLAYS. LOWER PART CHIEFLY CROSS-BEDDED SAND, UPPER PART CHIEFLY CLAY	FLUVIAL ESTUARINE			
PLIOCENE &/OR PLEISTOCENE	BACONS CASTLE FORMATION	INTERTONGUED SANDS AND CLAYS PROMINENT RED COLORATION LOWER PART CHIEFLY CROSS-BEDDED SANDS, UPPER PART CHIEFLY CLAY, GRAVEL AT BASE	FLUVIAL	NOT FOUND AT THE SITE		0
PLIOCENE &/OR PLEISTOCENE	SEDLEY FORMATION	BROWN SANDS AND CLAYS	ESTUARINE	NOT FOUND AT THE SITE		0
MIOCENE	YORKTOWN FORMATION	UNIT-4 GRAY CLAY WITH INTERCALATED 1" BEDS OF SHELL DEBRIS	MARINE	CROPS OUT WEST OF THE SITE AREA AND FOUND IN BORINGS AT THE SITE AT EL. -40±	YIELDS SMALL QUANTITIES OF HARD WATER TO WELLS. WATER MAY BE BRACKISH	130± FT ESTIMATED FROM DEEP WELLS IN THE AREA
		UNIT-3 HIGHLY FOSSILIFEROUS BEDS				
		UNIT-2 HIGHLY FOSSILIFEROUS BEDS CONTAINING CHAMA CONGREGATA				
		UNIT-1 SANDY FOSSILIFEROUS BEDS PECTEN CLINTONIUS BASAL 6"-8"				
MIOCENE	ST. MARYS FORMATION	INTERBEDDED SANDS AND HIGH FOSSILIFEROUS SANDS CONTAINING ISOGNOMON MAXILLATA	MARINE	CROPS OUT WEST OF THE SITE AREA FOUND IN DEEP WELLS IN THE VICINITY OF THE SITE	THIS FORMATION IS NOT WATER BEARING	40± FT. ESTIMATED FROM DEEP WELLS IN THE AREA

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Figure 2.6-7
GEOLOGIC MAP OF SITE AREA

Figure 2.6-8
REGIONAL TECTONICS

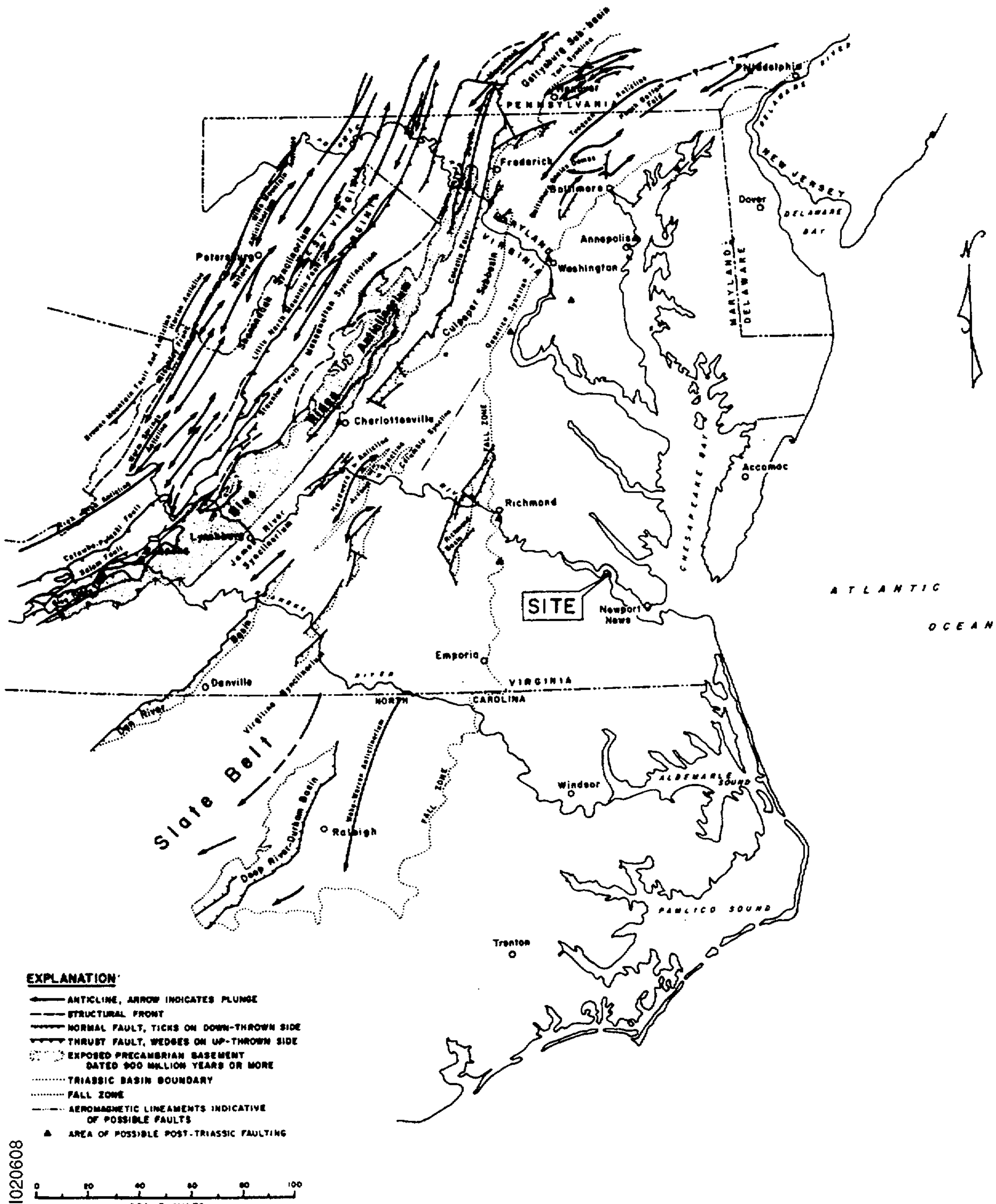


Figure 2.6-9
STRUCTURAL CONTOURS BASEMENT ROCKS

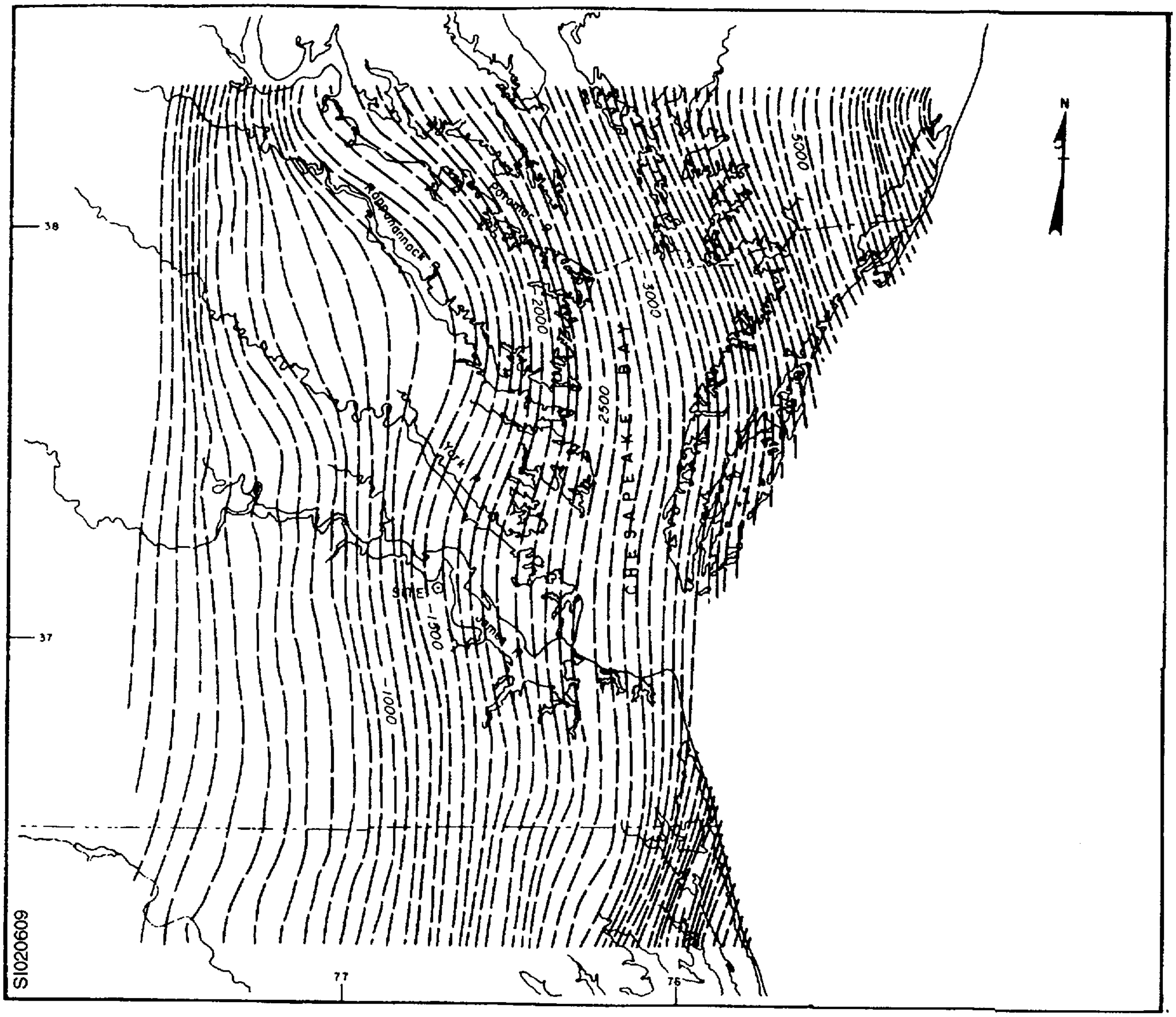


Figure 2.6-10
ISOPACH - CRETACEOUS AND LATE JURASSIC (UNIT H)

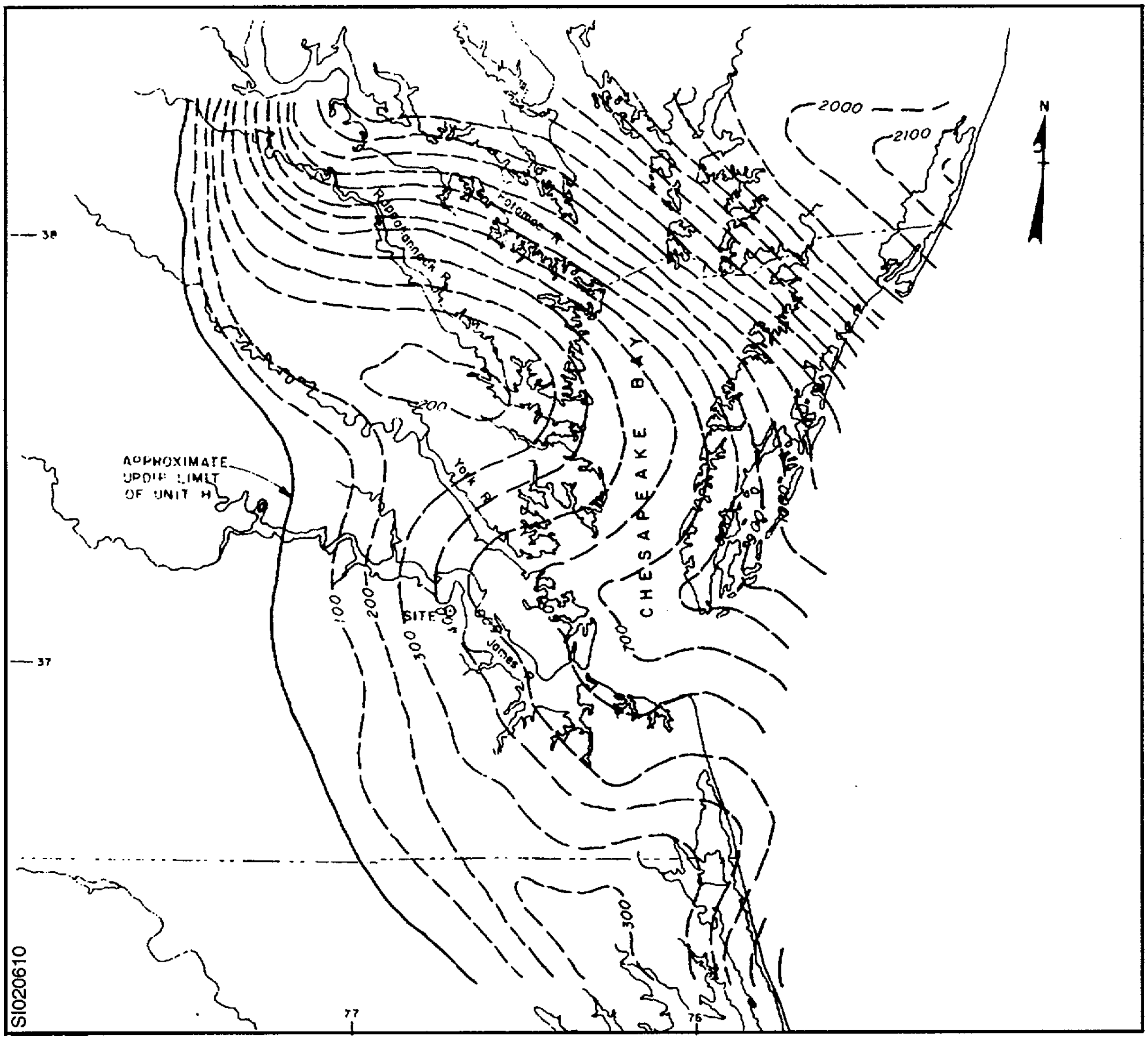


Figure 2.6-11
ISOPACHS - CRETACEOUS (UNIT G)

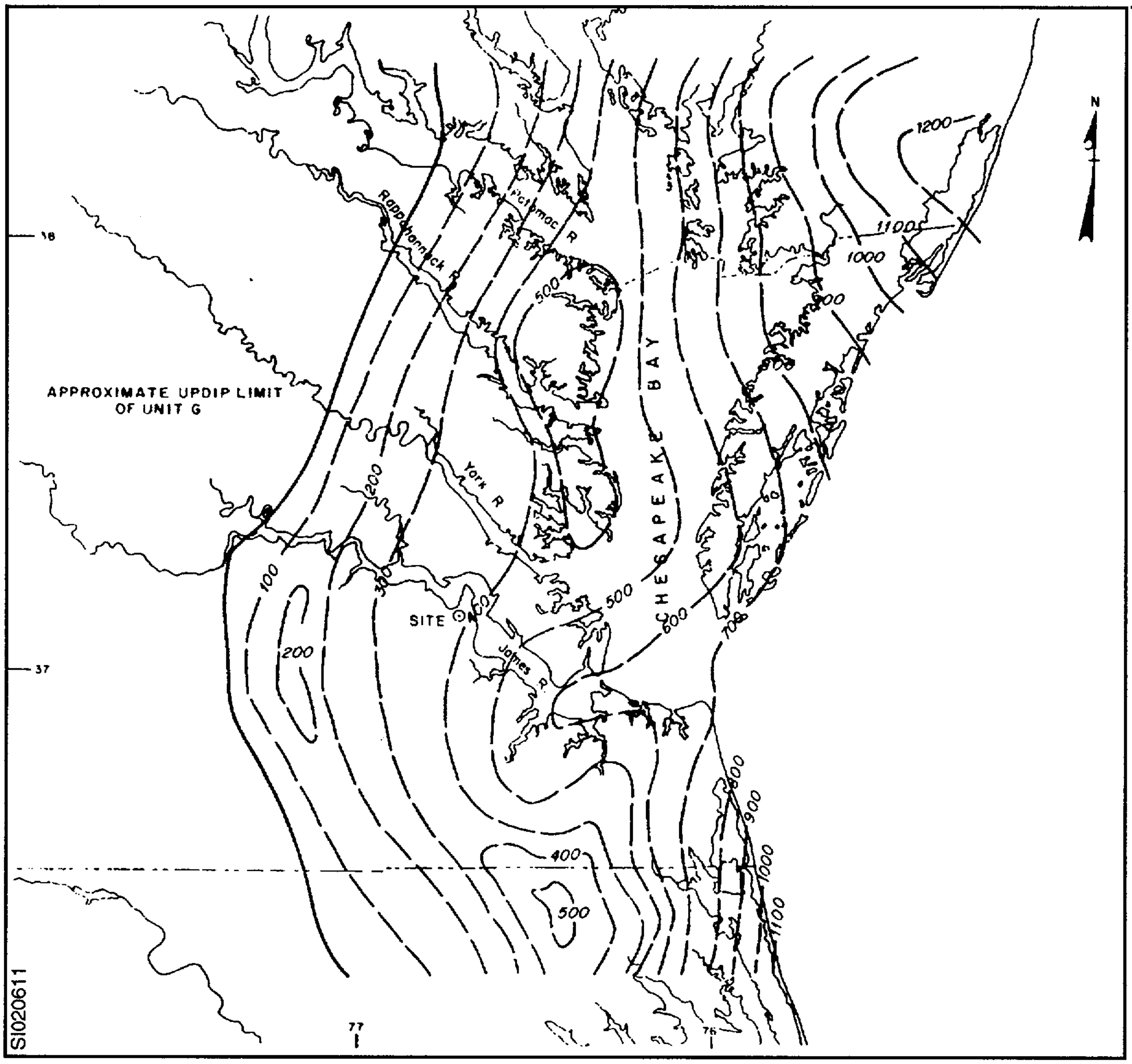


Figure 2.6-12
ISOPACHS - CRETACEOUS (UNIT F)

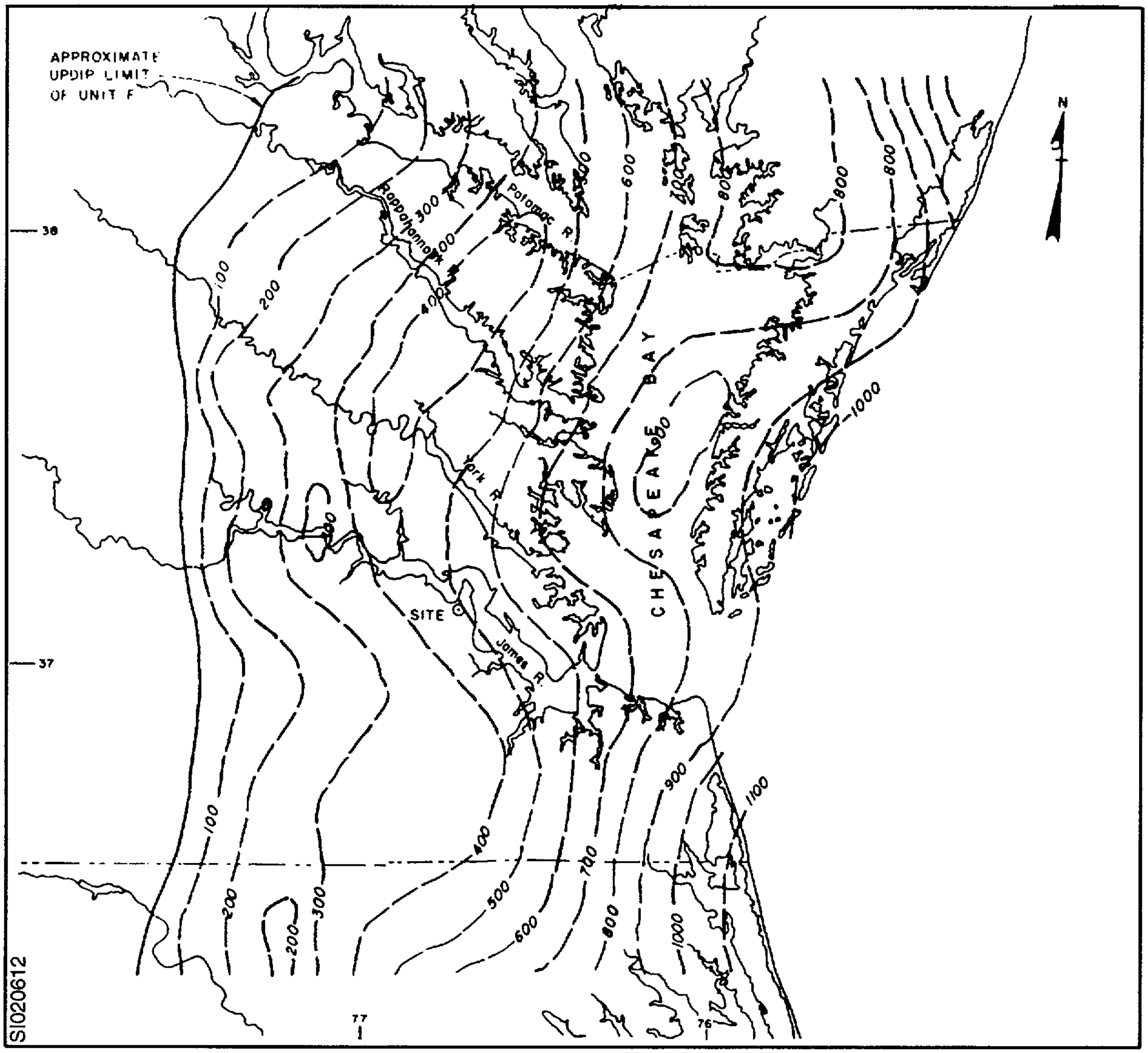


Figure 2.6-13
ISOPACHS - CRETACEOUS (UNIT C)

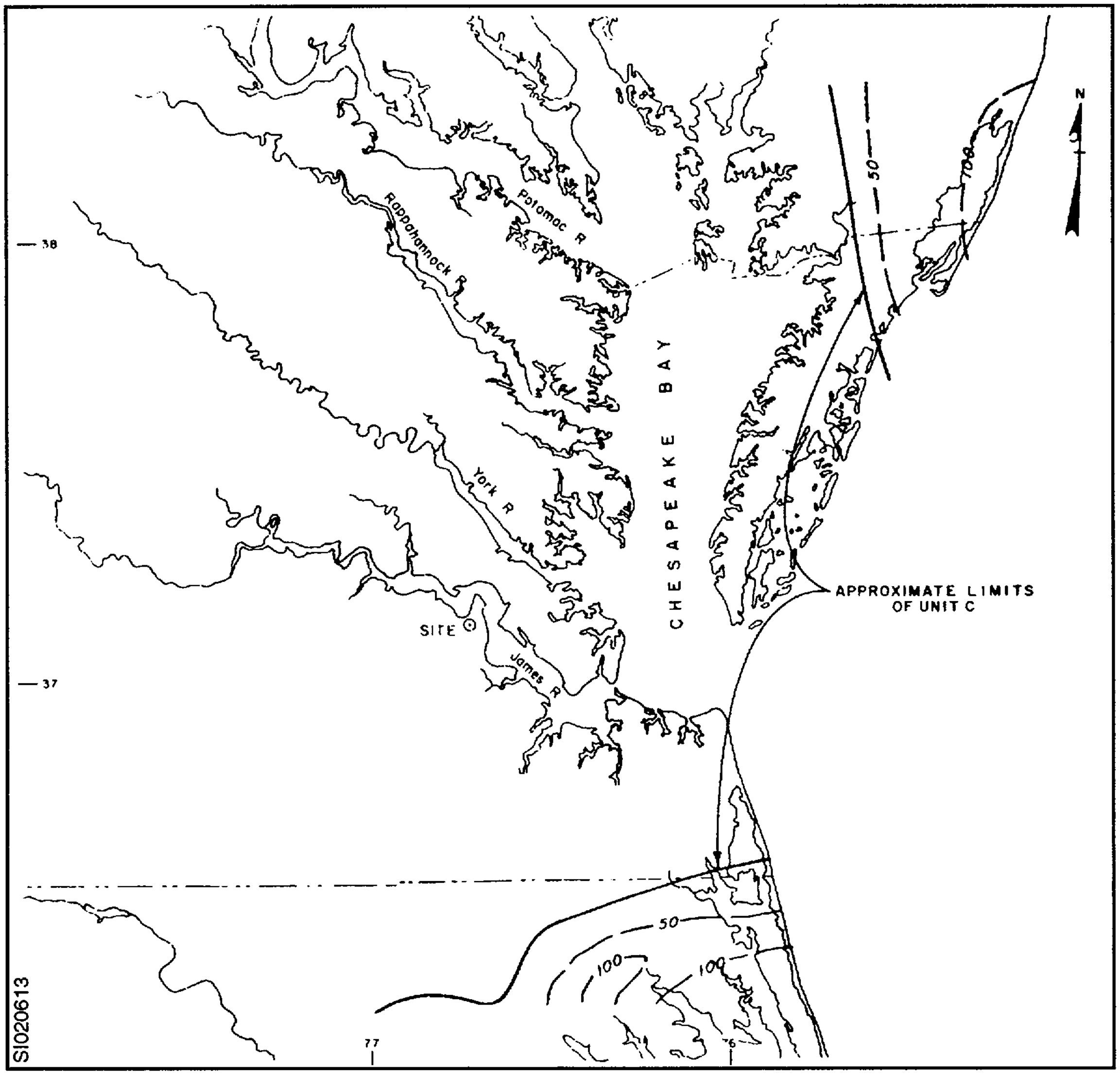


Figure 2.6-14
ISOPACHS - CRETACEOUS (UNIT B)

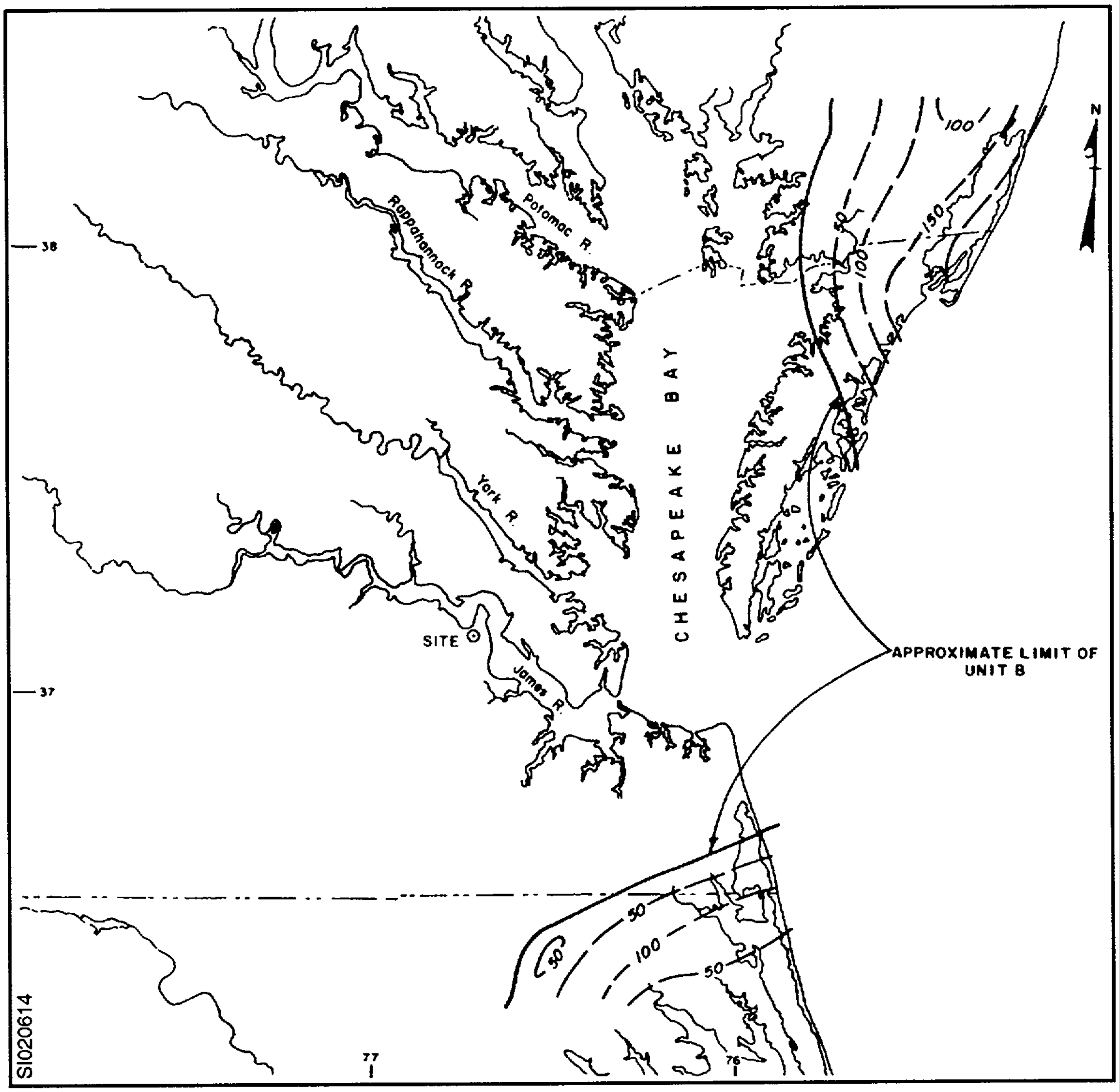


Figure 2.6-15
ISOPACHS - MIDWAY AGE ROCK

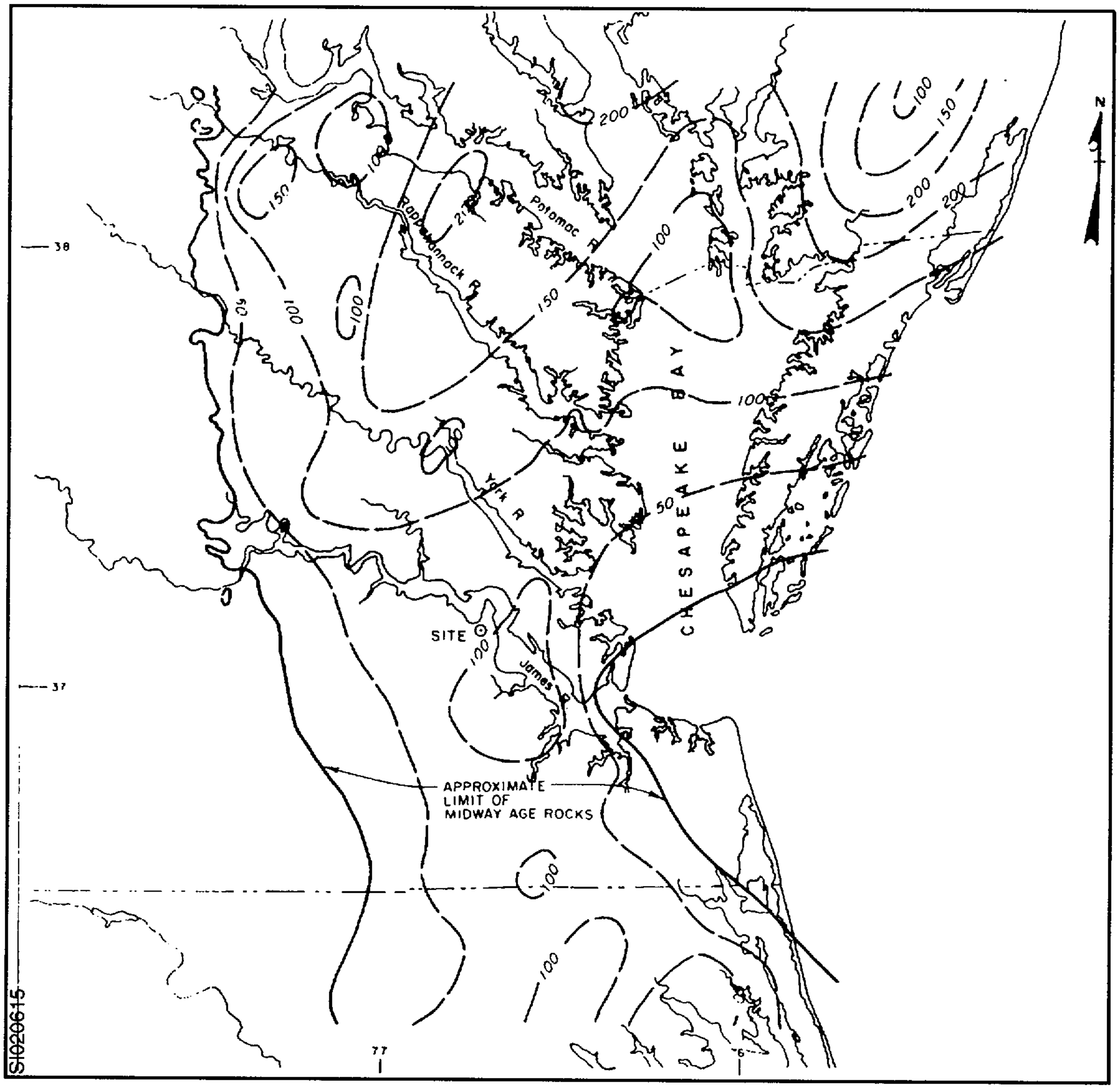


Figure 2.6-16
ISOPACHS - CLAIBORNE AGE ROCKS

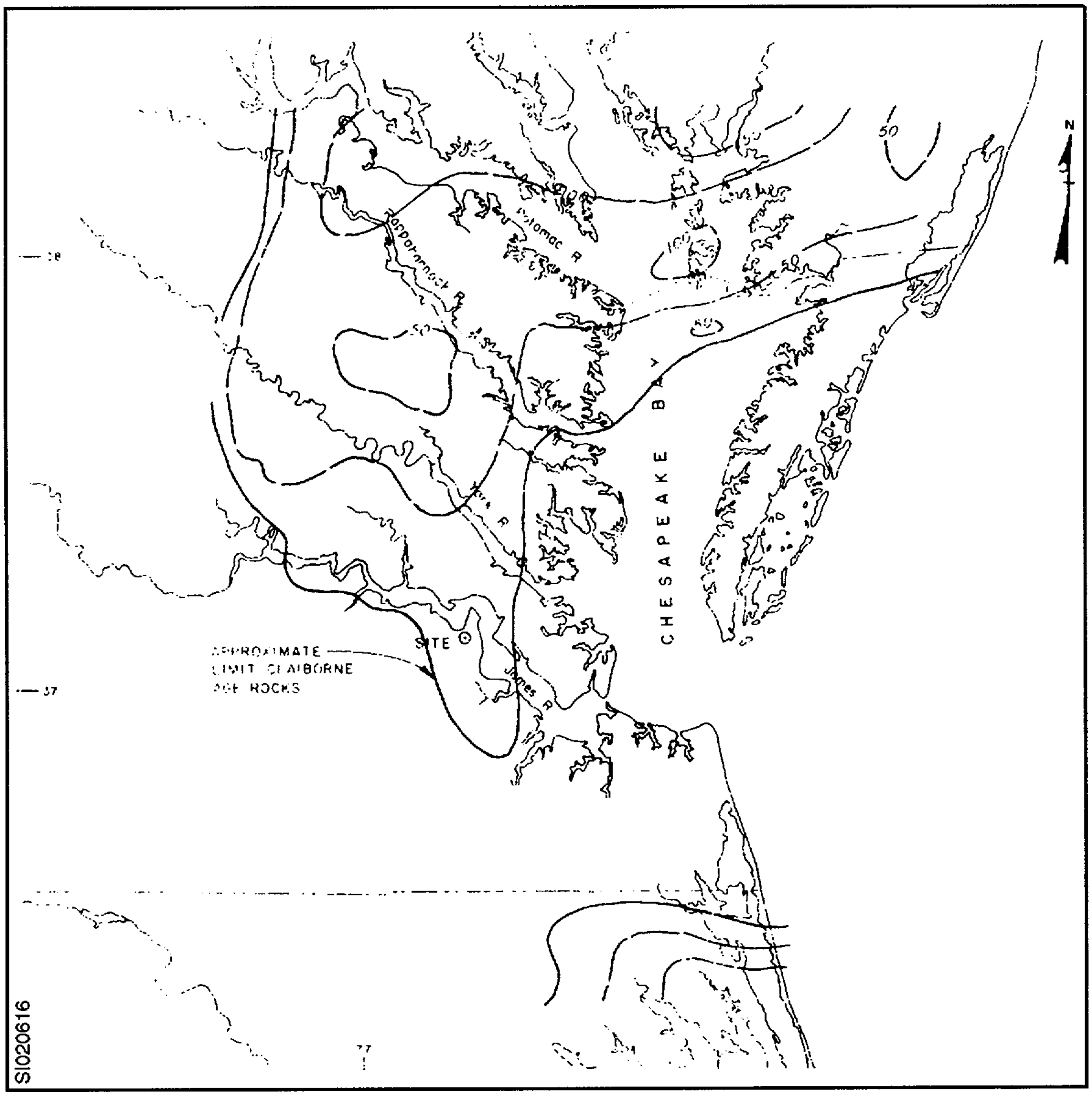


Figure 2.6-17
ISOPACHS - JACKSON AGE ROCKS

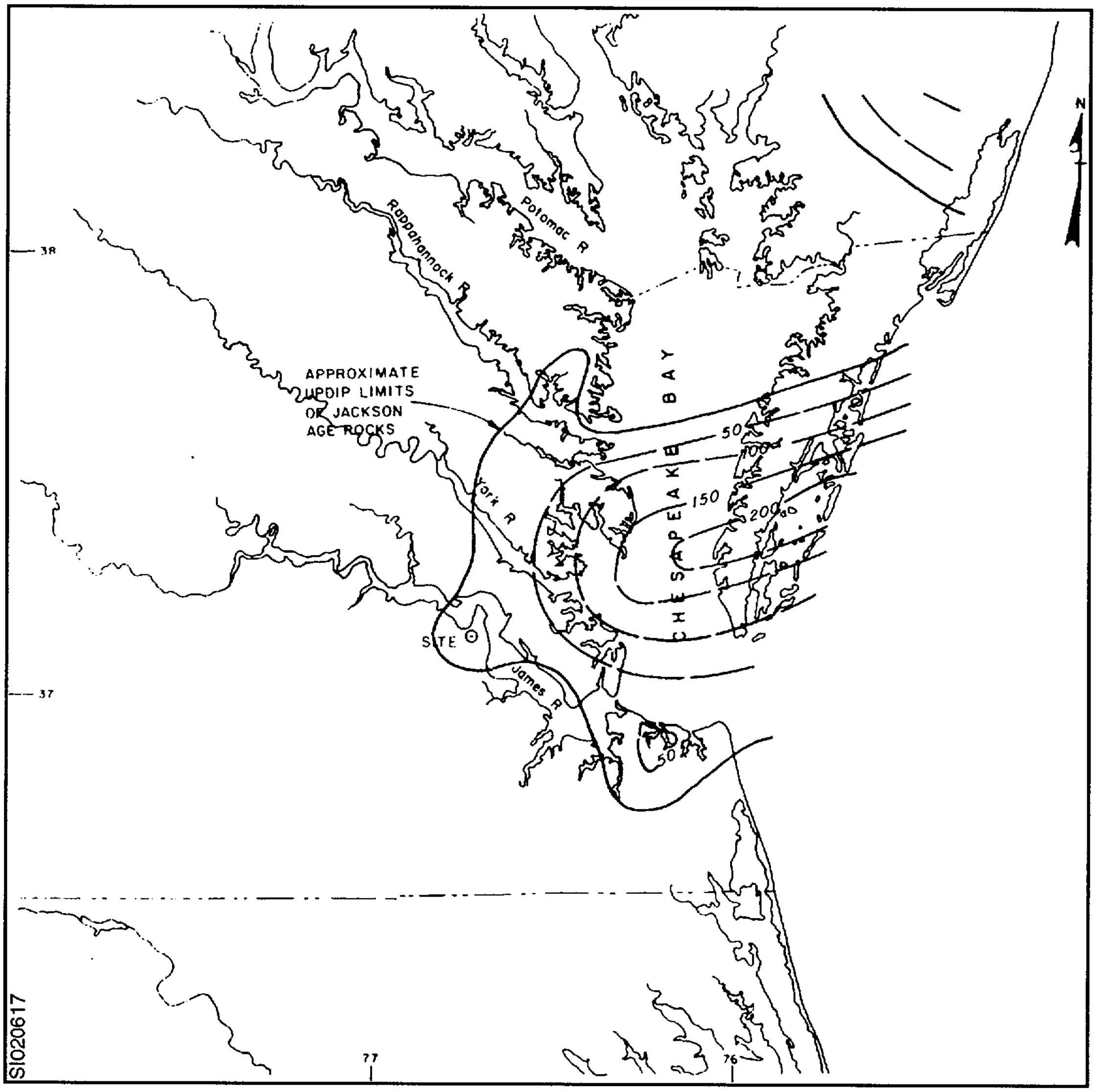


Figure 2.6-18
ISOPACHS - MIDDLE MIOCENE

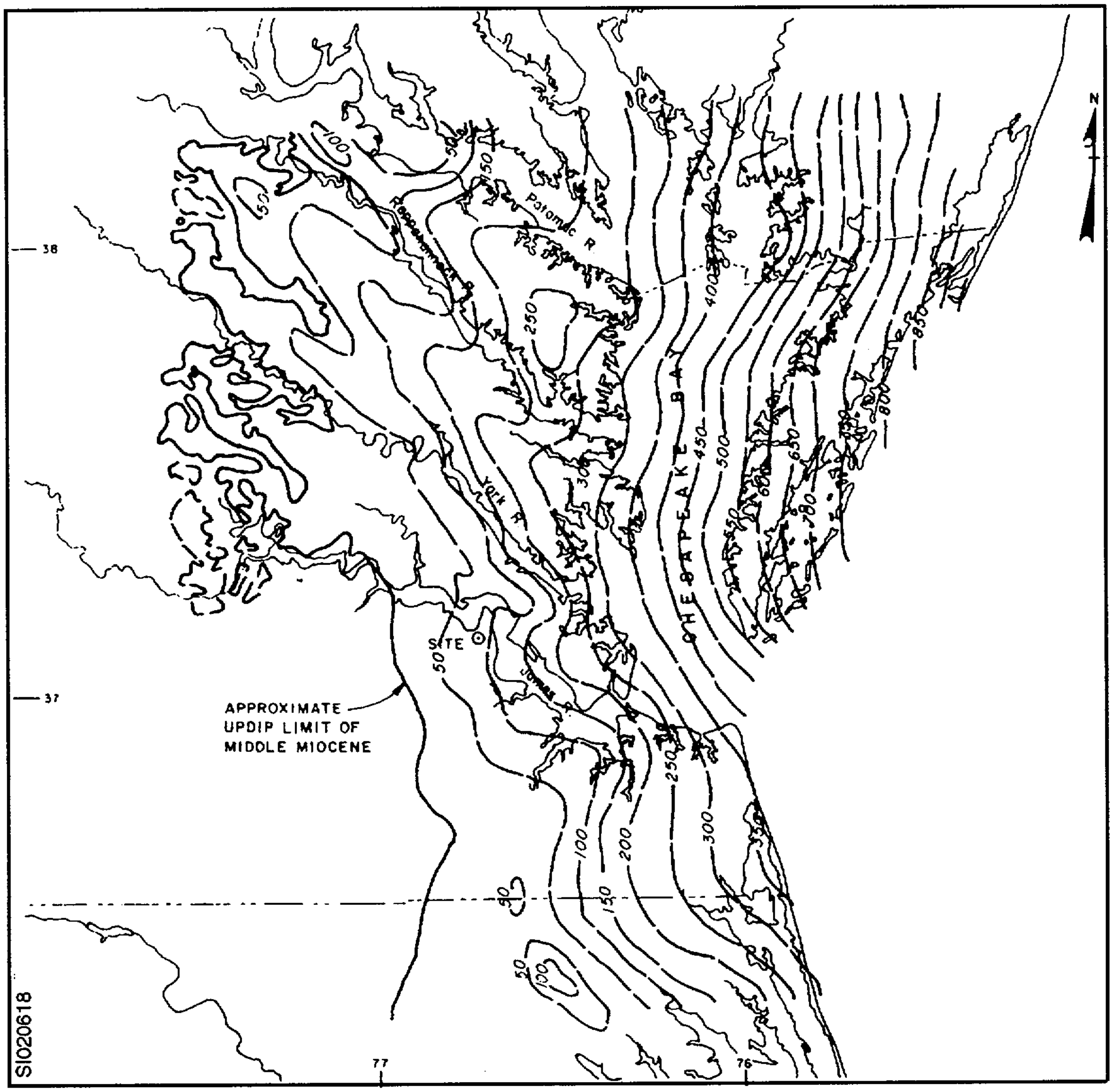


Figure 2.6-19
ISOPACHS LATE MIOCENE

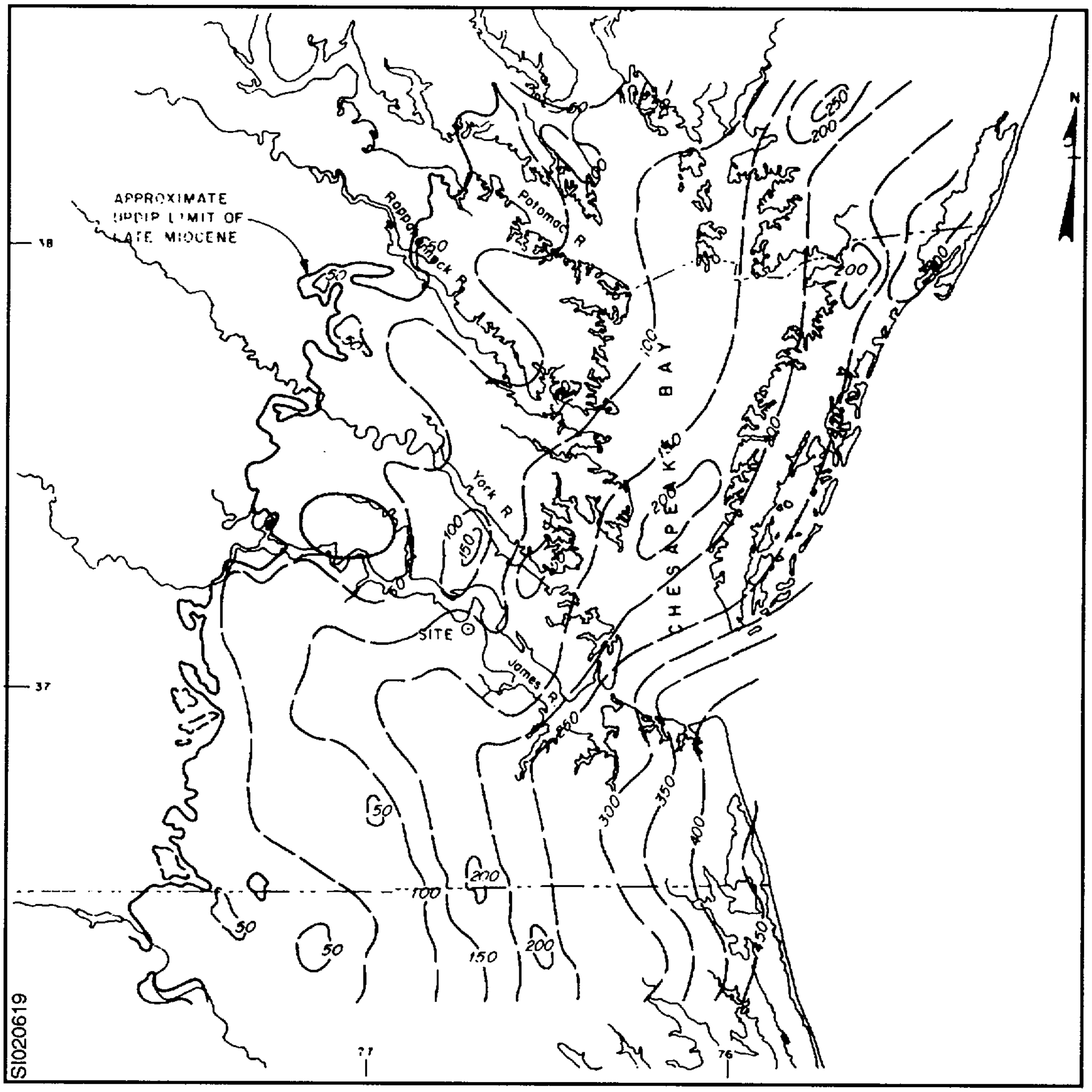


Figure 2.6-20
ISOPACHS - POST MIOCENE

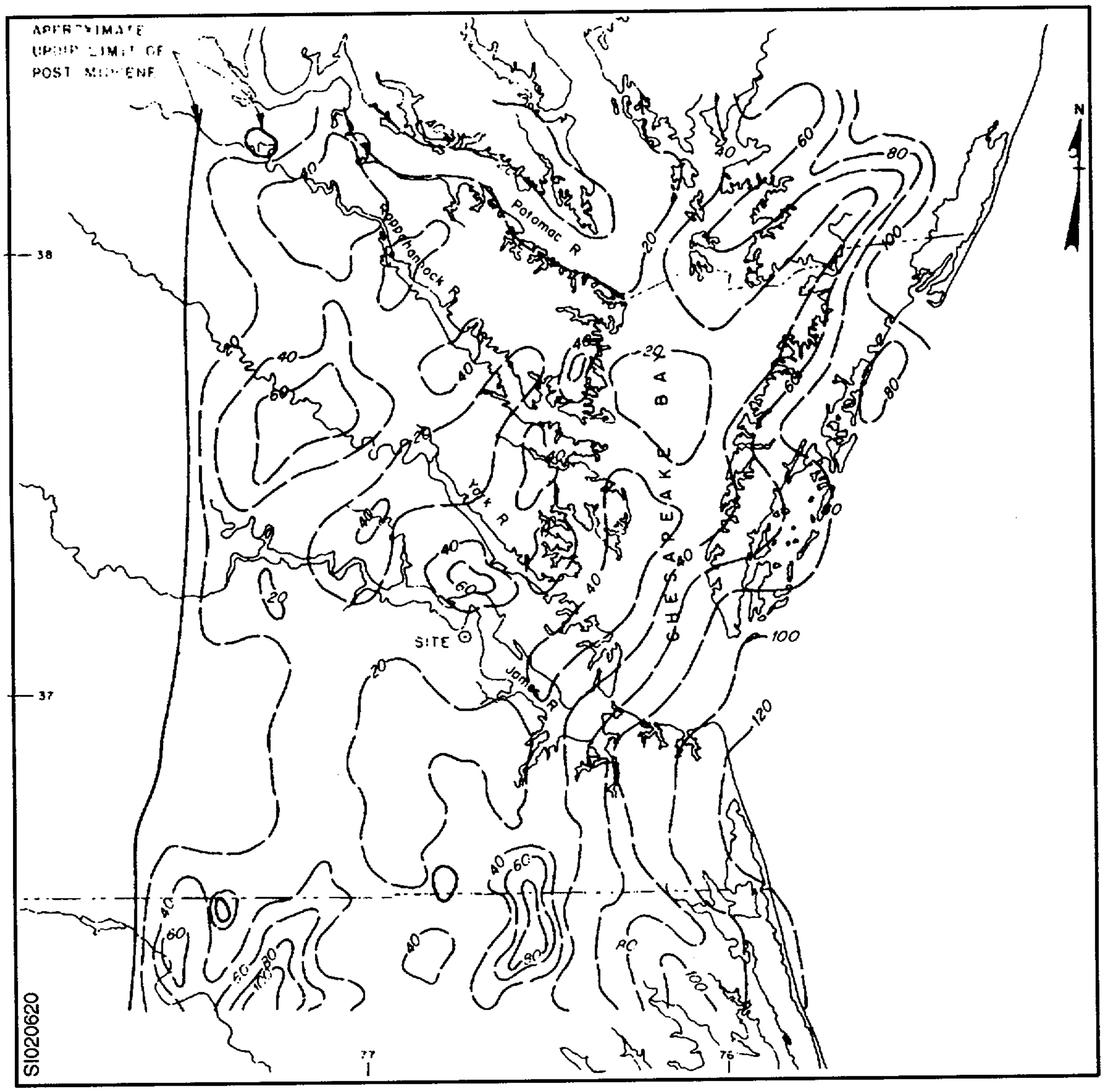


Figure 2.6-21
TOTAL INTENSITY AEROMAGNETIC MAP OF THE VIRGINIA COASTAL PLAIN

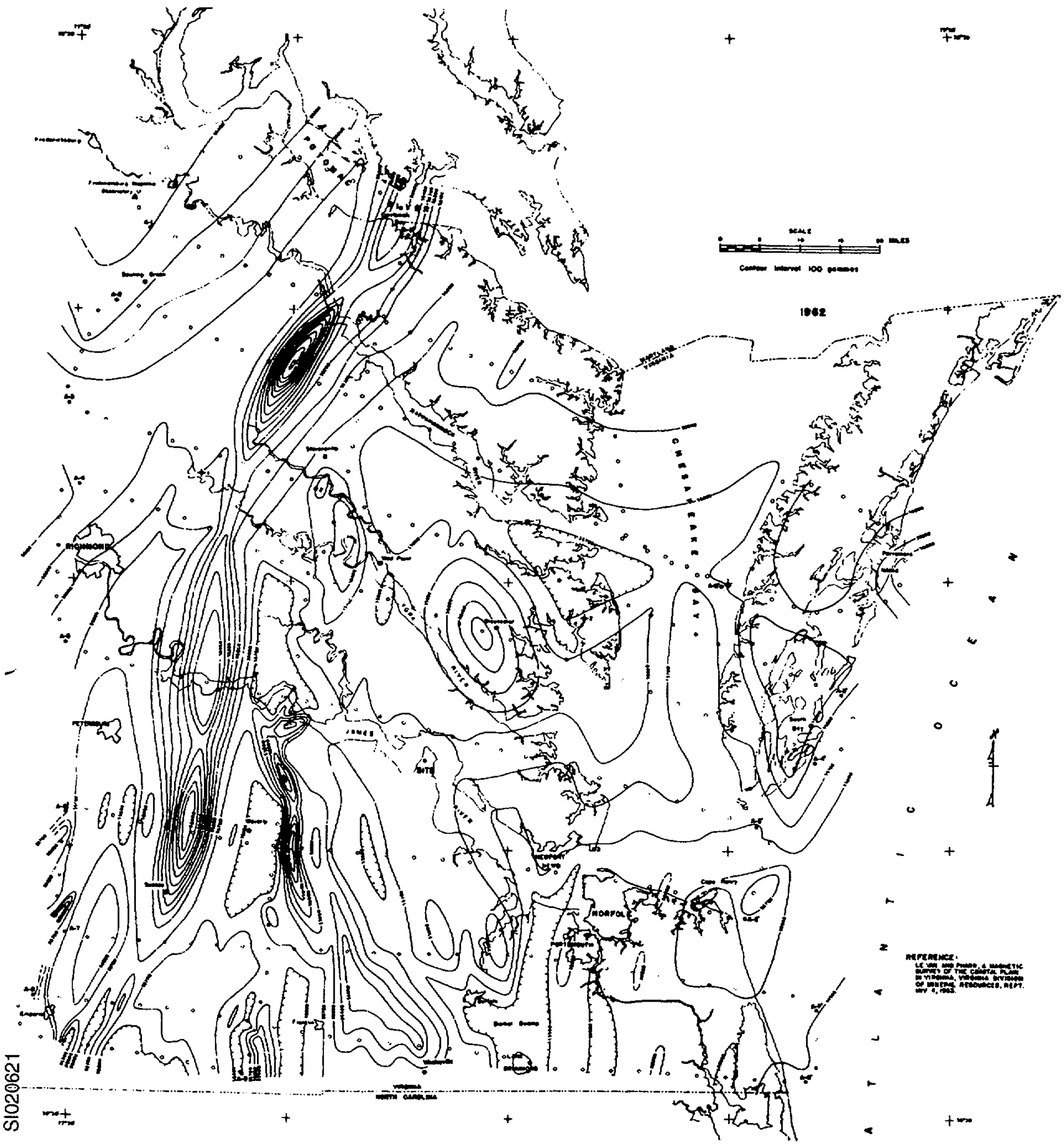
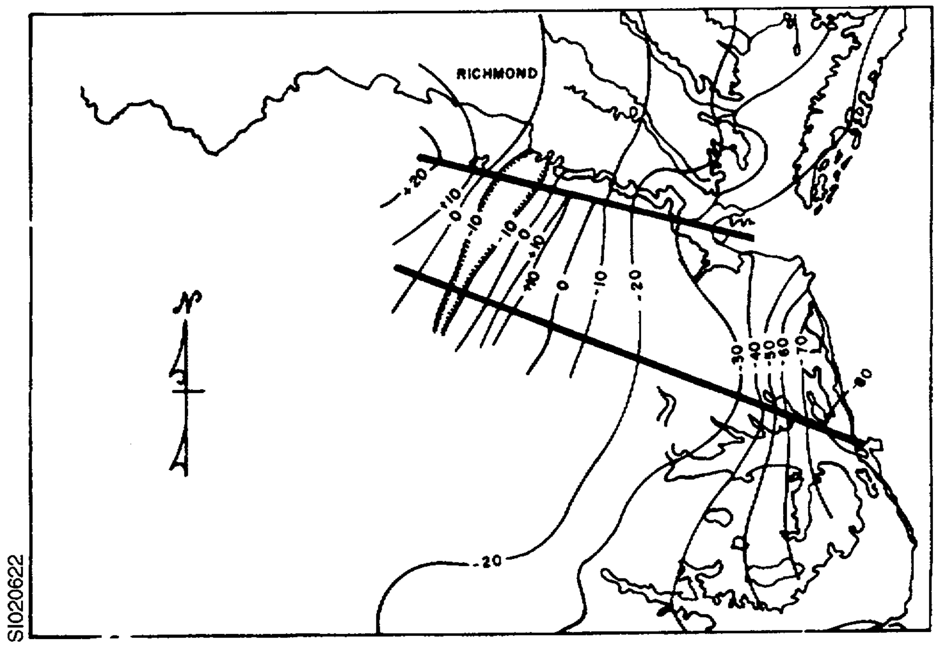


Figure 2.6-22
GRAVITY TRAVERSES OF COASTAL PLAIN IN SITE AREA



COUNTOUR INTERVALS: 10 Milligals

REFERENCE:
SWICK, 1938

Figure 2.6-23
INDEX OF GEOPHYSICAL TRAVERSES OF COASTAL PLAIN IN SITE AREA

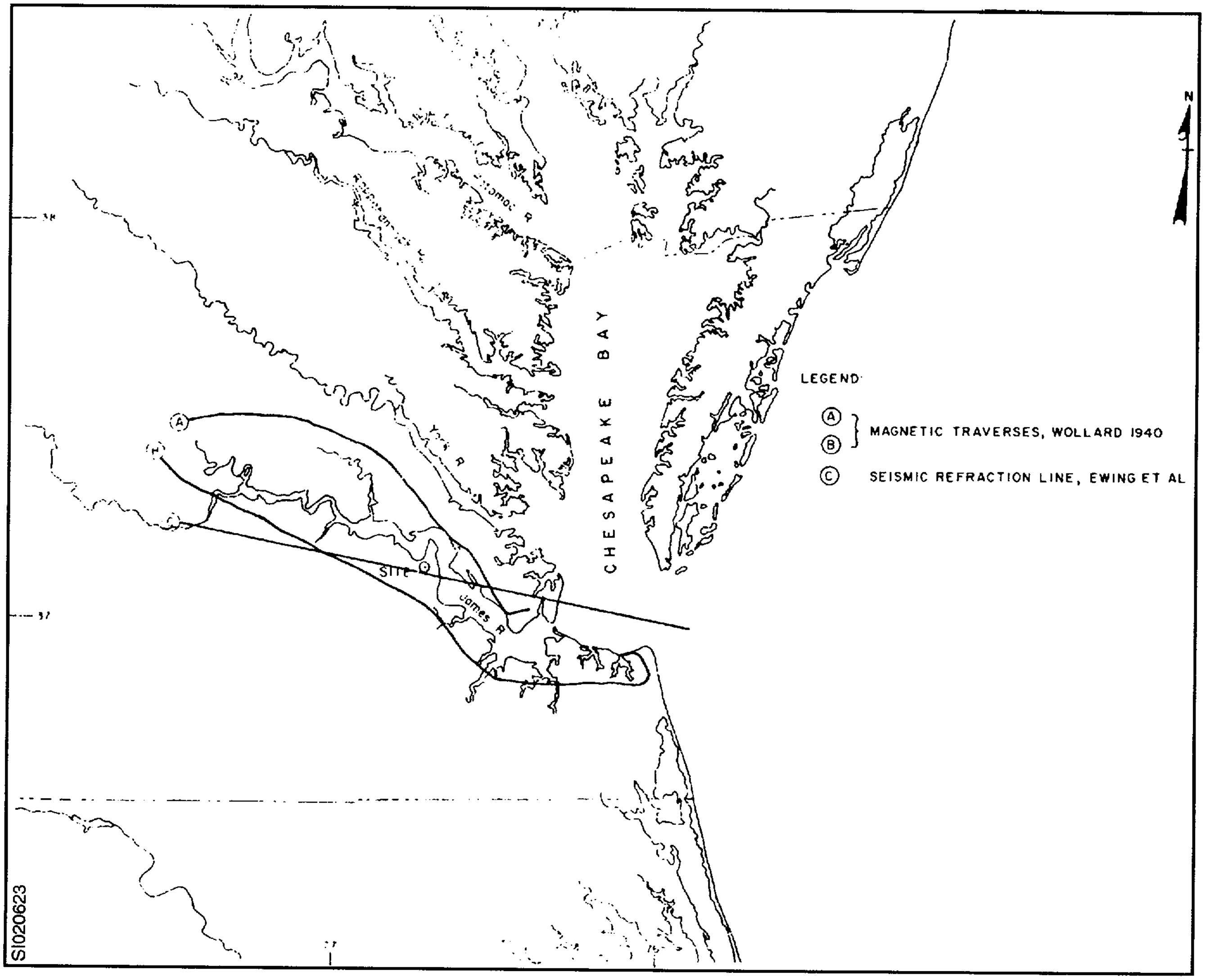


Figure 2.6-24
DEEP WELL LOCATIONS ON COASTAL PLAIN

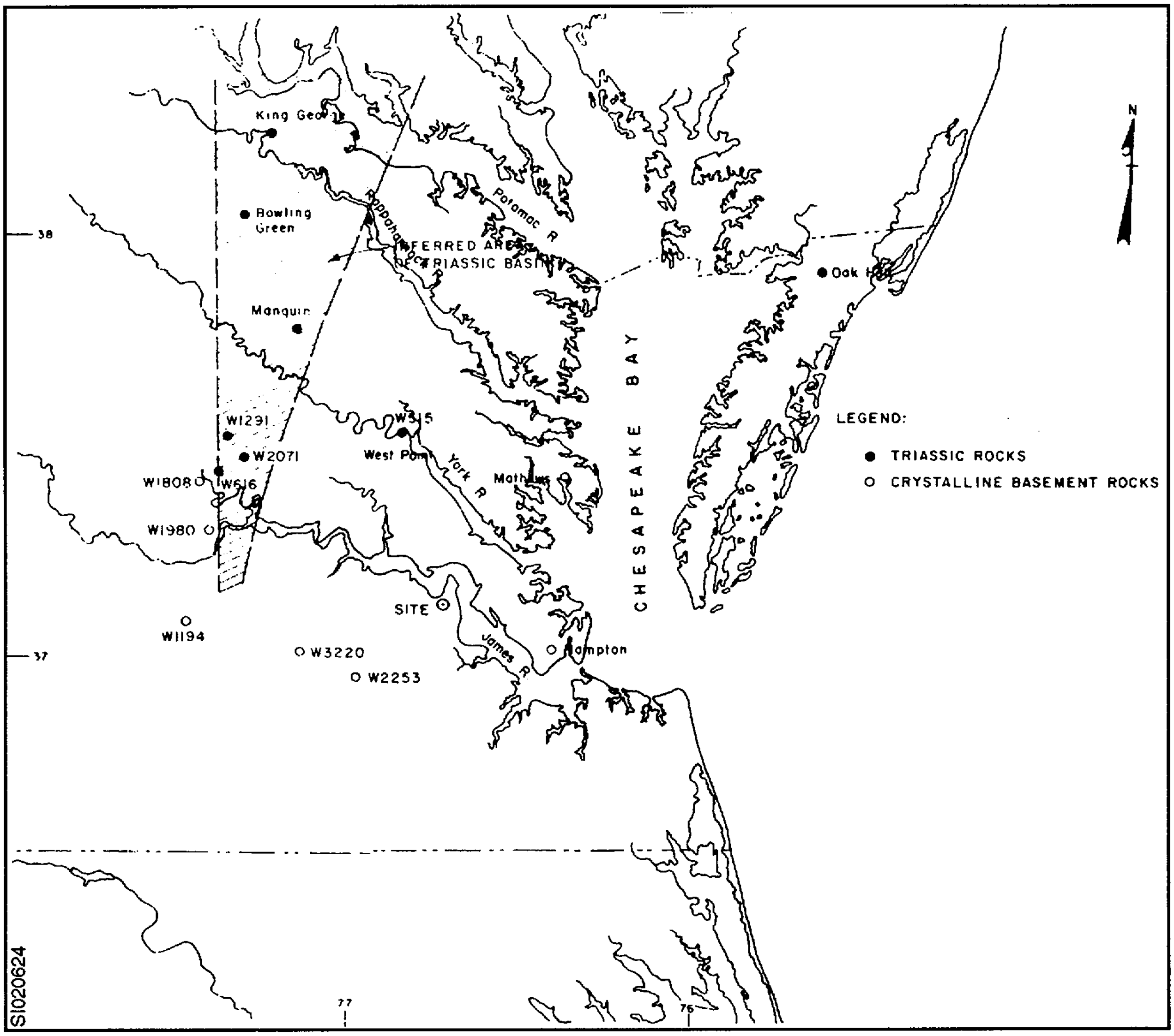


Figure 2.6-25
REGIONAL EPICENTER MAP

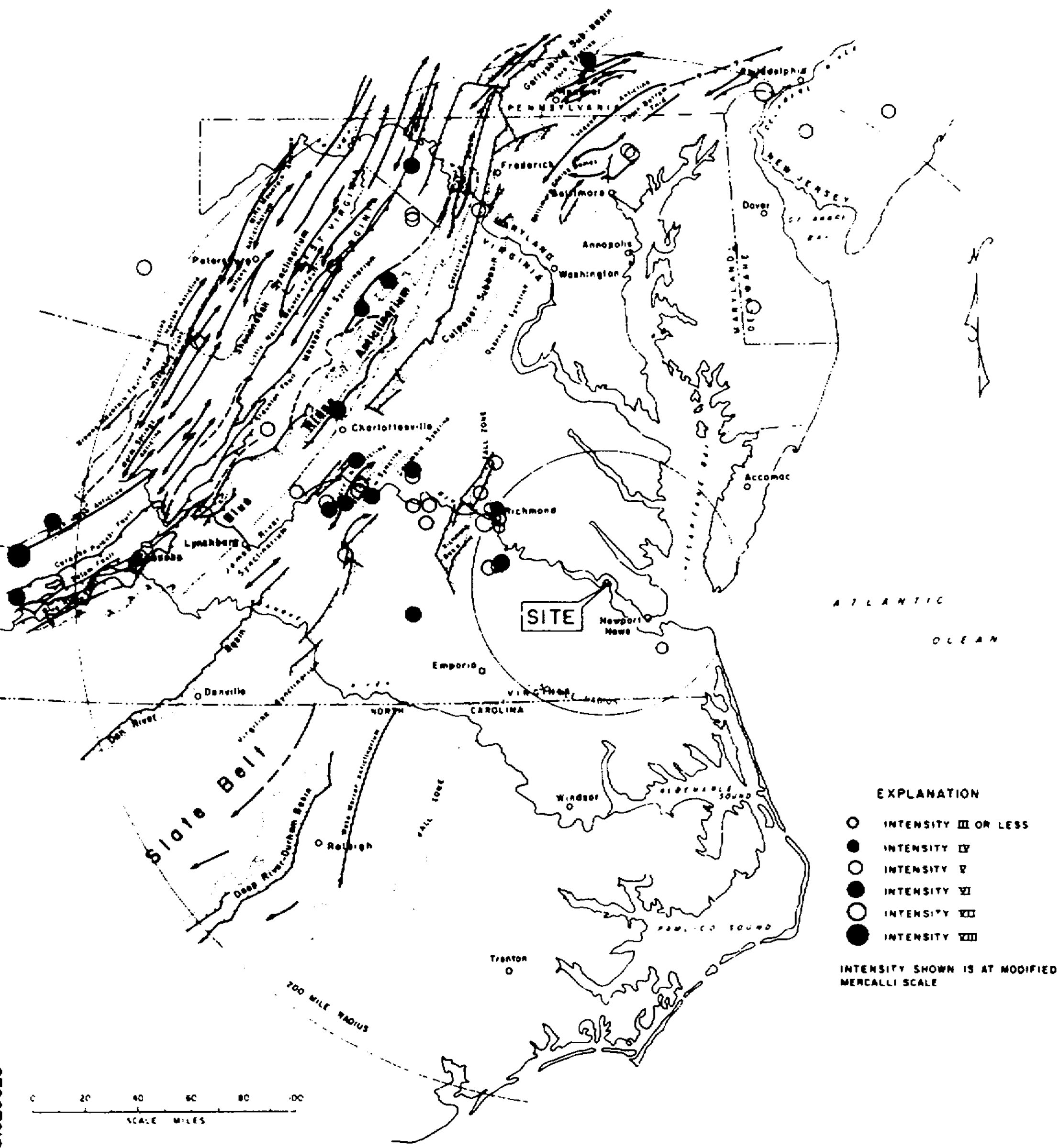


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Figure 2.6-26
EARTHQUAKE ACTIVITY OF THE CENTRAL VIRGINIA SEISMIC ZONE

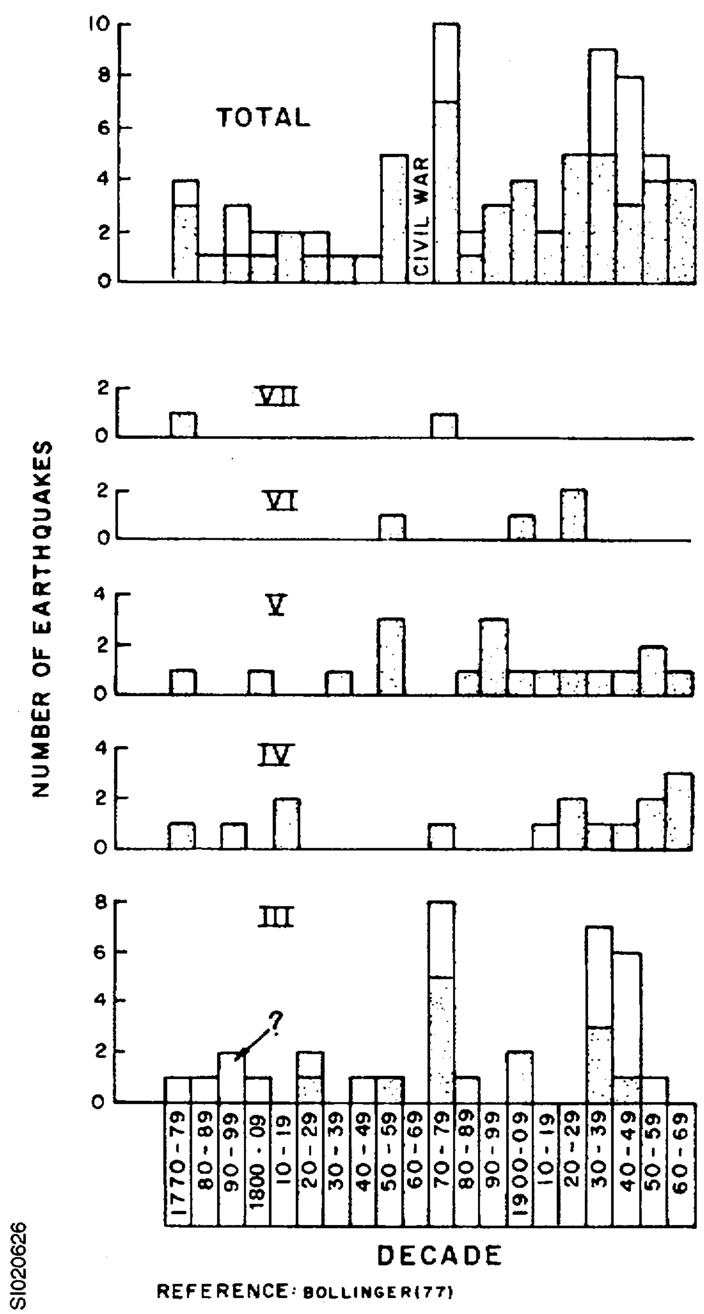

Figure 2.6-27
ISOSEISMAL PATTERNS SOUTH EASTERN UNITED STATES

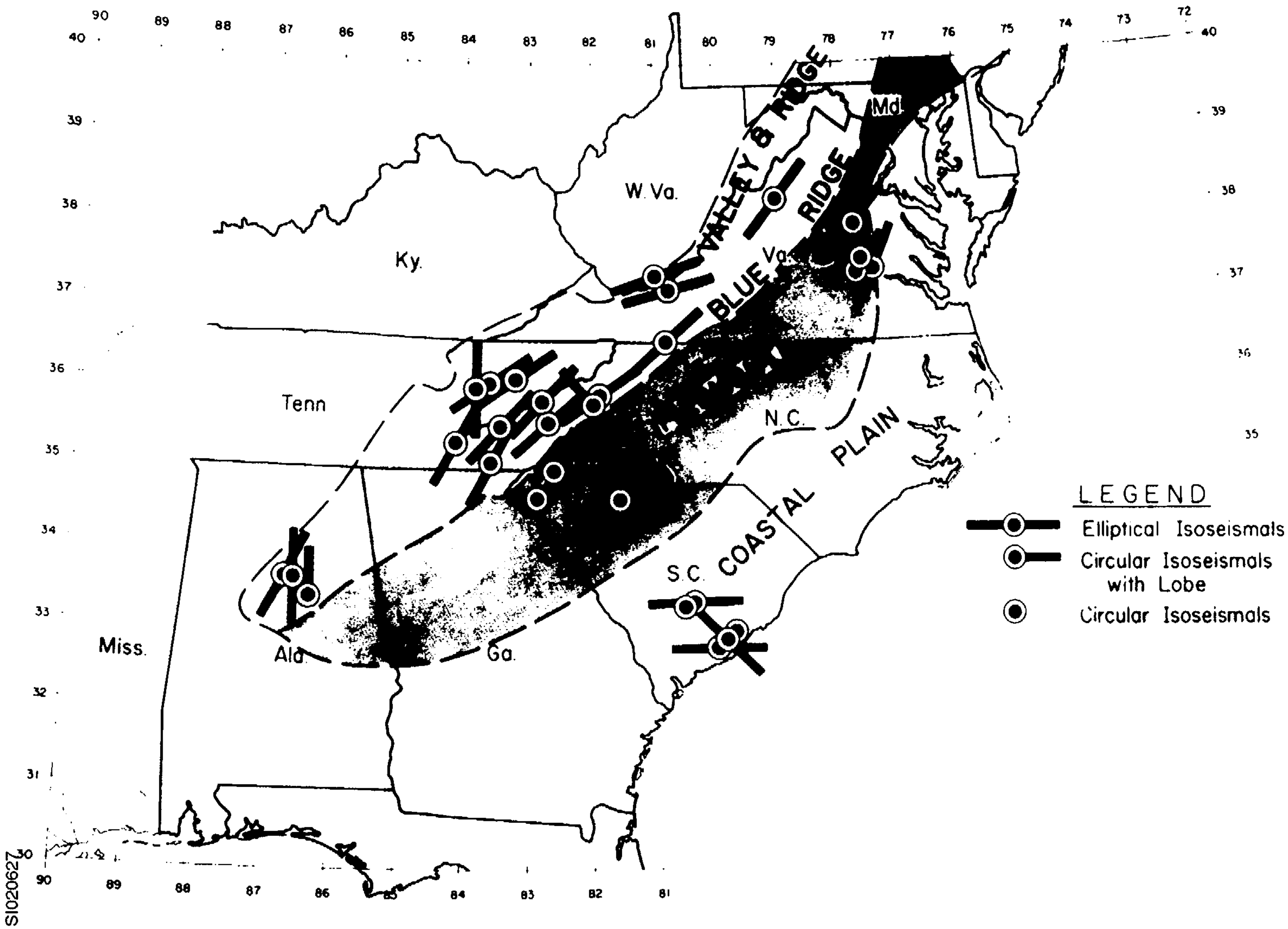

Figure 2.6-28
ISOSEISMAL MAPS; CENTRAL VIRGINIA - SEISMIC ZONES

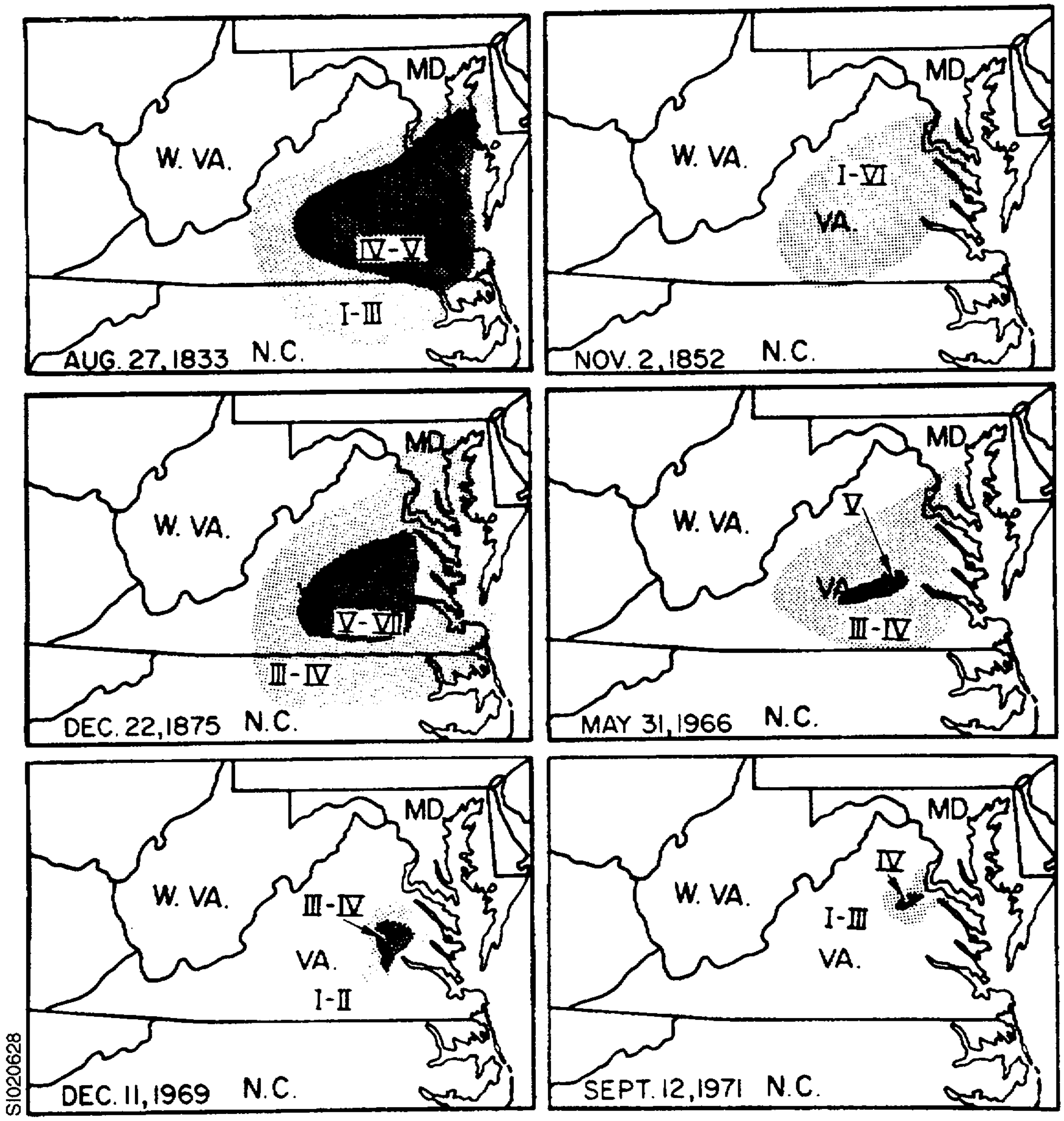

Figure 2.6-29
AEROMAGNETIC MAP OF THE CENTRAL EAST COAST OF THE UNITED STATES

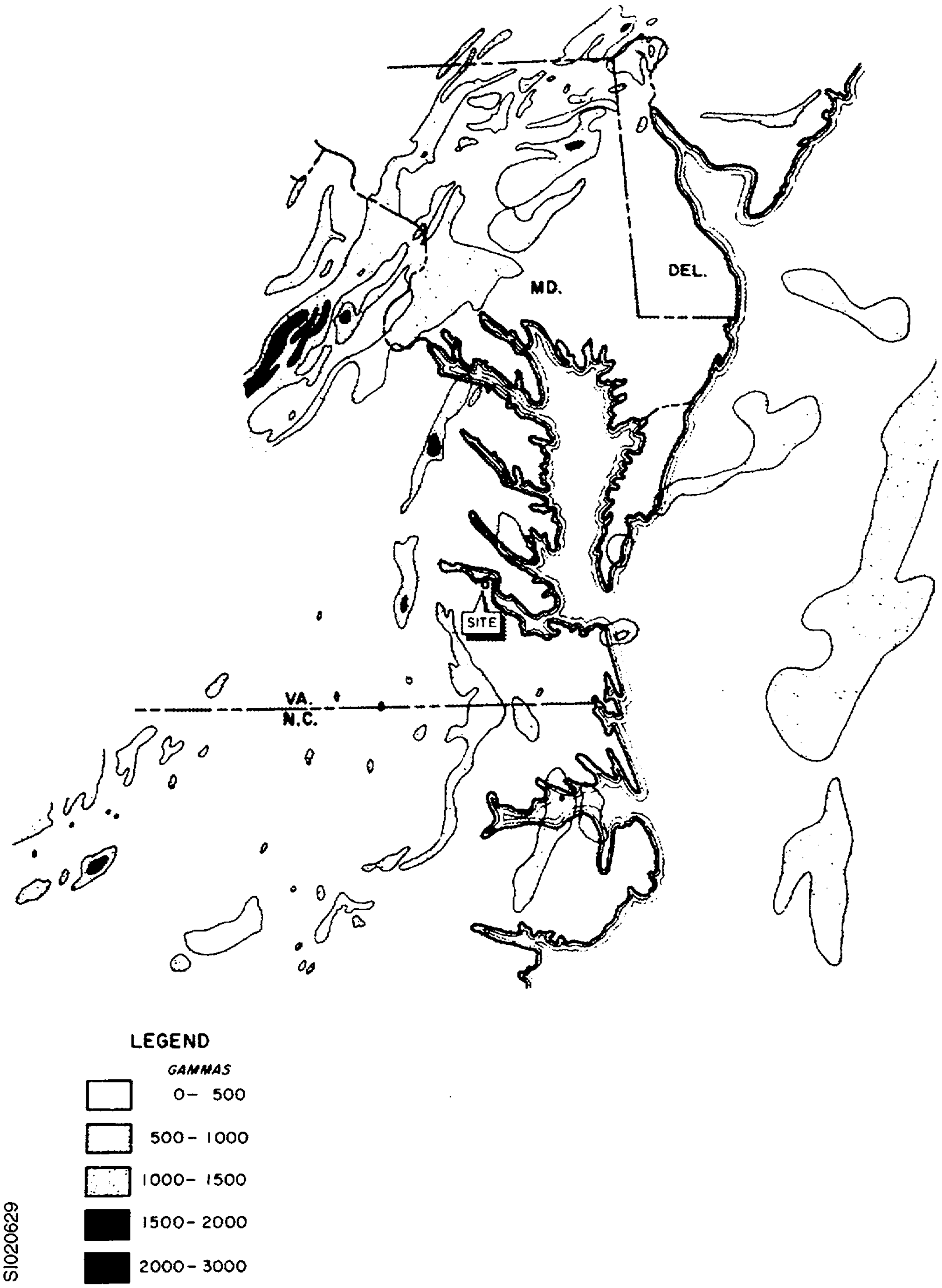

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Figure 2.6-30
CRUSTAL MOVEMENT MAP SHOWING PROBABLE VERTICAL MOVEMENTS OF THE EARTH'S SURFACE

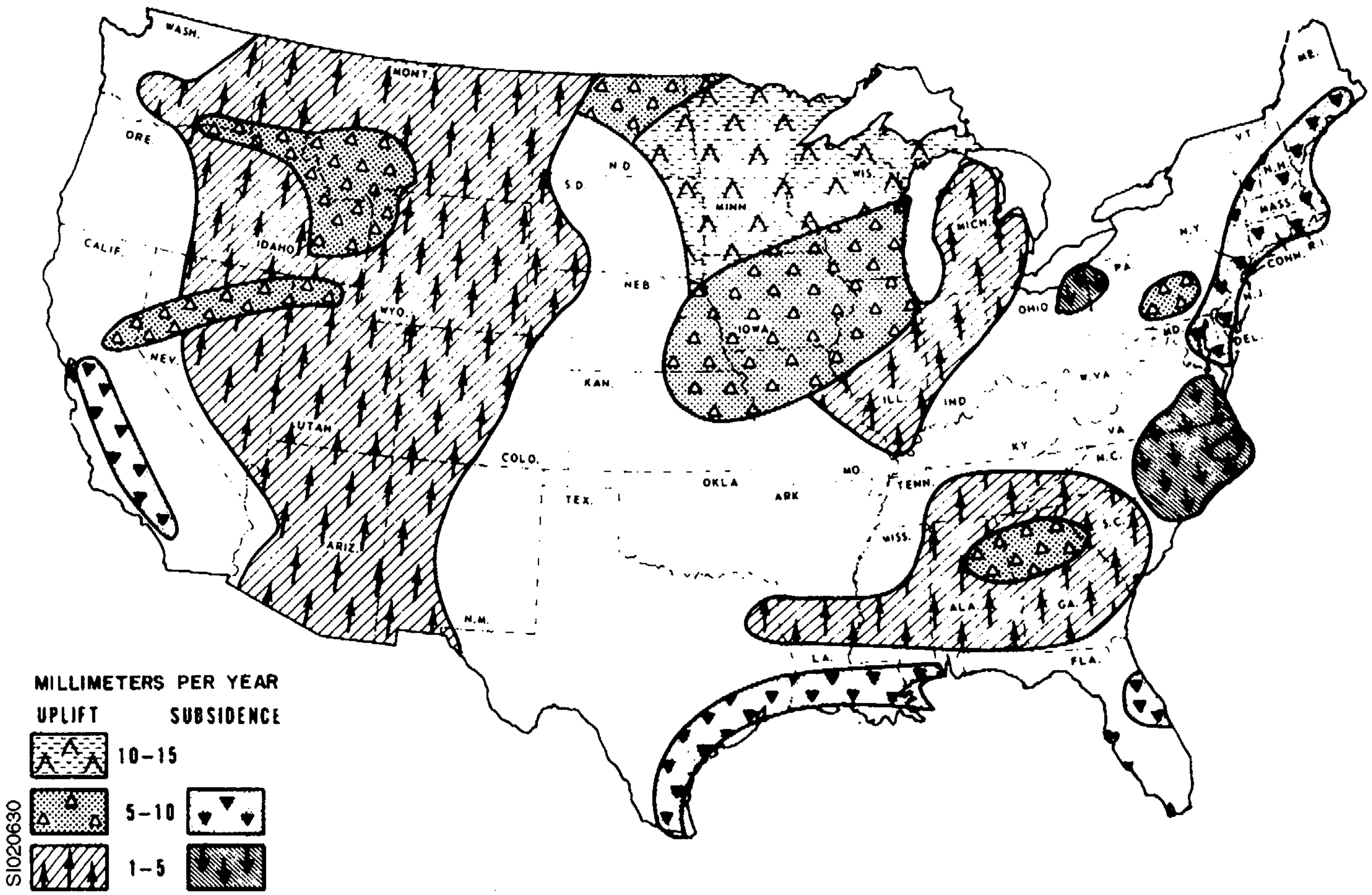
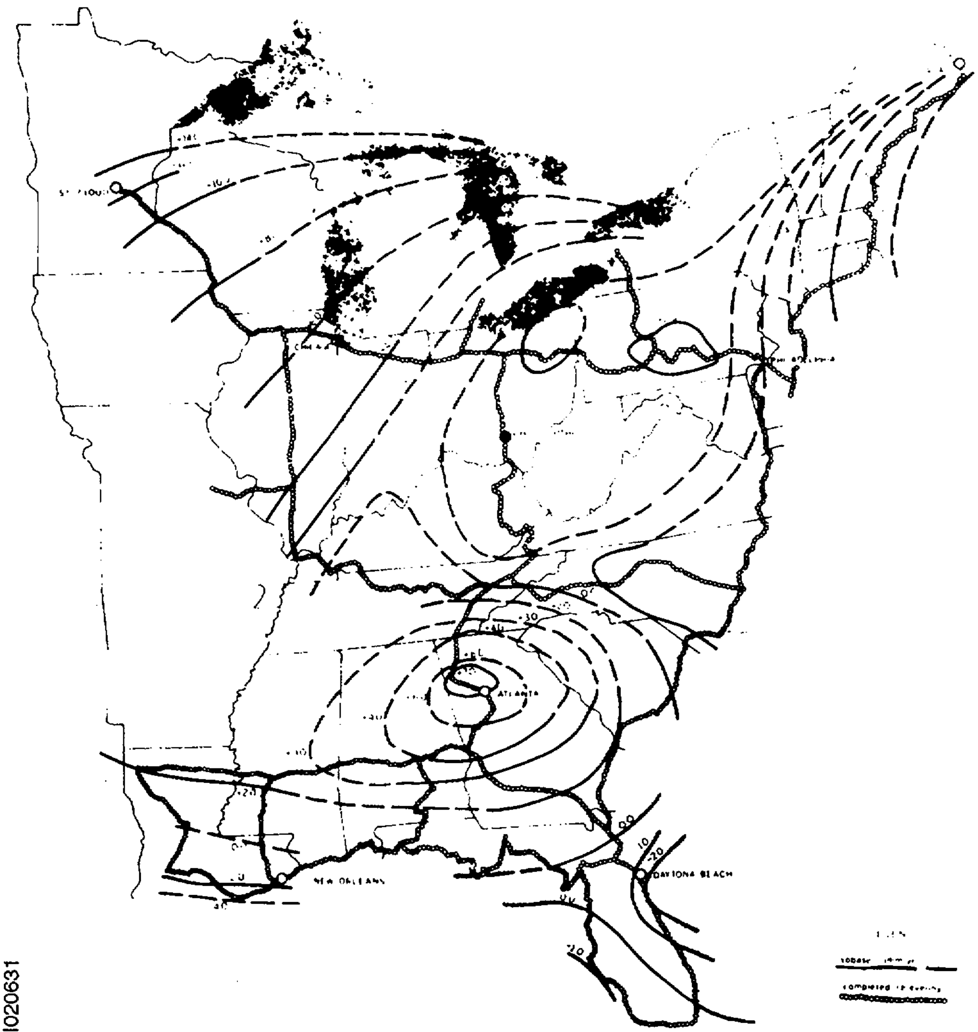


Figure 2.6-31
CRUSTAL MOVEMENT MAP OF EASTERN UNITED STATES



SI020631

Figure 2.6-32 (SHEET 1 OF 2)
BORING LOG—HOLE NO. B-1

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 OF 2	B-1

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Dry Cask ISFSI		90°	-

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE (INCHES)	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH (FT.)
5-7-82	5-7-82	Ayers & Ayers J. Ayers	CME 55	3¼"	90.5'	-	90.5'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING (FT.)	GROUND EL. (FT.)	DEPTH/EL. GROUND WATER (FT.)	DEPTH/EL. TOP OF ROCK (FT.)
-	-	22	-	33.9'	23.7'/10.2'	-

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140.25#/30"	None	K. R. Bell

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH (in.) / CORE RUN (Ft.)	SAMPLE RECOVERY (in.) / CORE RECOVERY (Ft.)	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6" / 4TH 6"	ELEVATION (FT.)	DEPTH-FT	UNIFIED SOIL CLASSIFICATION	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	18"		9	6	5	4			ML	1	Brown, medium-stiff, clayey SILT	[L]
SS	18"		10	3	4	6	30		CL	2	Gray, medium-stiff, silty CLAY	
SS	18"		10	3	4	6		5		3		
SS	18"		6	3	3	3				4		
SS	18"		9	2	3	6		10	CL	5	Reddish-brown, medium-stiff, silty CLAY, trace fine sand	[L]
SS	18"		16	6	8	8	20		SM	6	Tan, medium-dense, silty, fine SAND	
SS	18"		12	5	6	6		15		7		
SS	18"		16	6	7	9		20	SP	8	Tan, medium-dense, fine SAND	[L]
							10					▽
SS	18"		20	7	10	10		25	SP	9	Tan, medium-dense, medium to coarse SAND, trace fine gravel	
SS	18"		5	4	2	3		30		10	Tan, loose, medium to coarse SAND, trace fine gravel	[L]
SS	18"		12	3	5	7	0	35	SM	11	Brown, medium dense, silty, fine SAND, trace shells	[L]
SS	18"		7	2	3	4		40		12	Greenish-gray, loose, silty, fine SAND, trace shells	
SS	18"		6	3	3	3	-10	45		13		
SS	18"		7	3	3	4		50		14		[L]
SS	18"		6	2	3	3	-20	55		15		
SS	18"		7	2	3	4		60		16		
SS	18"		7	2	3	4	-30	65		17		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Dry Cask ISFSI	B-1

SI020632

GPD - 13234 Rev. 2/82 (Form 10070-1)

Figure 2.6-32 (SHEET 2 OF 2)
BORING LOG—HOLE NO. B-1

BECHTEL

BORING LOG

PROJECT: Vepco-Surry Power Station | JOB NO.: 14569 | SHEET NO.: 2 of 2 | HOLE NO.: B-1

Sampler Type and Diameter	Sampler Advance (In.) / Length Core Run (Ft.)	Sample Recovery (In.) / Core Recovery (Ft.)	Sample Blows "N" / Percent Core Recovery	Penetration Blows 1st 6"	2nd 6"	3rd 6" / 4th 6"	Elevation (Ft.)	Depth-Ft	Unified Soil Classification	Sample	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
SS	18"		12	4	5	7		70	SP / CH	18	Top 6": Greenish-gray, medium-dense, fine SAND Bottom 12": Greenish-gray, stiff, CLAY, trace silt, trace shells	
SS	18"		10	3	4	6	-40	75		19	Greenish-gray, medium-stiff CLAY, trace silt, trace shells	
SS	18"		9	3	3	6		80		20		[L]
SS	18"		8	3	3	5	-50	85		21		
SS	18"		6	3	3	3		90		22		
											Bottom of boring 90.5'	

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE: Dry Cask ISFSI | HOLE NO.: B-1

GPD-13234-A Rev. 2/82 (Form 10070-2)

SI020633

Figure 2.6-33
BORING LOG—HOLE NO. B-2

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 of 1	B-2

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Dry Cask ISFSI		90°	-

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE (INCHES)	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH (FT.)
5-10-82	5-10-82	Ayers & Ayers J. Ayers	CME 55	3¼"	56.0'	-	56.0'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING (FT.)	GROUND EL. (FT.)	DEPTH/EL. GROUND WATER (FT.)	DEPTH/EL. TOP OF ROCK (FT.)
-	-	17	-	31.9'	22.9'/9.0'	-

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140.25#/30"	None	K. R. Bell

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH (in.) / CORE RUN (ft.)	SAMPLE RECOVERY (in.) / CORE RECOVERY (ft.)	SAMPLE BLOWS "N"	PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6"	4TH 6"	DEPTH-FT	UNIFIED SOIL CLASSIFICATION	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	18"		7		3	3	4			CL	1	Brown, medium-stiff, silty CLAY	
ST	24"	24"									2		[L]
SS	18"		11		2	4	7		5	CL	3	Gray, stiff, silty CLAY	[L]
ST	24"	22"									4		[L]
SS	18"		9		3	3	6		10		5	Gray, medium-stiff, silty CLAY	[L]
ST	24"	24"									6		
SS	18"		9		3	4	5		15	SP	7	Reddish-brown, loose, fine to medium SAND	
SS	18"		9		3	4	5		20		8		
SS	18"		28		3	7	21		25	SP	9	Tan, medium-dense, fine to medium SAND, trace fine gravel	
SS	18"		11		4	5	6		30		10	Tan, medium-dense, medium to coarse SAND, trace fine gravel	
SS	18"		4		2	2	2		35	SM	11	Brown, loose, silty, fine SAND	
SS	18"		4		2	1	3		40	SM	12	Greenish-gray, loose, silty, fine SAND, trace shells	
SS	18"		5		3	3	2		45		13		
ST	24"	0"									14		[L]
SS	18"		7		3	3	4		50		15		
ST	24"	24"									16		[L]
ST	24"	0"							55		17		
												Bottom of boring 56.0'	

ELEVATION (FT.): 30, 20, 10, 0, -10, -20

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER	SITE: Dry Cask ISFSI	HOLE NO. B-2

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SI020634

Figure 2.6-34
BORING LOG—HOLE NO. B-2U

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 of 1	B-2U

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Dry Cask ISFSI		90°	-

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE (INCHES)	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH (FT.)
5-10-82	5-10-82	Ayers & Ayers J. Ayers	CME 55	3¼"	14'	-	14'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING (FT.)	GROUND EL. (FT.)	DEPTH/EL. GROUND WATER (FT.)	DEPTH/EL. TOP OF ROCK (FT.)
-	-	3	-	31.9'	-	-

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
-	None	K. R. Bell

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH (in.) / CORE RUN (Ft.)	SAMPLE RECOVERY (in.) / CORE RECOVERY (Ft.)	SAMPLE BLOWS "N"	PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6"	4TH 6"	ELEVATION (FT.)	DEPTH-FT	UNIFIED SOIL CLASSIFICATION	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
ST	24"	16"							30		CL	1	Brown silty CLAY	[L]
										5				
ST	24"	23"									CL	2	Gray silty CLAY	[L]
										10				
									20		SP	3	Reddish-brown fine to medium SAND	[L]
ST	24"	23"												
										15			Bottom of boring 14.0'	

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE: Dry Cask ISFSI — HOLE NO. B-2U

S1020635

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Figure 2.6-35 (SHEET 1 OF 2)
BORING LOG—HOLE NO. B-3

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 OF 2	B-3

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Dry Cask ISFSI		90°	-

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE (INCHES)	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH (FT.)
4-28-82	4-28-82	Ayers & Ayers R. Ayers	CME 55	3¼"	100.5'	-	100.5'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING (FT.)	GROUND EL. (FT.)	DEPTH/EL. GROUND WATER (FT.)	DEPTH/EL. TOP OF ROCK (FT.)
-	-	24	-	32.0'	20.5'/11.5'	-

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140.25# /30"	None	K. R. Bell

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH (in.) / CORE RUN (FT.)	SAMPLE RECOVERY (in.)	CORE RECOVERY (FT.)	SAMPLE BLOWS "N"	PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6" / 4TH 6"	ELEVATION (FT.)	DEPTH-FT	UNIFIED SOIL CLASSIFICATION	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	18"			7		2	3	4			CL	1	Brown, medium-stiff, silty CLAY	[L]
SS	18"			11		3	4	7	30		CH	2	Gray, stiff, silty CLAY	[L]
SS	18"			12		2	5	7		5		3		
SS	18"			13		2	5	8				4		
SS	18"			10		2	4	6		10	CL	5	Light brown, medium-stiff, fine sandy CLAY	
SS	18"			25		3	12	13	20		SM	6	Reddish-brown, medium-dense, silty fine SAND	[L]
SS	18"			22		4	10	12		15		7		
SS	18"			12		6	7	5	10	20	SP	8	Bottom 6": Gray, medium-dense, fine to medium SAND	▽
SS	18"			7		1	3	4		25	CH	9	Gray, soft, CLAY, some wood	[L]
SS	18"			43		12	20	23	0	30	SP	10	Bottom 15": Tan, dense, medium to coarse SAND, some fine gravel	
SS	18"			7		1	3	4		35	SM	11	Gray, loose, silty fine SAND	[L]
SS	18"			4		1	2	2	-10	40		12		
SS	18"			6		1	3	3		45	SM	13	Greenish-gray, loose, silty fine SAND, trace shells	[L]
SS	18"			10		3	5	5	-20	50		14		
SS	18"			12		3	5	7		55		15	Greenish-gray, medium-dense, silty fine SAND, trace shells	
SS	18"			7		1	3	4	-30	60		16	Greenish-gray, loose, silty fine SAND, trace shells	
SS	18"			12		3	4	8		65		17	Greenish-gray, medium-dense, silty fine SAND, trace shells	

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER	SITE	HOLE NO.
	Dry Cask ISFSI	B-3

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SI020636

Figure 2.6-35 (SHEET 2 OF 2)
BORING LOG—HOLE NO. B-3

BECHTEL

BORING LOG

PROJECT: Vepco - Surry Power Station | JOB NO.: 14569 | SHEET NO.: 2 OF 2 | HOLE NO.: B-3

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE (in.)	LENGTH CORE RUN (Ft.) / SAMPLE RECOVERY (in.)	CORE RECOVERY (Ft.)	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6" / 4TH 6"	ELEVATION (FT.)	DEPTH - FT	UNIFIED SOIL CLASSIFICATION	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	18"			12	2	5	7		70	CH	18	Greenish-gray, stiff, CLAY, trace silt, trace shells	
								- 40					
SS	18"			13	3	5	8		75		19		[L]
SS	18"			11	2	4	7		80		20		
								- 50					
SS	18"			13	2	4	9		85		21		
SS	18"			8	1	3	5		90		22	Greenish-gray, medium stiff, CLAY, trace silt, trace shells	
								- 60					
SS	18"			33	11	17	16		95		23	Greenish-gray, stiff, CLAY, trace silt, some cemented shell zones	
SS	18"			32	8	15	17		100		24		
								- 70				Bottom of boring 100.5'	

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE: Dry Cask ISFSI | HOLE NO.: B-3

GPO - 13234 - A Rev 2/82 (Form 10070-2)

SI020637

Figure 2.6-36 (SHEET 1 OF 2)
BORING LOG—HOLE NO. B-4

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 OF 2	B-4

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Dry Cask ISFSI		90°	

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE (INCHES)	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH (FT.)
5-6-82	5-6-82	Ayers & Ayers J. Ayers	CME 55	3¼"	100.5'	-	100.5'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING (FT.)	GROUND EL. (FT.)	DEPTH/EL. GROUND WATER (FT.)	DEPTH/EL. TOP OF ROCK (FT.)
-	-	24	-	34.4'	23'/11.4'	-

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140.25#/30"	None	K. R. Bell

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE (in.) / LENGTH CORE RUN (Ft.)	SAMPLE RECOVERY (in.) / CORE RECOVERY (Ft.)	SAMPLE BLOWS "N" / PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6" / 4TH 6"	ELEVATION (FT.)	DEPTH-FT	UNIFIED SOIL CLASSIFICATION	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	18"		5	3	2	3			CL	1	Brown, soft, silty CLAY	
SS	18"		9	2	4	5			CL	2	Gray, medium-stiff, silty CLAY	
SS	18"		9	2	4	5	30	5		3	Gray, medium-stiff, silty CLAY, trace reddish-brown fine sand seams	[L]
SS	18"		8	2	4	4				4		
SS	18"		8	2	3	5		10	CL	5	Bottom 6": Reddish-brown, medium-stiff, silty CLAY, trace iron nodules	
SS	18"		9	3	4	5			CL SM	6	Top 6": Gray, medium-stiff, sandy CLAY Bottom 12": Reddish-brown, medium-dense silty SAND	
SS	18"		20	7	9	11	20	15		7		[L]
SS	18"		20	5	6	14		20	SP	8	Tan, medium-dense, fine to medium SAND, trace fine gravel	
SS	18"		15	8	6	9	10	25	SP	9	Tan, medium-dense, medium to coarse SAND, trace fine gravel	▽
SS	18"		10	3	4	6		30		10		[L]
SS	18"		9	4	5	4	0	35	SC	11	Reddish-brown, medium-stiff, sandy CLAY	
SS	18"		6	3	3	3		40	SM	12	Greenish-gray, loose, silty fine SAND, trace shells	
SS	18"		6	3	3	3	-10	45		13		[L]
SS	18"		6	2	3	3		50		14		
SS	18"		7	3	3	4	-20	55		15		
SS	18"		7	2	3	4		60		16		
SS	18"		6	2	3	3	-30	65		17		

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER	SITE	HOLE NO.
	Dry Cask ISFSI	B-4

SI020638

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Figure 2.6-36 (SHEET 2 OF 2)
BORING LOG—HOLE NO. B-4

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	2 OF 2	B-4

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE (in.) / LENGTH CORE RUN (ft.)	SAMPLE RECOVERY (in.) / CORE RECOVERY (ft.)	SAMPLE BLOWS "N"	PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6" / 4TH 6"	ELEVATION (FT.)	DEPTH-FT	UNIFIED SOIL CLASSIFICATION	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
SS	18"		8		3	4	4		70	SM	18		
SS	18"		6		2	3	3	- 40	75	CL	19	Greenish-gray, medium stiff, silty CLAY, trace fine sand, trace shells	
SS	18"		9		3	3	6		80	CH	20	Greenish-gray, medium-stiff, CLAY, trace silt, trace shells	
SS	18"		9		3	3	6	- 50	85		21		[L]
SS	18"		7		2	3	4		90		22		
SS	18"		11		3	4	7	- 60	95		23		
SS	18"		8		3	3	5		100		24		
												Bottom of boring 100.5'	

	SITE	HOLE NO.
SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER	Dry Cask ISFSI	B-4

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