Surry Independent Spent Fuel Storage Installation

Final Safety Analysis Report Revision 16

Docket No. 72-2
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REVISION SUMMARY

Revision 16—06/04

Chapter/Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
6.3.6	Added the low-level waste storage facility and the sea van storage pad to the description of storage facilities.
9.1.4	Clarified the Nuclear Oversight Department procedure audit function.
10.4, 10.5, 10.6	Incorporated correct references to 10 CFR 72 concerning material status reports, nuclear material transfer reports, and financial reports.
A.5	Updated a document reference from "TN-32 Topical Safety Analysis Report, Revision 11" to "TN-32 Final Safety Analysis Report, Revision 0."
A.5	Provided bolt torque ranges for the TN-32 casks.
A.5, A.5 Attachment 4	Incorporated additional analyses regarding TN-32 cask gap between center basket rails.

Amendment 15—06/02

Chapter/Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
2.2, 2.2.3.2.1, Table 2.2-5	Transferred the description of chemical products and hazardous substances from a table to text. Augmented the discussion of fuel oil stored at the Gravel Neck Combustion Turbine site.

Amendment 15—06/02

Chapter/Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
3.1.1, 3.1.1.1.1.1, 3.1.1.1.1.2, 3.1.1.1.1.3, Table 3.1-1, 3.3.4.1, 3.3.4.2, 3.3.4.3, 3.3.5.2, 4.2.3.3, 5.1.3.1, 7.2.1, 7.3.2.1, 7.3.2.2, 7.3.4, 7.3.5, Tables 7.3-1, 7.3-2, 7.3-3, 7.3-4, & 7.3-5, Figures 7.3-2, 7.3-3, 7.3-4, 7.3-5, & 7.3-6, 7.4.1, 7.4.2, 7.4.3, Tables 7.4-1, 7.4-2, 7.4-3, & 7.4-4, 7.6, 7.6.2, 8.2.9, A.1/7.3.2.1, A.1/7.3.2.2, Tables A.1/7.3-2, A.1/7.3-3, & A.1/7.3-4, Figures A.1/7.3-2, A.1/7.3-3a, A.1/7.3-3b, A.1/7.3-4a, A.1/7.3-4b, A.1/7.3-5a, A.1/7.3-5b, A.1/7.3-6, A.1/7.3-7a, A.1/7.3-7b, A.1/7.3-8a, A.1/7.3-8b, A.1/7.3-9a, A.1/7.3-9b, & A.1/7.3-10, A.2/7.3.2.1, A.2/7.3.2.2, Figure A.2/7.3-6, A.3/7.3.2.1, A.3/7.3.2.2, Figure A.3/7.3-6, A.4/7.3.2.1, A.4/7.3.2.2, Figure A.4/7.3-6, A.5/3.1.2, A.5/3.3.4, A.5/3.3.4.1, A.5/4.2.3.3, Table A.5/4.2-1, A.5/7.3.2.1.1, A.5/7.3.2.2, A.5/7.3.5, Table A.5/7.3-2, Figures A.5/7.3-2, A.5/7.3-3, A.5/7.3-4, A.5/7.3-5, A.5/7.3-6, & A.5/7.3-7, A.5/8.2.9	Updated the shielding, criticality, thermal, and accident evaluations used to support the revised fuel limits for the TN-32 cask. [10 CFR 72.56 License Amendment]
10.2.1.1	Changed the fuel record requirement from date of manufacture to delivery date.
10.8.1	Updated management titles for those positions responsible for safe operation of the ISFSI.
A.1/3.1.1, A.1/7.3.5, A.2/3.1.1, A.2/7.3.5, A.3/3.1.1, A.3/7.3.5	Included more information on the storage of burnable poison rod assemblies or thimble plug devices with the fuel assemblies placed in the CASTOR V/21, MC-10, and NAC I/28 storage casks. [10 CFR 72.56 License Amendment]

Amendment 15—06/02

Chapter/Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
Appendix A.5, Appendix A.5 Attachment 1	Added provisions for the use of TN-32 casks fabricated to the requirements of the TN-32 FSAR, Revision 0.
A.5, A.5 Attachment 1	Incorporated the modified TN-32 cask lid bolt analysis.
A.5, A.5 Attachment 3	Modified the TN-32 cask protective cover and overpressure system.
A.5/7.3.2.1	Added guidance on the calculation of separate gamma and neutron average side surface dose rates for TN-32 storage casks.
A.5 Attachment 3	Reconfigured the TN-32 overpressure system tubing.

Amendment 14

Chapter/Section	Changes Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
A.5	Revised the description of the weld in the neutron shield outer shell of TN-32 casks.
A.5	Clarified the location of borated aluminum plates in the fuel basket of TN-32 casks.
A.5, A.5 Attachment 2	Incorporated structural analyses for missile impacts on TN-32 casks.
A.5/3.1.1, A.5/7.3.5 Refs	Added information on the storage of burnable poison rod assemblies and thimble plug devices in TN-32 casks. [10 CFR 72.56 License Amendment]

Amendment 13

Chapter/Section	Changes
1.2, 1.3, 1.4, Table 1.1-2, Table 1.1-3, Figure 1.2-1, 3.1.2, 3.2.1.1, 3.3.1, 3.3.2.1, 3.3.4, 3.3.5.1, Table 3.3-1, 4.1.2.4, 4.2.3.3, Table 4.2-1, 4.3.2.1, 4.3.8, 4.3.12, 5.1.1, 5.1.4, Table 5.1-1, 5.2.1, 5.2.2, 5.3.1.1, 5.3.1.3, 5.3.2, 6.3.1, 6.4.2, 7.1.1, 7.1.2, 7.1.3, Table 7.1-1, Table 7.1-2, 7.2.1, 7.3.1, 7.3.3, 7.5, 7.5.1, 7.5.2, 7.5.3, Table 7.5-1, Table 7.5-2, Table 7.5-3, Table 7.5-4, Table 7.5-5, Table 7.5-6, Figure 7.5-1, 7.6, 7.6.1.4, Table 7.6-1, Table 7.6-2, Table 7.6-3, Figure 7.6-1, Figure 7.6-2, Figure 7.6-3, Figure 7.6-4, 8.2.5, 8.2.10, 9.2.3, 9.4.1.2, 9.4.2, 10.1, 10.2.1.2, 10.2.2.3, 10.3, A.2/3.1.1, A.2/7.3.2.1, A.2/7.3.2.2, A.2/7.3.5, A.2/8.2.8, & A.3/7.3.2.2	Incorporated technical and editorial corrections and clarifications resulting from the Integrated Configuration Management Project compliance review of the Surry ISFSI facility. The proposed changes include conversion of the entire SAR document to electronic media to facilitate publishing and availability to end-users on the MIND system.

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SURRY ISFSI SAR

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Chapter 1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

1.1 INTRODUCTION

The spent fuel pool at the Surry Power Station, like those at most other nuclear power plants in this country, was designed only for short-term storage with the expectation that fuel reprocessing would be available. Fuel reprocessing, however, has not become available, nor is it expected to become available in the near future. Interim storage at away-from-reactor (AFR) fuel storage facilities, and storage at permanent repositories have also yet to become viable alternatives. The independent spent fuel storage installation (ISFSI) at the Surry site is designed to store all the anticipated spent fuel resulting from the operation of the Surry Power Station Units 1 and 2 in excess of that which can be stored in the spent fuel pool.

The Surry ISFSI is located within the site boundary of the Surry Power Station and is owned and operated by Virginia Electric and Power Company (Virginia Power). The fuel is stored in dry sealed surface storage casks (SSSCs) which ensure the confinement of the radioactive fission products and provide shielding. The casks are cooled by natural convection.

The Surry Power Station spent fuel pool has a capacity of 1044 fuel assemblies, and according to the current refueling schedule (60 assemblies discharged per unit every 18 months) would be totally filled by 1987. However, the capability to discharge an entire core (157 assemblies) would be lost in 1986. Structural limitations preclude adding additional capacity to the spent fuel pool through the use of, for example, higher density spent fuel storage racks. The Surry ISFSI began operation in 1986 in order to avoid the loss of the full core discharge capability, and will continue to operate throughout the life of the power plant or until other arrangements are made to dispose of the spent fuel.

Bechtel Associates Professional Corporation (Virginia), hereafter referred to as Bechtel, is the Architect/Engineer. Casks to be used in the Surry ISFSI are designed and manufactured by other organizations and will be purchased or leased by Virginia Power.

Detailed information describing the SSSCs is provided in SSSC topical reports referenced in Appendix A of this Safety Analysis Report (SAR). General references to the SSSC topical reports are made in sections of this SAR, as needed, to supplement information contained in the SAR. Each cask type is described in a subappendix of Appendix A. Also, the subappendices provides cask-specific information not contained in the SSSC topical reports. The combination of this SAR, including appendices, and any one of the reports describing the SSSCs (one per type of cask or manufacturer) provides all the information described in the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 3.48, *Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation (Dry Storage).* The Surry ISFSI

utilizes only those casks described in these reports and meeting the design criteria specified in Chapter 3 of this SAR.

This SAR is primarily directed towards analyzing the safety aspects of cask handling and storage once the casks have left the Surry Power Station decontamination building, and how the safety requirements in 10 CFR Part 72 are satisfied. Handling of the casks inside the fuel and decontamination buildings is addressed as part of the license for the Surry Power Station under 10 CFR Part 50. A summary of SAR sections addressing the technical requirements in 10 CFR Part 72 is presented in Tables 1.1-1 and 1.1-2.

Table 1.1-1
COMPLIANCE WITH TECHNICAL REQUIREMENTS IN 10 CFR PART 72

Section in 10 CFR Part 72	Topic	SAR Section Where Addressed
Subpart E		
72.90 to 72.102	Site characteristics and definition of design basis external events	Chapters 2 and 3 (1)
72.104	Radiological consequences	Chapters 7 and 8
72.106	Controlled area	Section 4.1.2 and Chapter 8
72.32	Emergency planning	Sections 4.1.2.3 and 9.5 (2)
Subpart F		
72.122 (a)	Quality standards	Sections 3.1.2, 3.4, 9.4.1.8, and Chapter 11 (3)
(b)	Protection against environmental conditions	Sections 3.2, 4.2.3, 8.2.2, and 8.2.3
(c)	Fires and explosions	Sections 3.3.6, 4.3.8, 8.2.4, and 8.2.5
(d)	Sharing of structures	Section 5.1.1
(e)	Proximity of sites	Sections 3.3.7.1 and 7.6.2 (1)
(f)	Testing and maintenance	Table 3.3-1, Sections 4.3.9, 4.5, 9.2, and 9.4.1.4, and Chapter 5
(g)	Emergency capability	Section 9.5
(h)	Confinement barriers	Sections 3.3.2, 4.2.2.3, 4.2.3, 4.3.1, 7.3.3, 8.2.9, and 8.2.11
(i)	Instrumentation and controls	Sections 3.3.3.2, 4.3.7, 5.4.1, 7.3.4, and 10.9
(j)	Control areas	Section 5.5 (4)
(k)	Utility services	Sections 4.3 and 8.1
72.124	Criticality	Sections 3.3.4, 4.2.3, and 5.1.3.1
72.126 (a)	Radiation exposure control	Chapter 7 and Sections 5.1.3.5, 9.4.1.3, and 9.4.1.4
(b)	Radiological alarm systems	Sections 3.3.3.2, 3.3.5.3, 4.3.7, 5.1.3.4, 5.4.1, and 10.9
(c)	Effluent and direct radiation monitoring	Sections 7.3.4 and 7.6.1

Table 1.1-1 (continued)
COMPLIANCE WITH TECHNICAL REQUIREMENTS IN 10 CFR PART 72

Section in 10 CFR Part 72	Topic	SAR Section Where Addressed
72.126 (d)	Effluent control	Sections 7.3.1, 7.6, and 8.2.11
72.128 (a)	Criteria for spent fuel storage and handling systems	Chapter 3
(b)	Criteria for waste treatment	Section 3.3.7
72.130	Decommissioning	Sections 3.5 and 9.6 (5)
Subpart G		
72.140	Quality assurance	Chapter 11 and Sections 3.3.2.1 and 9.4.1.8 (3)
Subpart H		
72.182	Physical protection	(4)
Subpart I		
72.190	Operator requirements	Chapter 9
72.192	Operator training and certification	(6)
72.194	Physical requirements	Chapter 9

Notes:

(1) Also addressed in Environmental Report

(2) Also addressed in Emergency Plan

(3) Also addressed in Quality Assurance Program

(4) Also addressed in Physical Security Plan, Design for Physical Security, and Safeguards Contingency Plan

(5) Also addressed in Decommissioning Plan

(6) Also addressed in Training Program

Table 1.1-2
INDEX OF MAJOR TECHNICAL TOPICS

	SAR Sections Where Criteria are Set	SAR Sections Where Addressed	Sections in 10 CFR Part 72 Where Requirements are Placed
Site			
Site Descriptions		2.1.1, 2.1.2, 2.1.4, 4.1	72.90
Meteorology	3.2.4	2.3, 8.3	72.122(b)
Hydrology		2.4, 2.5	72.90, 72.122(b)
Population		2.1.3	72.98, 72.100
Seismology/Geology	3.2.3	2.6, 8.2.1	72.102, 72.122(b)
Natural Hazards	3.2.1, 3.2.2	4.2.3, 8.2.2, 8.2.3	72.90, 72.92, 72.102, 72.122(b)
Man-Made Hazards	3.3.6	2.2, 4.2.3, 4.3.8, 8.2.4, 8.2.5	72.94, 72.98, 72.122(c)
Casks			
Design	3.2.5	3.2.1.2, 4.2.3	
Confinement Capabilities	3.3.2	4.2.2.3, 4.2.3, 8.2.9, 8.2.11	72.122(h), 72.128(a)
Thermal Analyses	3.1.1, 3.1.2	4.2.3	72.128(a)
Criticality Control	3.3.4	4.2.3, 5.1.3.1	72.124
Handling	3.1.2, 3.3.1, 3.3.7.1, 3.3.8	5.1.1, 5.1.2, 5.2.1, 5.2.2	
Instrumentation	3.3.3.2, 3.3.5.3	4.3.7, 5.1.3.4, 5.3.2, 5.4, 5.5, 7.3.4, 7.6.1.4, 9.2, 9.4.1.2, 10.9	72.122(i), 72.126(c), 72.128(a)
Fuel	3.1.1, 3.1.2, 3.3.7.1		

Table 1.1-2 (continued)
INDEX OF MAJOR TECHNICAL TOPICS

	SAR Sections Where Criteria are Set	SAR Sections Where Addressed	Sections in 10 CFR Part 72 Where Requirements are Placed
ISFSI			
Concrete Slabs		4.1.1, 4.2.1	
Access Control	3.3.5.1	9.4.1.1, 9.4.1.3	72.180, 72.182, 72.184, 72.186
Radiological Control			
Onsite Doses		7.3.2.2, 7.4, 9.4.1.3	72.126
0ffsite Doses		7.6, 8.2.11	72.104, 72.106
ALARA	3.3.5.2	7.1, 7.3.1, 7.5	72.104(b), 72.126(c)
Shielding	3.3.5.2	7.2.1, 7.3.2	72.128(a)
Decontamination		4.4, 5.6, 6.1, 6.3.2.1, 6.3.3	
Interaction with Power Plant	3.1.2, 3.3.7.1	5.1.1, 5.1.2, 6.1, 7.4, 8.2.6, 8.2.10, 9.1, 9.2	72.122(d) and (e)
Emergency Planning		4.1.2.3, 9.5	72.32, 72.122(g)
Technical Specifications		Chapter 10	
Quality Assurance	3.1.2, 3.4	9.4.1.8, Chapter 11	72.122(a), 72.140
Accident Analyses	3.3.2	Chapter 8	72.122(b)
Maintenance	3.3.3.2	4.3.9, 4.5, 5.1.3.5, 9.4.1.4	72.122(f)
Waste Handling	3.3.7	6.3, 6.4, 6.5	72.128
Decommissioning	3.5	9.6	72.130

1.2 GENERAL DESCRIPTION OF INSTALLATION

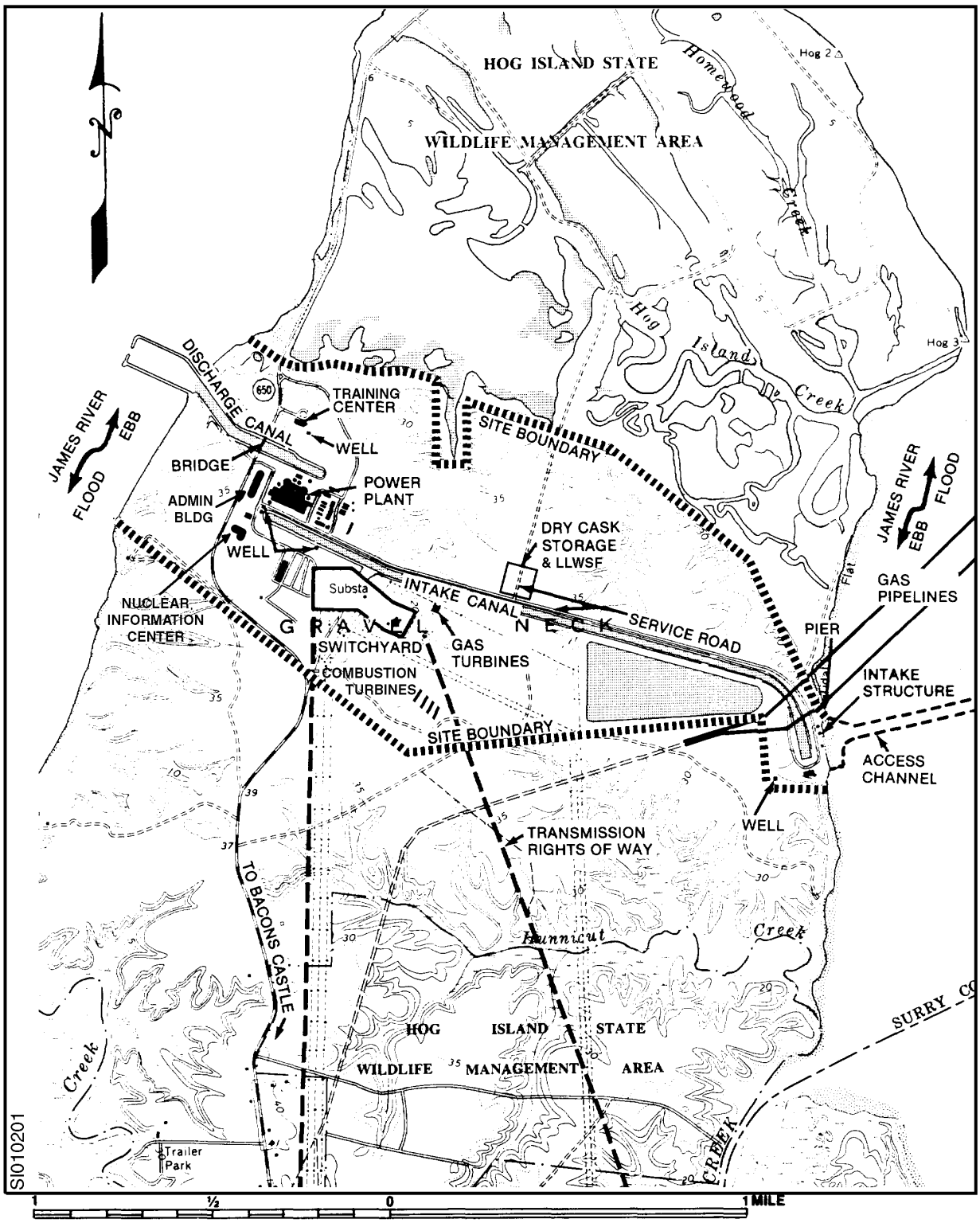
The Surry site comprises about 840 acres in Surry County, Virginia. The ISFSI is located near the center of the site, about 3300 feet east of the Surry Power Station. Figure 1.2-1 shows a general layout of the site.

The Surry Power Station consists of two closed-cycle pressurized water reactors (PWR) provided by Westinghouse. Operating licenses were issued by the Atomic Energy Commission (AEC) in May 1972 and January 1973 for Units 1 and 2, respectively. Unit 1 started commercial operation in December 1972 and Unit 2 in May 1973. A complete description of the power station is provided in the Final Safety Analysis Report (FSAR), AEC/NRC dockets 050-280/281.

An application for a Construction Permit (CP) for two additional units at the Surry site was filed with the AEC in April 1973, and a CP was issued in December 1974. These plants have subsequently been cancelled, but the Preliminary Safety Analysis Report (PSAR) for Units 3 and 4 is referenced in this SAR as a source of more recent information describing the Surry site. The Units 3 and 4 application was filed under AEC/NRC dockets 050-434/435.

The Surry ISFSI consists of three concrete slabs on which the loaded storage casks are placed. The slabs will be built in sequence, as needed, and in an order which minimizes radiation exposures. Each slab is surrounded by an inner security fence which in turn is surrounded by an outer fence (hereinafter referred to as the ISFSI fence). The ISFSI fence also surrounds the nearby Low Level Waste Storage Facility (LLWSF). The only support systems required are those necessary for transferring the loaded and sealed casks from the Surry Power Station to the ISFSI. The SSSCs are the only components with a safety function. The other components, e.g., monitors, alarms, power supplies, lights, etc., do not perform safety functions.

Figure 1.2-1
GENERAL SITE LAYOUT



1.3 GENERAL SYSTEMS DESCRIPTION

The Surry ISFSI uses sealed storage casks to store fuel irradiated at the Surry Power Station. Typically the casks are large cylindrical vessels capable of storing 24 unconsolidated PWR fuel assemblies. The casks are carbon steel, stainless steel, or cast iron with stainless steel cladding, about 16-feet long and 8-feet in diameter, with walls several inches thick and weighing 100 to 125 tons fully loaded. The fuel is stored in a dry atmosphere, possibly inerted, and held in place by a basket or rack.

Several steps are necessary for the loading and preparation of the casks, which take place within the fuel and decontamination buildings of the existing Surry Power Station. The casks are loaded under water in the spent fuel pool where the primary lid is positioned prior to lifting the casks out of the water. The water in the casks is pumped to the Spent Fuel Pool. The casks are then moved to the Decon Building where they are vacuum dried, backfilled with helium, and leak tested. Following decontamination of the outer surface, the casks are placed on a transporter outside the fuel building. The casks are then transferred to the ISFSI, where they are emplaced on one of the three concrete slabs.

The SSSCs are totally passive systems, with natural convection cooling sufficient to maintain safe fuel clad temperatures. The cask walls provide adequate shielding, and no radioactive products are released under any credible conditions.

1.4 QUALIFICATIONS OF AGENTS AND CONTRACTORS

Bechtel has been contracted for the engineering design of the Surry ISFSI, excluding the casks, and for the preparation of the license application.

The cask manufacturers are responsible for cask fabrication, testing, delivery to the site, and delineation of specific cask requirements, if any. Information related to the qualifications of the cask manufacturers is contained in the topical reports referenced in Section 1.5.1.

Site preparation and necessary construction will be performed by Vepco’s construction department, using specialty subcontractors, as required.

1.5 MATERIAL INCORPORATED BY REFERENCE

1.5.1 Topical Reports

The Topical Reports issued by SSSC suppliers, which are referenced in this SAR and Appendix A, are listed in Appendix A, Table A/1.5-1.

1.5.2 Other Reports

The following documents related to the licensing of the Surry Power Station Units 1 and 2, and 3 and 4, which are already on file with the NRC, are reference throughout this SAR:

1. Surry Power Station Units 1 and 2 Final Safety Analysis Report, 1971.

2. Surry Power Station Units 3 and 4 Preliminary Safety Analysis Report, 1973.

3. Surry Power Station Environmental Report for Units 3 and 4, 1973.

4. Surry Power Station Emergency Plan.

5. Virginia Electric and Power Company Operational Quality Assurance Program Topical Report, VEP-1-5A, (updated).

Chapter 2
THE SITE CHARACTERISTICS

2.1 GEOGRAPHY AND DEMOGRAPHY

2.1.1 Site Location

The location of the Independent Spent Fuel Storage Installation (ISFSI) is approximately 3300 feet southeast of the Surry Power Station Units 1 and 2 reactor buildings and within the boundaries of the Surry site (see Figure 2.1-1). The facility occupies approximately 15 acres.

The Surry site is located in Surry County, Virginia, on the south shore of the James River, on a point of land called Gravel Neck. The site is at the end of Route 650, 12 miles from Surry, 44 miles southeast of Richmond, 38 miles east of Petersburg, 7 miles south of Colonial Williamsburg, and 4-1/2 miles west-northwest of Fort Eustis.

Approximate coordinates of the ISFSI are:

LATITUDE-LONGITUDE	UNIVERSAL TRANSVERSE MERCATOR
37° 9.8' N - 76° 41.65' W	4,113,800 mN 349,700 mE Zone 18

2.1.2 Site Description

The Surry site is located on a point of land which projects into the James River from the south giving the appearance of a peninsula. The tip of this peninsula, known as Hog Island, is very marshy and almost severed from the rest of Gravel Neck by many streams and creeks. The site area is mostly wooded to the south. Route 650, a state secondary road, provides the only land access to the Surry site and the Hog Island State Waterfowl Refuge.

Locations of public facilities and institutions, e.g., parks, recreational areas, and schools, in the site area are described in Section 2.1.3.5.

The site plan for the Surry ISFSI and its relative location to the Surry Power Station are presented on Figure 2.1-1. Consistent with the Surry Power Station Units 1 and 2 Updated FSAR, the restricted area for the ISFSI is the Surry site boundary. The controlled area boundary is also the site boundary. As shown on Figure 2.1-1, the minimum distance to the controlled area boundary is approximately 1500 feet and occurs in the northwest sector relative to the ISFSI.

2.1.2.1 Other Activities Within The Site Boundary

Since the controlled area for the Surry ISFSI is wholly within the property lines for the Surry site, Vepco has full authority to determine all activities including the exclusion and the removal of personnel and property.

No activities unrelated to operation of the Surry Power Station or the ISFSI are permitted within the controlled area.

2.1.2.2 **Boundaries for Establishing Effluent Release Limits**

There are no radioactive effluent releases associated with the Surry ISFSI. The boundary line corresponds to the property lines for the site. The nearest real individual is approximately 1.5 miles from the ISFSI.

2.1.3 Population Distribution and Trends

2.1.3.1 **Population Within 10 Miles**

Figure 2.1-2 shows the general locations of the ISFSI and the municipalities and other cultural features within 10 miles of the site.

In the Virginia Radiological Emergency Response Plan, June 1983 (Reference 1), the distribution within 10 miles of the site was reported as shown in Figure 2.1-3. According to this report, the estimated 1980 permanent resident population within 10 miles of Surry Power Station was 84,574 persons. The permanent resident population is a subset of the total population shown in Figures 2.1-3 to 2.1-7, which includes permanent residents and transient and institutional populations. The area within 10 miles of the plant site is predominantly rural and is characterized by coastal lowland farms interspersed with marshy areas near the James River. There are populated areas in the northern and eastern sectors. As indicated on Figure 2.1-2, the municipalities which are wholly or partly within 10 miles of the site are:

	1980 Population (Reference 2)	Distance (Miles) from Surry Site	Direction from Surry Site
Newport News	144,903	4.5 (closest point)	ESE
Williamsburg	9870	7	N
Surry	237	8	WSW

The population projections for the areas within 10 miles for the years 1990, 2000, 2010, and 2020, as shown in Figures 2.1-4 through 2.1-7, were based on Virginia County projections found in the Virginia Population Projections 2000 (Reference 3) and supplemental information provided by the Virginia Department of Planning and Budget Research Section (Reference 4). The specific procedure used to calculate the population involved first dividing each sector along county boundaries so that each applicable county comprises a specific percentage of the individual sector area. Uniform population density throughout each county is assumed. The counties are then assumed to contribute a fraction of their population to the sector which is directly proportional to the fraction of area they contribute to the sector. Consequently, the sector populations are a summation of the area-weighted fraction, by sector, of the projected population contributed by the counties which comprise the sector.

2.1.3.2 **Population Between 10 and 50 Miles**

Towns and cities within 50 miles of the site are shown on Figure 2.1-8. These centers of population are listed in Table 2.1-1 along with their 1980 resident population and their distance and direction from the site. Estimates of the 1980 resident population from 10 to 50 miles are based on data compiled by the Commonwealth of Virginia utilizing the 1980 census figures. Figure 2.1-3 shows the estimated 1980 population distribution.

The population projections for the areas between 10 and 50 miles for the years 1990, 2000, 2010, and 2020, as shown in Figures 2.1-4 through 2.1-7, were based on Virginia County projections found in the Virginia Population Projections 2000 (Reference 3) and supplemental information provided by the Virginia Department of Planning and Budget Research Section (Reference 4). The procedure used to calculate the population by sector from this data was identical to that used for the 0- to 10-mile sector population projections discussed in Section 2.1.3.1.

2.1.3.3 **Transient and Institutionalized Population**

Listings of the nearby transient and institutionalized population, based on the Virginia Radiological Emergency Plan (Reference 1), are provided in Tables 2.1-4 and 2.1-5, respectively.

2.1.3.4 **Population Center**

The nearest population center is the City of Newport News, which had a 1980 population of 144,903 (Reference 3) and whose closest point is 4-l/2 miles east-southeast of the site

2.1.3.5 **Public Facilities and Institutions**

Schools

Schools within 10 miles of the site are listed in Table 2.1-2 and indicated on Figure 2.1-9.

Parks and Recreational Areas

Recreational areas within 10 miles of the site are listed in Table 2.1-3 and indicated on Figure 2.1-10. The recreational facility closest to the site is the Chippokes State Park, 2.5 miles southwest, which had a maximum 2-day attendance of 70,000 during 1981. Busch Gardens at the Anheuser Busch Brewery, 6 miles north of the site, opened in 1975. The combined annual attendance for the brewery and the gardens reached 2,160,000 (estimated) in 1980. The Hog Island State Waterfowl Refuge, 1 mile north-northeast of the site, maintained by the State of Virginia, harbors wild geese, ducks, deer and cranes, as well as other species of wildlife. This area is used by an estimated 25,000 people annually (estimated by refuge manager). The Williamsburg-Jamestown area, 6 miles north, is a popular historical attraction. About a million people per year visit the historical sites in this region.

2.1.4 Uses of Adjacent Lands and Waters

The Surry site is located on a peninsula projecting into the James River. The area within 10 miles of the site covers parts of Surry, Isle of Wight, York, and James City counties, and part of the City of Newport News. Immediate environs of the plant site are shown on Figure 2.1-2. Surry and Isle of Wight Counties are predominantly rural and characterized by farmland, wood tracts of land, and marshy wet lands. York and James City counties and Newport News City are more urban and are characterized by recreational areas and growing population centers. The tip of the peninsula, north of the site, is very marshy and almost severed by many streams and creeks. The Hog Island State Waterfowl Refuge is located on this tip of land.

About half of the total area in Surry and Isle of Wight Counties is used for agricultural purposes. The principal agricultural activity is crop farming. Forest products are also of great importance in the site region. The dominant species are loblolly pine, oak-pine, and oak-hickory. Public and private water supplies for nearby towns and dwellings, recreational facilities, and fishing facilities are described in Section 2.1.3 of the ER.

The discovery of kepone contamination in the James River was made in 1975 and has been responsible for extended periods of fishing restrictions which have varied from a total ban on fishing to selective closure by species, river section, or purpose (commercial or sport). Generally, these restrictions have reduced commercial and sport catches with the exception of channel catfish. Fishing for this species is now open to sport and commercial fisherman.

2.1.5 References

1. The Commonwealth of Virginia Radiological Emergency Response Plan (COVRERP) Annex I-V to Volume II, The Commonwealth of Virginia, Emergency Operations Plan Peacetime Disasters, Revised 1983.

2. Bureau of the Census, U. S. Department of Commerce 1980 Census of Population, Number of Inhabitants, PC (l)-A48, Virginia, February 1982.

3. Virginia Population Projections 2000, Virginia Department of Planning and Budget, Research Section, January 1983.

4. Supplemental Population Projections 2010 and 2020, Virginia Department of Planning and Budget, Research Section, January 1983.

Table 2.1-1 (SHEET 1 OF 2)
TOWNS AND CITIES WITHIN 50 MILES OF PLANT SITE

Town/City	1980 Population	Distance from Surry Site (miles)	Direction from Surry Site
0-10 Miles			
Newport News (closest point)	144,903	4.5	ESE
Williamsburg	9870	7	N
Surry	237	8	WSW
10-20 Miles			
Smithfield	3718	13	SSE
Dendron	307	15	WSW
Hampton (closest point)	122,617	15	ESE
Claremont	380	16	WNW
Poquoson	8726	17	E
20-30 Miles			
Ivor	403	21	SSW
Wakefield	1355	21	SW
Norfolk (closest point)	266,979	24	SE
Portsmouth (closest point)	104,577	24	SE
Waverly	2284	24	WSW
Windsor	985	24	S
Chesapeakes (closest point)	106,426	26	SSE
West Point	4236	27	NNW
30-40 Miles			
Saratoga Place			
Suffolk	35,533	31	S
Urbanna	518	33	N
Virginia Beach (closest point)	257,269	33	SE
Hopewell	23,507	35	WNW
Irvington	567	36	NNE
White Stone	409	36	NNE
Franklin	7308	36	SSW
Ft. Lee	9784	37	W
Courtland	976	37	SW
Cape Charles	1512	38	E
Petersburg	41,055	38	W
Colonial Heights	16,509	39	W

Table 2.1-1 (SHEET 2 OF 2)
TOWNS AND CITIES WITHIN 50 MILES OF PLANT SITE

Town/City	1980 Population	Distance from Surry Site (miles)	Direction from Surry Site
40-50 Miles			
Kilmarnock	869	40	NNE
Cheriton	695	41	ENE
Capron	238	42	SW
Stony Creek	329	42	WSW
Eastville	238	43	ENE
Highland	10,911	43	NW
Chester	11,728	44	WNW
Newsome	368	44	SSW
Richmond (closest point)	219,214	44	WNW
Mechanicsville	9269	48	NW
Boykins	791	49	SW
Jarrat	614	49	WSW
Nassawadox	630	50	ENE

Table 2.1-2 (SHEET 1 OF 2)
SCHOOL ENROLLMENT WITHIN 10 MILES OF THE PLANT SITE
BY MUNICIPAL JURISDICTION

	Subzone	Fall 1979 Enrollment	Total
Counties			
James City			
Berkeley School	10A	485	
Lafayette H.S.	10A	1727	
Rawlsbyrd School	5A	494	
			2706
Surry			
Lebanon School	10F	180	
Surry Elementary	10F	157	
Surry H.S.	10F	545	
			882
York			
Bruton High School	10B	729	
Magruder Elementary	10B	559	
Queens Lake Intermediate	10B	321	
Yorktown Intermediate	10C	590	
Waller Mill Elementary	10B	448	
			2647
Cities			
Newport News			
Lee Hall Elementary	10D	662	
B.C. Charles Elementary	10D	504	
Denbigh Elementary	10D	324	
Denbigh H.S.	10D	1635	
Dozier Intermediate	10D	1144	
Dutrow Elementary	10D	579	
Horace Hepes Elementary	10D	548	
Jenkins Elementary	10D	566	
McIntosh Elementary	10D	689	
Menchville H.S.	10D	2030	
R.O. Nelson Elementary	10D	602	
Reservoir Elementary	10D	823	
Richneck Elementary	10D	821	
Sanford Elementary	10D	702	
			11,629

Table 2.1-2 (SHEET 2 OF 2)
SCHOOL ENROLLMENT WITHIN 10 MILES OF THE PLANT SITE
BY MUNICIPAL JURISDICTION

	Subzone	Fall 1979 Enrollment	Total
Williamsburg			
Blair Middle School	10B	782	
Bruton Heights School	10B	671	
Walsingham Academy	10B	549	
William & Mary College	10B	6000	
			8560
	TOTAL		26,424

Table 2.1-3
RECREATIONAL AREAS WITHIN 10 MILES OF SURRY SITE

Park/Recreational Area	Distance and Direction From Site	Total Annual Attendance
Chippokes State Park	2.5 mi. SW	70,000 (peak two-day attendance 1981)
Jamestown Island National Historical Park	4 mi. NW	471,107 (1971)
Jamestown Festival Park	5 mi. NW	449,317 (1971)
Anheuser-Busch Brewery and Busch Gardens	6 mi. N	2,160,000 (1980)
Colonial Williamsburg	7 mi. N	1.5-2 million yearly
Yorktown National Historical Park	10 mi. ENE	201,116 (1971)

Table 2.1-4
TRANSIENT POPULATION WITHIN 10 MILES
OF THE PLANT SITE

Transient Population Centers	Maximum Daily Attendance [a]
Jamestown Colonial National Historical Park	2500
College of William and Mary	8300
Colonial Williamsburg Foundation	15,400
Busch Gardens	35,000
Yorktown Colonial National Historical Park	2500
Chippokes State Park	55
TOTAL	63,755

a. The transient population figures above represent the maximum daily attendance at the facilities during the peak season.

Table 2.1-5
INSTITUTIONALIZED POPULATION WITHIN
10 MILES OF THE PLANT SITE

Institutionalized Population Centers	Daily Attendance
Walsingham Academy	600
Eastern State Hospital	1500
Williamsburg Community Hospital	400
Pines Convalescent Center	290
Camp Peary	300
Naval Supply Depot - Cheatham Annex	200
Ball Corporation	400
Yorktown Naval Mine Depot	2400
Badische Corporation	550
Fort Eustis	8500
City Farm Penal Facility	150
TOTAL	15,290

Figure 2.1-1
GENERAL SITE LAYOUT

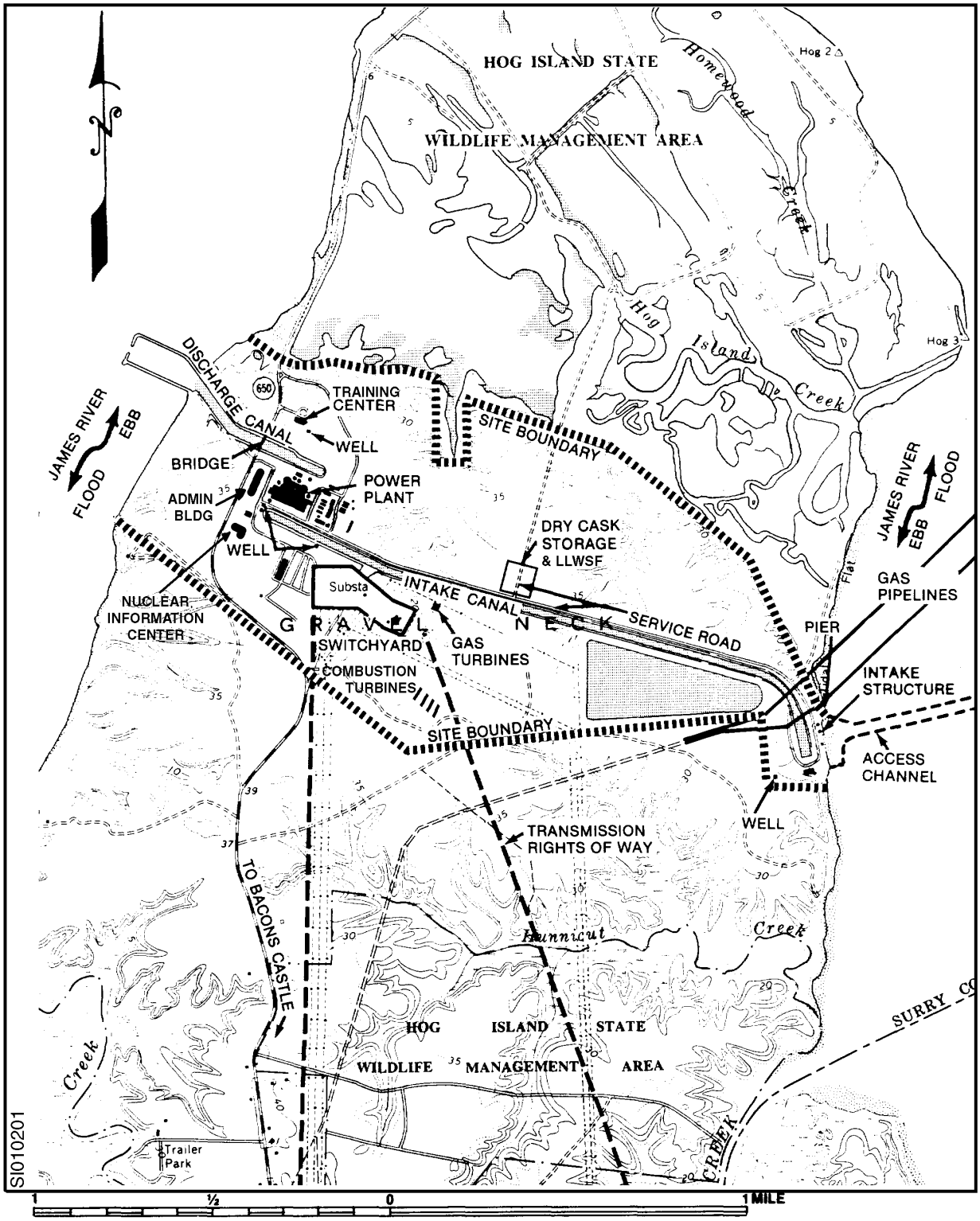


Figure 2.1-2
IMMEDIATE ENVIRONS OF PLANT SITE; SURRY POWER STATION

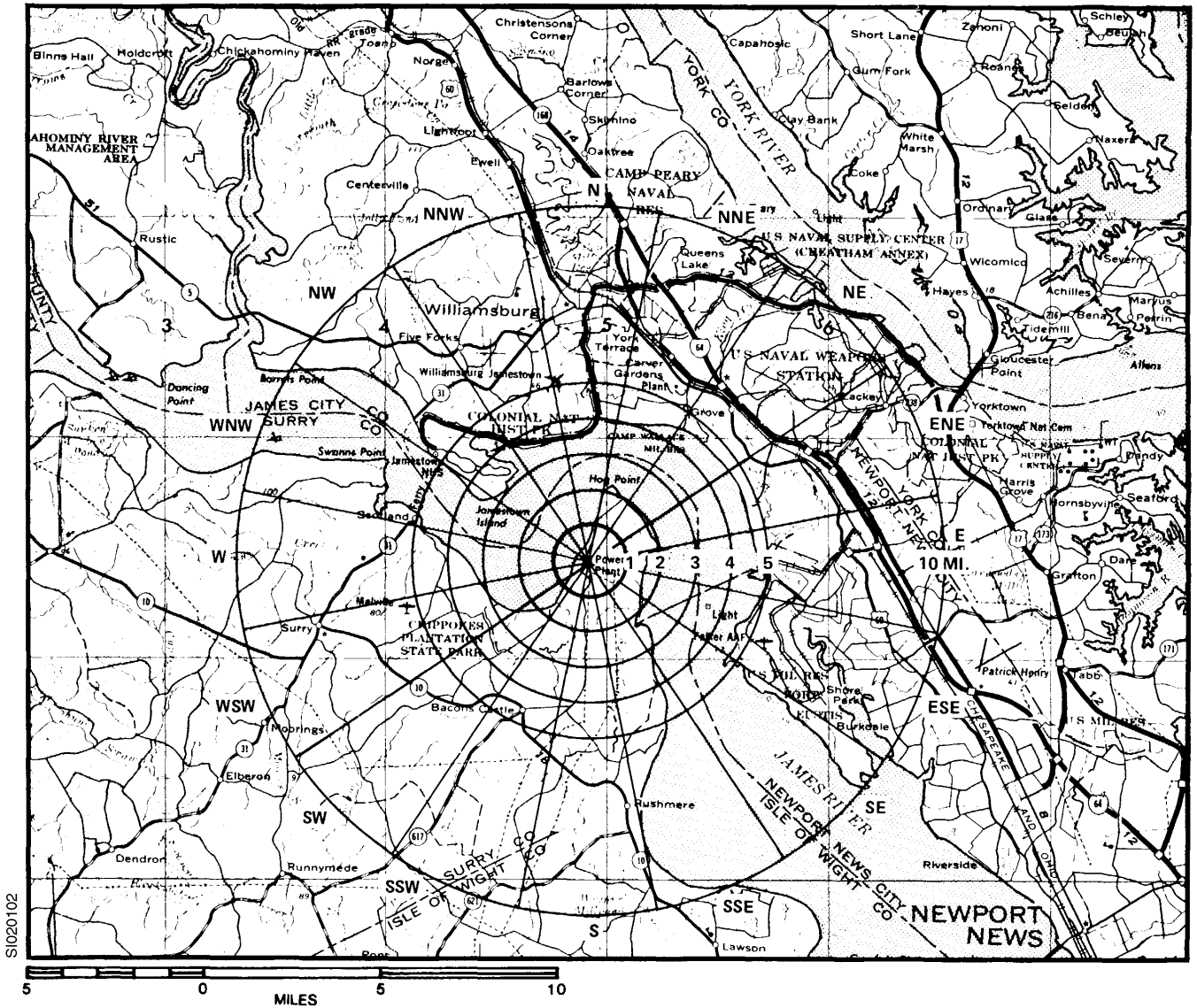
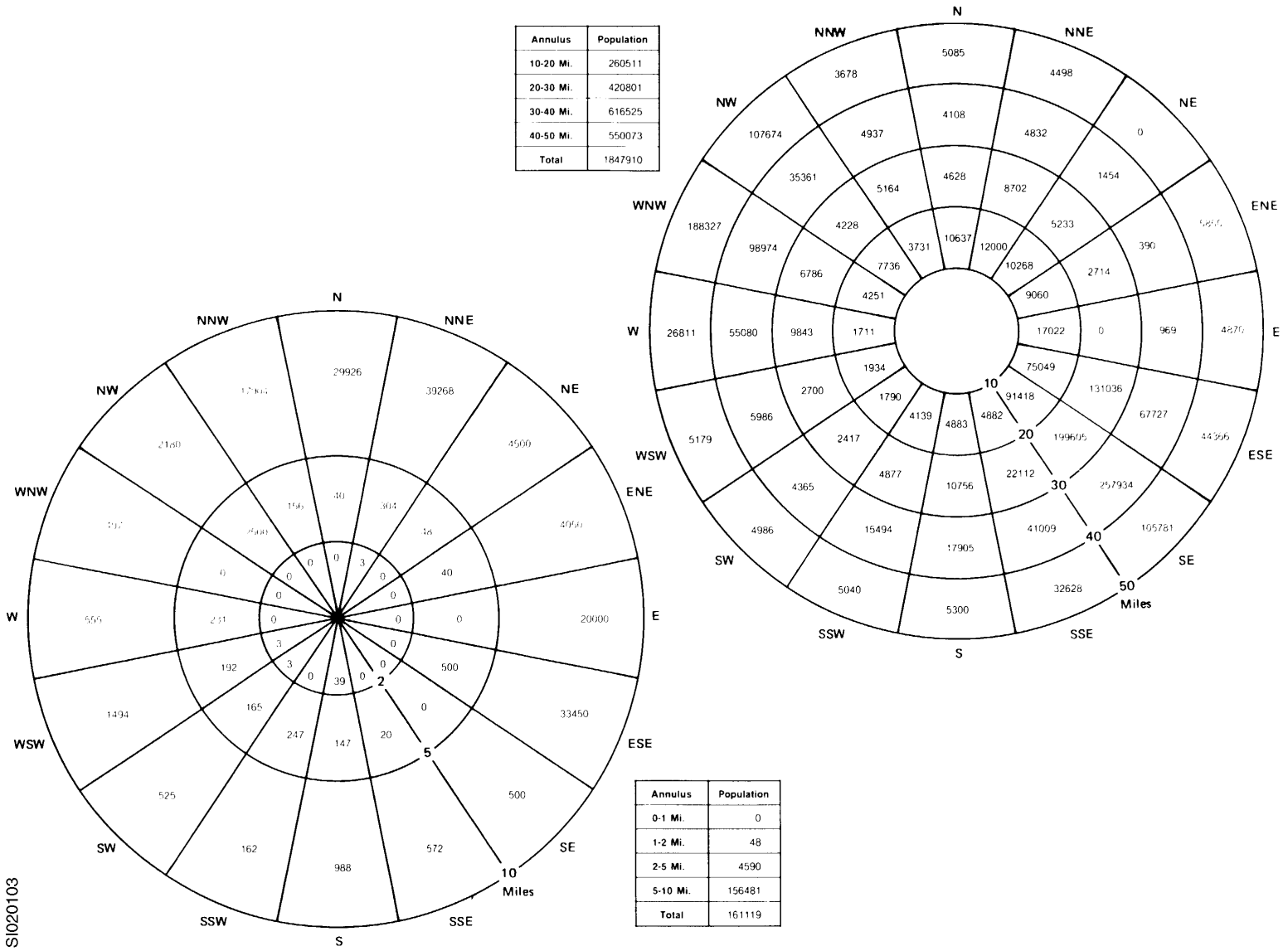


Figure 2.1-3
POPULATION DISTRIBUTION; 0-10 AND 10-50 MILES; SURRY POWER STATION; 1980

Annulus	Population
10-20 Mi.	260511
20-30 Mi.	420801
30-40 Mi.	616525
40-50 Mi.	550073
Total	1847910

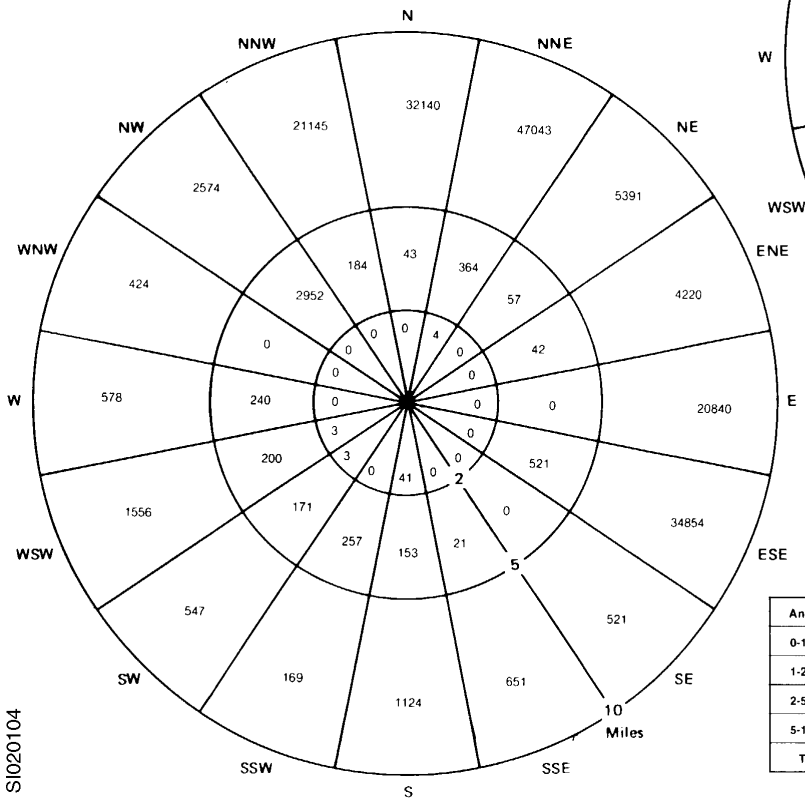


Annulus	Population
0-1 Mi.	0
1-2 Mi.	48
2-5 Mi.	4590
5-10 Mi.	156481
Total	161119

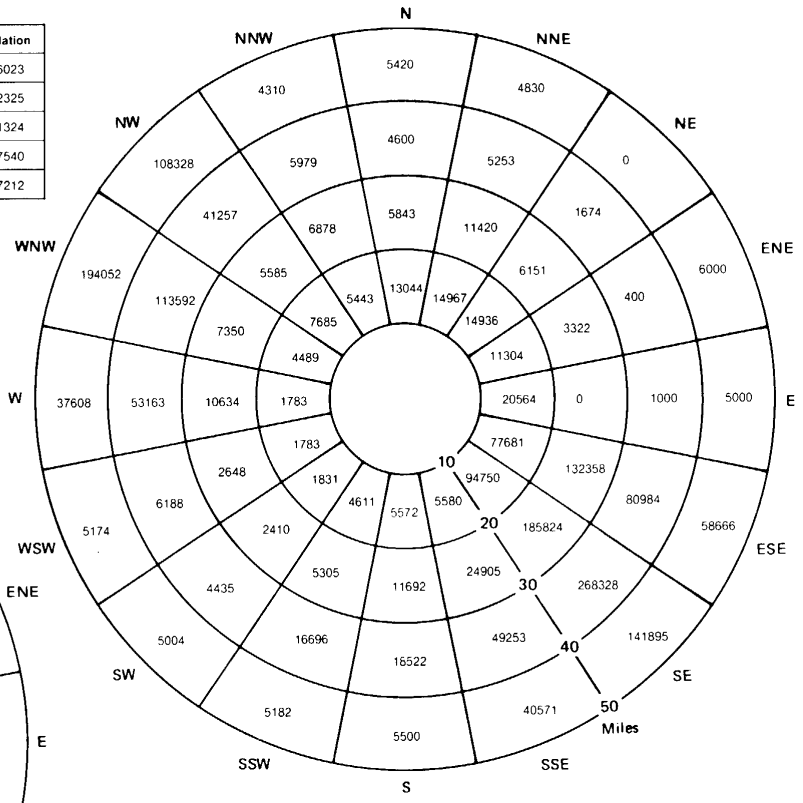
SI020103

Figure 2.1-4
POPULATION DISTRIBUTION; 0-10 AND 10-50 MILES; SURRY POWER STATION - UNITS 3 AND 4; 1990

Annulus	Population
10-20 Mi.	286023
20-30 Mi.	422325
30-40 Mi.	671324
40-50 Mi.	627540
Total	2007212



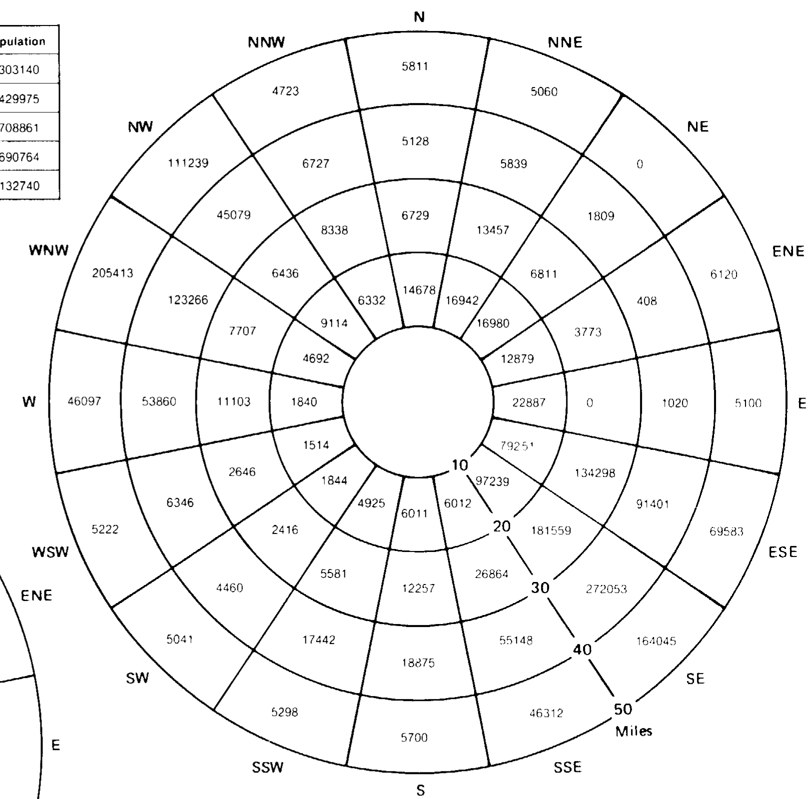
Annulus	Population
0-1 Mi.	0
1-2 Mi.	51
2-5 Mi.	5205
5-10 Mi.	173777
Total	179033

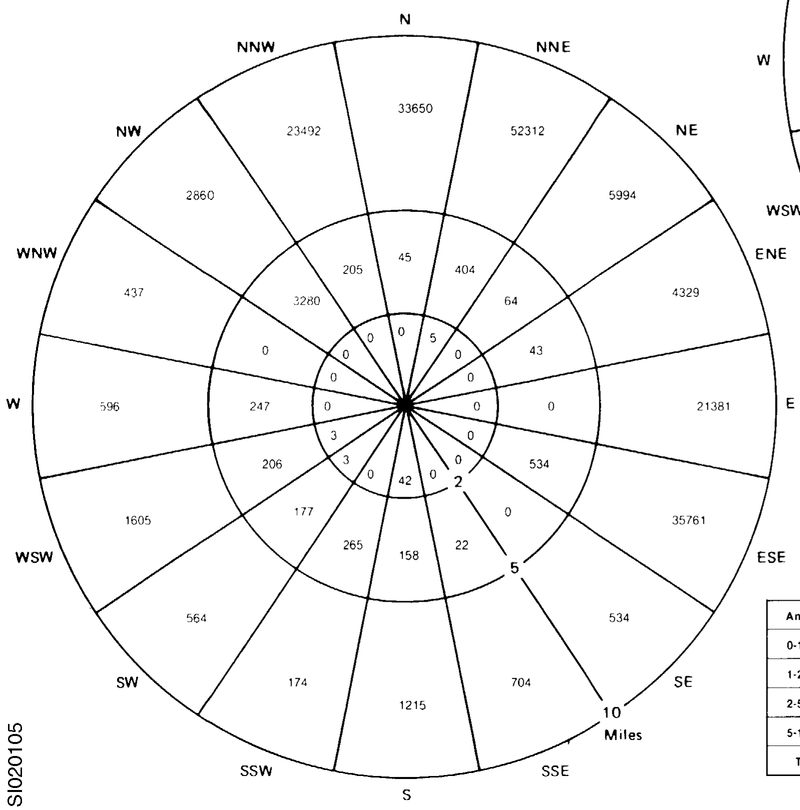


SI020104

Figure 2.1-5
POPULATION DISTRIBUTION; 0-10 AND 10-50 MILES; SURRY POWER STATION - UNITS 3 AND 4; 2000

Annulus	Population
10-20 Mi.	303140
20-30 Mi.	429975
30-40 Mi.	708861
40-50 Mi.	690764
Total	2132740

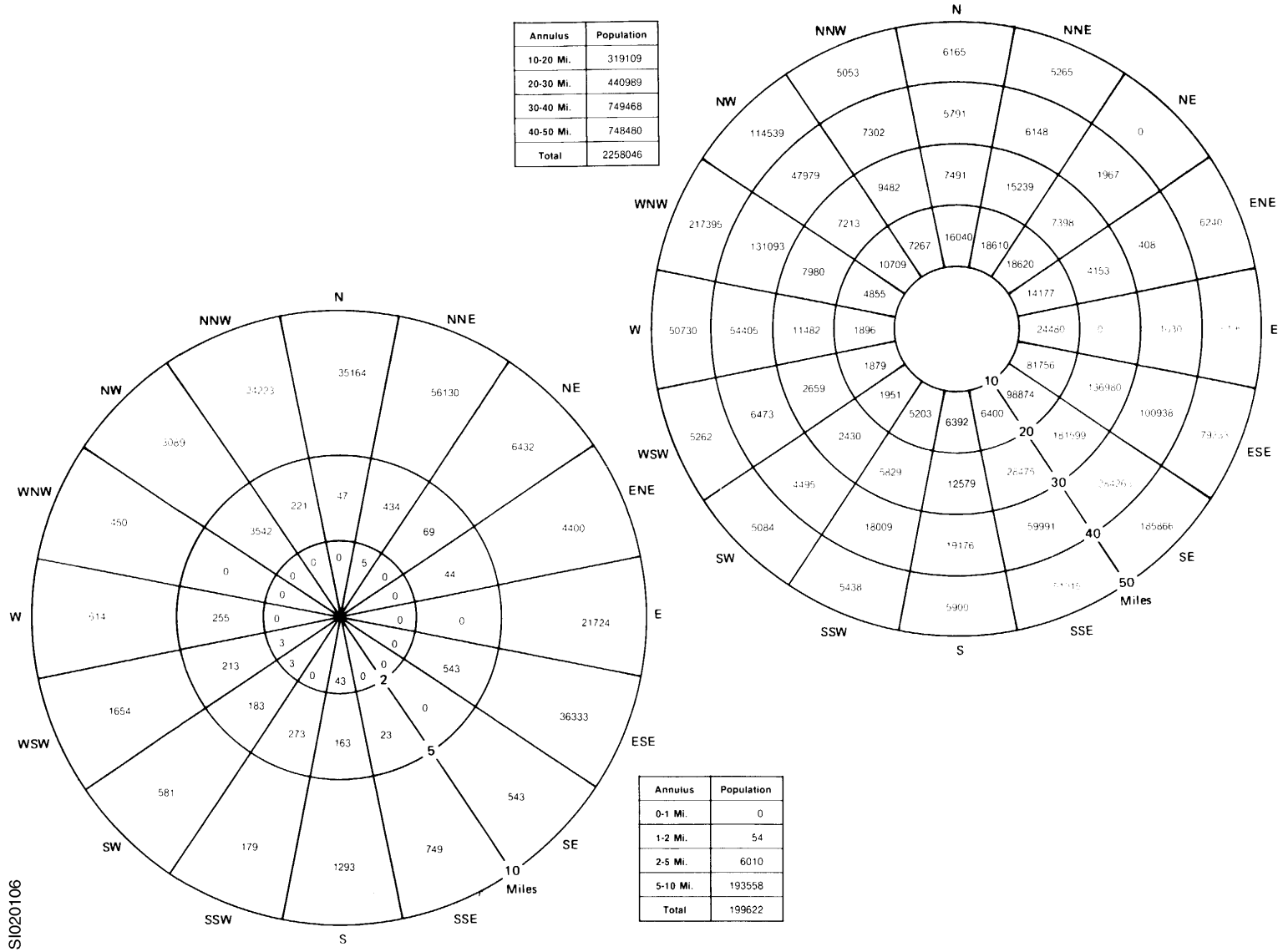




Annulus	Population
0-1 Mi.	0
1-2 Mi.	53
2-5 Mi.	5650
5-10 Mi.	185608
Total	191311

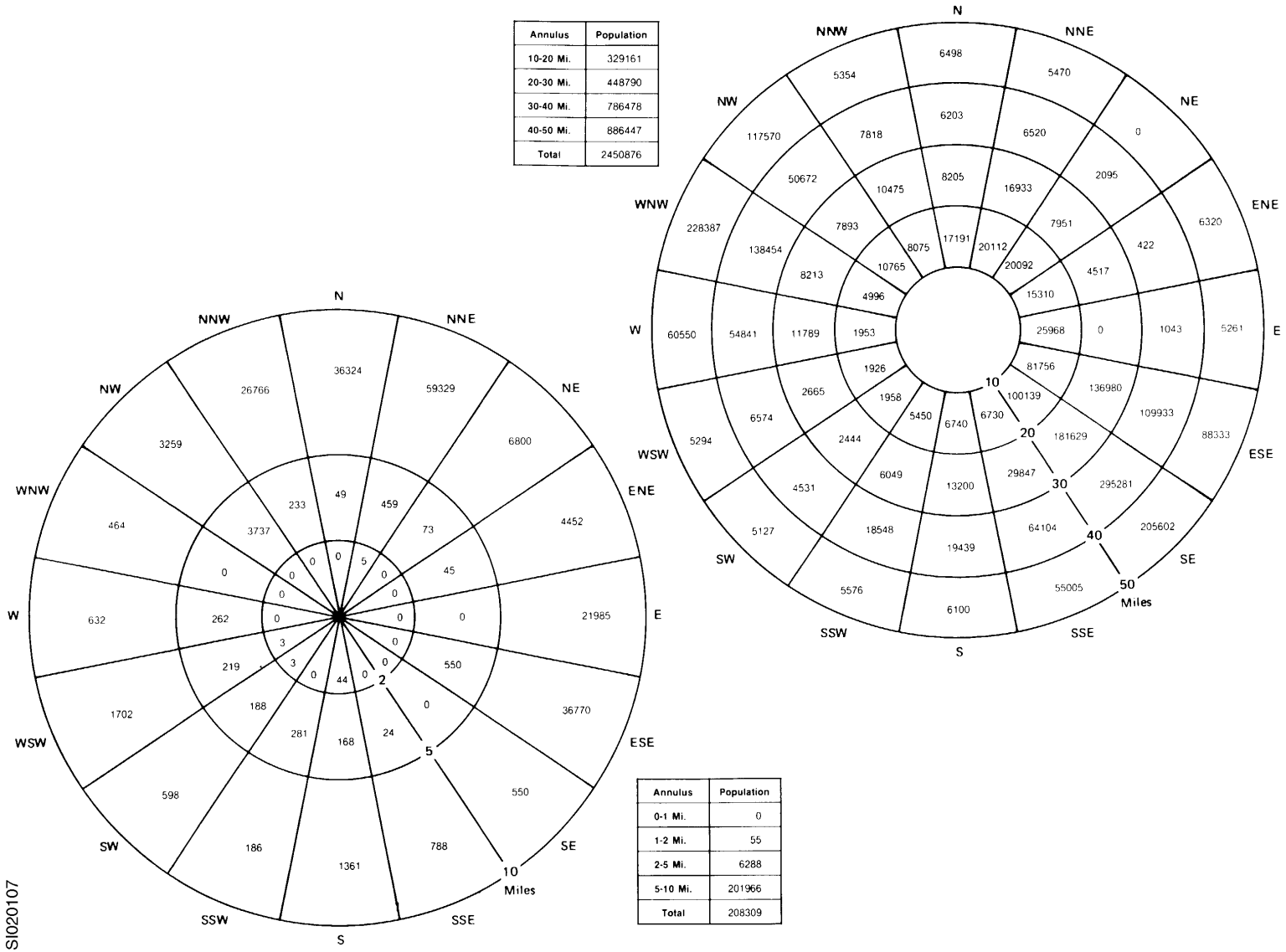
SI020105

Figure 2.1-6
POPULATION DISTRIBUTION; 0-10 AND 10-50 MILES; SURRY POWER STATION - UNITS 3 AND 4; 2010



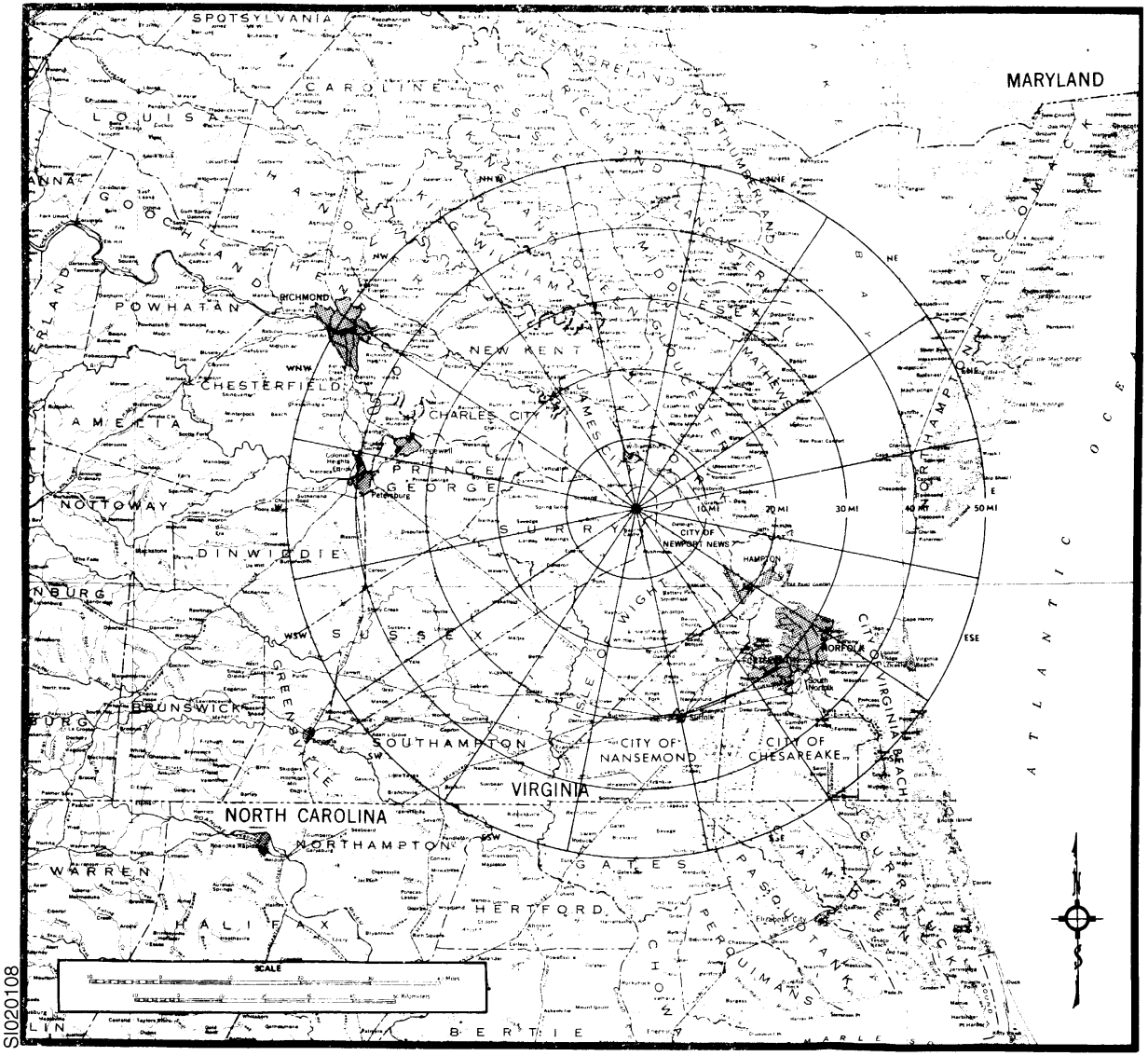
SI020106

Figure 2.1-7
POPULATION DISTRIBUTION; 0-10 AND 10-50 MILES; SURRY POWER STATION - UNITS 3 AND 4; 2020



SI020107

Figure 2.1-8
REGION SURROUNDING PLANT SITE



LEGEND

- State capital
- County seat
- City, town, or village
- Corporate boundary shown for towns over 5,000 population

POPULATION KEY

RICHMOND	more than 100,000
ROANOKE	50,000 to 100,000
Charlottesville	10,000 to 50,000
Lexington	2,500 to 10,000
Berryville	less than 2,500

Figure 2.1-9
SCHOOLS WITHIN 10 MILES OF THE SITE; SURRY POWER STATION

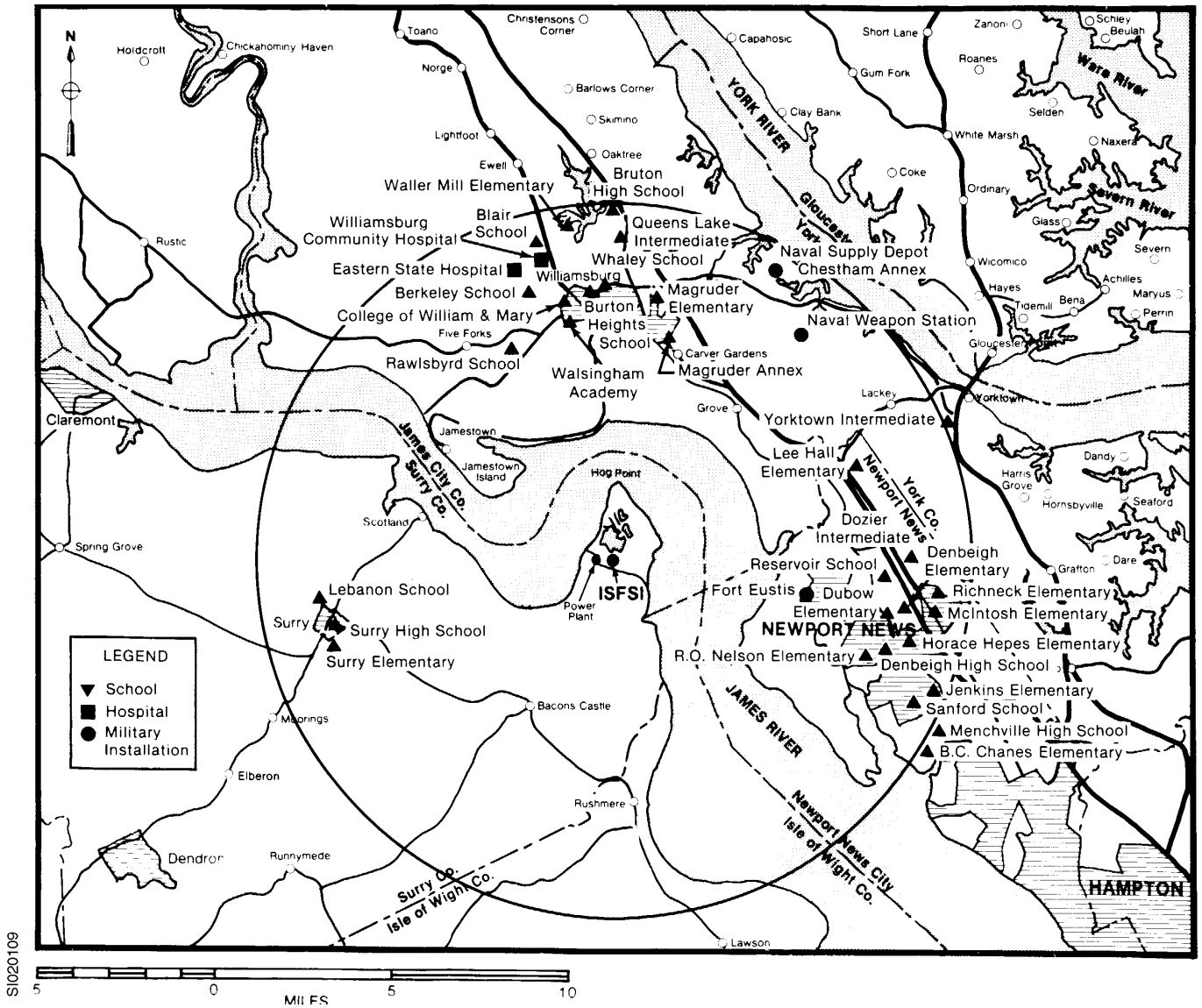
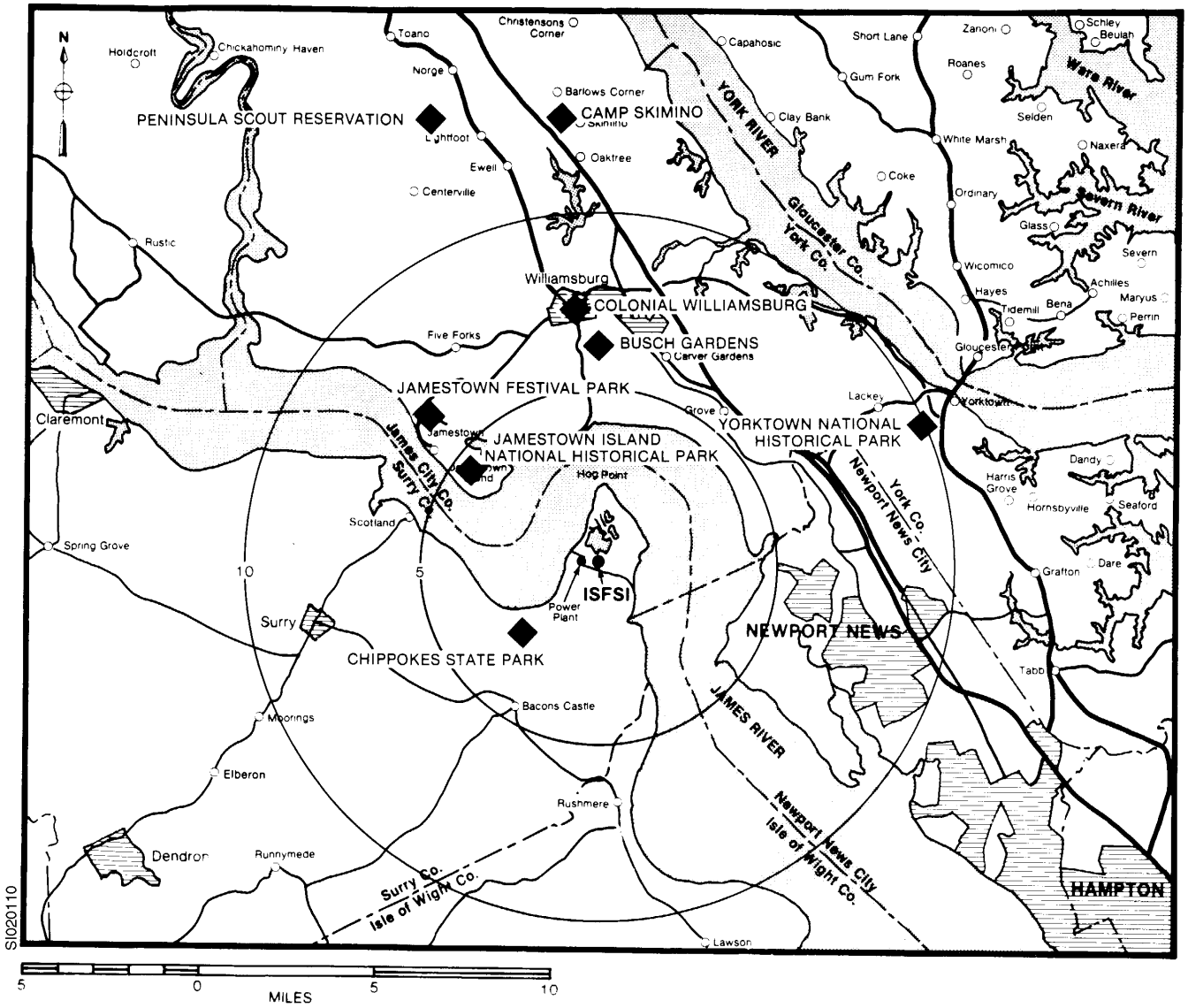


Figure 2.1-10
PARKS AND RECREATIONAL AREAS; SURRY POWER STATION; UNITS 3 & 4



2.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

This section evaluates the effects of potential accidents in the vicinity of the site from industrial, transportation, and military installations and operations to determine whether they present a hazard to the safe operation of the Surry ISFSI.

Potentially hazardous chemicals used and stored onsite were previously quantified in tabular format in this section. The list of chemicals in the table included morpholine, acetone, cyclohexylamine, sulfuric acid, ammonium hydroxide, carbon dioxide, No. 2 fuel oil, chlorine, hydrazine, and dimethylamine. Not all of these chemicals continue to be used and stored onsite. The current requirements, responsibilities, and methodology for control of chemical products and hazardous substances are governed by station administrative procedures. The ongoing chemical control program and spill prevention control and countermeasure plan described in procedures provide details of the quantities of substances and their proper handling and use.

2.2.1 Location and Routes

Route 650, a state secondary road, provides the only land access to the ISFSI. Roads within 10 miles of the site are shown on Figure 2.2-1. Also shown on Figure 2.2-1, the Chesapeake and Ohio Railway passes approximately 6 miles northeast of the ISFSI at its closest approach. The site is bordered on the east and west by the James River and is accessible by water craft at the eastside pier. As discussed in Section 2.2.2.5, there are two airports 5 miles from the Surry site, Williamsburg-Jamestown Airport (5 miles north northwest) and Felker AAF field (5 miles southeast). Airports within 10 miles of the site are illustrated on Figure 2.2-2.

There are no major communities within 5 miles of the Surry site. The closest industrial facilities to the site are Anheuser-Busch, a brewery plant (4.5 miles northeast), and Dow Badische Co., a synthetic fibers factory (4.9 miles north). Other industries within 10 miles of the site are discussed in Section 2.2 of the Surry Power Station Units 3 and 4 PSAR. They are mostly food processing plants or hardware/clothing manufacturers.

The largest and nearest military installation within 5 miles of the site is the U. S. Army Transportation Center at Fort Eustis (5 miles east-southeast).

As shown on Figures 2.2-3 and 2.2-4, both the Commonwealth Natural Gas Corporation and Colonial Pipeline Company own pipelines which cross the southeast corner of the site. The Commonwealth pipeline branches into the combustion turbine building which is located south of the cooling canal to supply natural gas to the Surry station. There are no other pipelines within 5 miles of the facility.

There are no known mine or stone quarries within 5 miles of the site or nuclear facilities other than the Surry Power Station within 50 miles of the Surry ISFSI.

2.2.2 Description

2.2.2.1 Description of Facilities

Table 2.2-1 lists the primary function, major products, and the number of people employed for all the industrial, transportation, and military facilities identified in Section 2.2.1.

2.2.2.2 Description of Products and Materials

A survey (Reference 1) of the Surry site was conducted in 1981 to identify locations of chemical compounds transported, stored, and/or used within 5 miles of the facility. The James River comprises most of the study area, with marsh/swamp land distributed over the peninsula, farmland on the southern boundaries and residential and recreational areas on the northern boundary. The James River and Virginia Highway 10 are the only two transportation routes serving the site area.

Chemical compounds shipped along the James River are listed in Table 2.2-2. Table 2.2-3 provides the list of chemical compounds transported on a regular basis by truck on Virginia Highway 10. This list does not include shipments of small amounts of chemical compounds shipped to and used by the local farmers and merchants in Surry and Isle of Wight counties.

State secondary Route 650 is the only land access to the Surry site. It ends at the Hog Island State Waterfowl Refuge, north of the site. No chemicals or cargo are expected to be transported on this portion of Route 650 unless the chemicals are used by the Surry Power Station.

2.2.2.3 Pipelines

The location and size of the pipelines are shown on Figure 2.2-3 and 2.2-4. No automatic check valves are located in the vicinity of the Surry Power Station. The products carried in each pipeline and their operating pressures are given in Table 2.2-5.

2.2.2.4 Waterways

Since the ISFSI does not involve the use of an intake structure, this section does not apply.

2.2.2.5 Airports

There are three airports within approximately 5 miles of the site. Melville, a private field with a 2900-foot unpaved runway, lies 6 miles west-southwest of the site. Williamsburg-Jamestown Airport, 5 miles north-northwest has a 3200-foot paved runway. Felker AAF field is 5 miles southeast of the site. This facility maintains a control tower and has a 3000-foot paved runway. These and other airports within 25 miles of the site are listed in Table 2.2-6. There are no federal airways within 5 miles of the plant (Reference 2).

2.2.3 Effects of Potential Accidents

2.2.3.1 Explosions and Flammable Vapor Clouds

Based on information presented in Section 2.2.1 and 2.2.2, possible sources of explosion and formation of flammable vapor clouds include the natural gas or petroleum products carried by the pipelines passing near the site or explosive materials/chemicals used by nearby industrial facilities, carried by truck traffic on Virginia Highway 10, or carried by waterborne traffic on the James River.

2.2.3.1.1 Truck Traffic

As shown in Table 2.2-3, the largest explosive load transported on Highway 10 contains 8500 gallons of gasoline. The explosive force of this quantity of gasoline is estimated to be equivalent to 50,700 pounds of TNT using a simple TNT equivalent yield formula (Reference 3).

According to NRC Regulatory Guide 1.91 *Evaluation of Explosives Postulated to Occur on Transportation Routes Near Nuclear Power Plants* (Reference 4), if this amount of gasoline were to explode at the closest point to the site, 4.5 miles, on Highway 10, a peak overpressure of 1 psi would be experienced about 1900 feet away from the point of explosion. The overpressure experienced by the casks 4.5 miles downwind of the explosion would be significantly less than 1 psi.

Flammable vapor clouds formed from a spill of gasoline on the highway, do not present an explosive hazard because gasoline vapor clouds are not known to detonate in unconfined areas (References 5 & 6). The other chemicals listed in Table 2.2-3 are not flammable in nature.

2.2.3.1.2 Waterborne Traffic

Traffic on the James River is confined to a dredged ship channel which is 2.5 miles from the ISFSI at its closest point. As indicated in Table 2.2-2, gasoline carried by barge is the only chemical transported on the river that would present a potential explosion hazard.

Assuming the whole barge is filled with gasoline, 1,300,000 gallons, and is involved in an explosion, the explosive force generated by this quantity of gasoline is estimated (Reference 3) to be equivalent to 7,760,000 pounds of TNT.

Regulatory Guide 1.91 (Reference 4) indicates an overpressure of 1 psi would be experienced about 8000 feet (1.6 miles) downwind of the explosion. Therefore, the overpressure experienced by the casks 2.5 miles away would be much less than 1 psi.

2.2.3.1.3 Industrial Facilities

The nearest industrial facility, as identified in Section 2.2.1, is located 4.5 miles from the site. Chemical compounds used by, and/or stored at the nearby chemical facilities are listed in Table 2.2-4.

As shown in Table 2.2-4, only acrylonitrile and methyl acrylate are explosive. The explosive forces generated by 50,000 gallons of acrylonitrile and 25,000 gallons of methyl acrylate are estimated (Reference 3) to be equivalent to 240,000 and 99,000 pounds of TNT respectively. Assuming an explosion involving one tank of either chemical compound, Regulatory Guide 1.91 (Reference 4) estimates that a peak overpressure of 1 psi would be experienced at a distance less than 3000 feet from explosion of either chemical.

Therefore, the overpressure experienced by the casks 4.5 miles downwind of the explosives would be significantly less than 1 psi.

2.2.3.1.4 Pipelines

The largest and closest natural gas pipeline, 12 inches in diameter, is located 1300 feet southwest of the ISFSI, and a 14-inch petroleum-products pipeline, carrying a number of different fuels (leaded and unleaded gasoline, aviation fuel, kerosene, and No. 2 fuel oil) is located 3600 feet south of the ISFSI.

An explosion of either natural gas or any petroleum products occurring in the pipelines is considered to be impossible due to the absence of oxygen. However, potential explosions may result from ruptured or leaking pipelines. As indicated in Regulatory Guide 1.91 (Reference 4), for an overpressure of about 1 psi to be experienced at about 1300 feet or 3600 feet down-wind, explosions involving the equivalent of 25,000 pounds or 500,000 pounds TNT of explosive material, respectively, would be needed. Based on these findings and the nature of the chemicals, the natural gas pipeline poses the most significant hazard to the safe operation of the ISFSI.

The amount of natural gas, which would produce an explosive force equivalent to 25,000 pounds TNT, corresponds to the contents of a 2.6-mile section of the pipe. In the case of a leaking pipeline, any possible explosion will not involve the whole quantity of the natural gas within the pipeline. This is due to the fact that the natural gas will be dispersed and carried downwind by the ambient wind as soon as it leaks from the pipeline. An unconfined natural gas vapor cloud is not known to explode (References 6, 7 & 8). In the ruptured pipeline case, assuming the whole quantity is involved in an explosion and natural gas is escaping at sonic velocity, it will take more than 12 seconds to empty a 2.6-mile pipe section. The natural gas cloud will eventually occupy a volume of 450,000 ft^3 without wind advection. If the gas cloud is advected by a very low wind, i.e., 1 meter per second, the elongated gas cloud will have a diameter of 135 feet. As discussed in the leaking pipeline case, an unconfined natural gas vapor cloud is not known to explode. There- fore, the assumption of an explosion involving the 2.6-mile section of a natural gas pipeline is a very conservative assumption.

2.2.3.2 **Fires**

The potential sources of fire are: (1) fossil fuels stored on or off the Surry Power Station site; (2) the flammable liquids carried by the truck traffic on Virginia Highway 10; (3) the flammable liquids carried by the waterborne traffic on James River; (4) the flammable

liquids/gases carried by pipelines passing near the site; and (5) security-related equipment (Reference 16).

2.2.3.2.1 Fuel Storage Facility

A 320,000 gallon tank of No. 2 fuel oil, is stored at 1300 feet southwest of the ISFSI. The tank is surrounded by a dike. An open pool of fire, restricted to the area enclosed by the dike, has been assumed for evaluation of heat effects on the casks. Based on the results of a simplified study, it is estimated that the hot buoyant plume will not intercept the 16-foot-high cask under any meteorological conditions using the Briggs' plume rise equation (Reference 9). Therefore, any heat effects on the cask would be from radiation heating. Using a flame temperature of 1800°F (References 10 & 11), the estimated air temperature 1300 feet away from the fire would be 8°F higher than the ambient temperature.

In addition, the fuel storage facility has been enlarged to include two 3 million gallon tanks of No. 2 fuel oil located approximately 2600 feet south of the ISFSI. Each of these tanks is also surrounded by a dike. Radiant heat flux to a target is a function of the inverse of the distance squared. Therefore, the above analysis based on a fire involving the 320,000 gallon tank remains bounding since it is the closest to the ISFSI.

2.2.3.2.2 Flammable Liquid

Flammable vapor clouds resulting from liquid spills on Virginia Highway 10 and James River or pipeline ruptures have the potential to deflagrate. If a delayed ignition takes place within the flammable vapor cloud, it would potentially flash back to the source and burn. Since the separation between any potential fire hazard source and the Surry ISFSI is greater than the separation of the No. 2 fuel oil storage tank and the ISFSI, the heat effects on the casks from any of the potential flammable liquid sources would be less than the heat effect resulting from the No. 2 fuel oil burning.

2.2.3.2.3 Security-Related Equipment

Adequate separation from the storage slabs has been provided for security-related equipment.

2.2.3.3 **Aircraft Accidents**

The probability of an aircraft accident is a direct function of target area, traffic volume of the airfield involved, and the probability of a fatal crash in the area of the target.

An aircraft accident probability analysis has been conducted for Surry Power Station. Results of the analysis are reported in NRC NUREG-75/014 (Reference 12), The study concluded that the probability of an aircraft accident due to the flights passing near the Surry site from either of the two airports 5 miles from the site, Felker AAF and Williamsburg-Jamestown Airport, was less than 7×10^{-7} per year. The target area used in the study was 0.005 square mile for small aircraft.

Using the same methodology as the NRC study, the area of the ISFSI is 0.00053 square mile. The ratio between the target area of the Surry Power Station, reactor buildings, and the ISFSI is approximately 10:1. Thus the probability of an aircraft accident at the ISFSI due to operations of the two airports 5 miles from the site is conservatively estimated to be less than 1×10^{-7} per year.

Melville, which lies 6 miles west southwest of the site, is a private field with a 2900-foot unpaved runway. Use of the airfield is limited to a low volume of small aircraft. Any aircraft accident probability due to operation of Melville airfield will be less than the probability due to operation of the two airports analyzed. There are no more airfields within 10 miles of the site.

Patrick Henry, 11 miles east-southeast of the site, is an international airport with 1982 projected movements of 172,000 (Reference 13). Using a probability of 1.2×10^{-9} per square mile per aircraft movement (Reference 12) for a fatal crash for a runway that is more than 10 miles away from the site, the probability of an aircraft accident occurring at the Surry ISFSI is estimated to be 2.7×10^{-8} per year. Airports/airfields further away from the site are not considered to be significant in the aircraft accident probability analysis.

2.2.4 References

1. *Surry Offsite Toxic Chemical Release Analysis,* NUS Corporation, Md., June 1981.
2. NOAA, Washington, Sectional Aeronautical Chart, 29th Edition, March 14, 1981.
3. W. C. Brasie and D. W. Simpson, *Guidelines for Estimating Damage Explosions,* American Institute of Chemical Engineers, Chemical Engineering Process, 1968.
4. NRC Regulatory Guide 1.91, *Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants,* Rev. 1, February 1978.
5. Morgan, T., (Bechtel, Gaithersburg Power Division) Personal Communication with Mr. Keller of the National Fire Protection Agency, Boston Mass., June 1982.
6. CHRIS: Hazardous Chemical Data, U. S. Coast Guard, 1978.
7. Marshall, V. C., *Unconfined - Vapor-Cloud Explosions,* Chemical Engineering, June 14, 1982.
8. U.S. Nuclear Regulatory Commission, Safety Evaluation Report, Tennessee Valley Authority, Hartsville Nuclear Plant A and B, NUREG-0014, April 8, 1976.
9. G. A. Briggs, *Plume Rise,* U. S. Atomic Energy Commission, 1969.
10. Morgan, T., (Bechtel, Gaithersburg Power Division) Personal Communication with Mr. Menery of the National Fire Protection Agency, Boston Mass., July 1982.
11. Belason, B., et al., *A Fire Simulation Facility for Materials Response Testing,* Fire Technology, Vol. 6, No. 2, May 1970.

12. *Reactor Safety Study, An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants,* U. S. NRC, NUREG-75/014, October 1975.

13. U.S. Department of Transportation, Terminal Area Forecasts for Fiscal Years 1981-1982, FHA-APO-80-10, February 1981.

14. Personal Communication, P. C. Carr, Bechtel Associates Professional Corporation (Virginia) to B. Godfrey, Commonwealth Gas Pipeline Corporation, October 10, 1983.

15. Personal Communication, P. C. Carr, Bechtel Associates Professional Corporation (Virginia) to R. Calcupa, Colonial Pipeline Company, October 10, 1983.

16. Security Program, Dry Cask Independent Spent Fuel Storage Installation, Surry Power Station, Virginia Electric and Power Company, July 29, 1983.

Table 2.2-1
FACILITIES NEAR THE SITE

Facility	Primary Function Products	Number of Employees	Location (from site)
Industry			
Anheuser-Busch, Inc.	Brewery	300	4.5 mi NE
Dow Badische Co.	Synthetic Fibers	500	4.9 mi ENE
Military Base			
Fort Eustis	Army	16,000	5 mi ESE
Supervisory of Ship Building	Navy	435	5 mi ESE
Airport			
Felker AAF	Military		5 mi SE
Williamsburg-Jamestown	Commercial		6 mi NNW
Melville	Private		6 mi WSW

Data Source: Section 2.2 of the PSAR for Surry Power Station Units 3 and 4.

Table 2.2-2 (SHEET 1 OF 2)
CHEMICAL COMPOUNDS SHIPPED ON THE JAMES RIVER

Chemical	Site Container	Quantity Per Unit	Type Container	Distance Miles[a]
Diaminocyclo Hexane Corrosive Liquid	55 gal/barrel 80 to 140	4400 to 7700 gals	Closed Van Ocean Vessel	1 1/2
Ethanol/Inflammable Liquid	55 gal/barrels 80 to 140	4400 to 7700 gals	Closed Van Ocean Vessel	1 1/2
Tiazinetrione Dry Oxidizer	50 lb bags Palletized	40,000 to 60,000 lbs	Closed Van Ocean Vessel	1 1/2
Napthyl Methyl Carbonate - Poison	50 lb bags Palletized	40,000 to 60,000 lbs	Closed Van Ocean Vessel	1 1/2
Ethyl Alcohol Flammable Liquid	55 gal/barrels 80 to 140	4400 to 7700 gals	Closed Van Ocean Vessel	1 1/2
Sodium Meta Periodate - Oxidizer	50 lb bags Palletized	40,000 to 60,000 lbs	Closed Van Ocean Vessel	1 1/2
Nitro Imidayol Poison - Solid	50 lb bags Palletized	40,000 to 60,000 lbs	Closed Van Ocean Vessel	1 1/2
Ethyacloxysilane Corrosive Liquid	55 gal/barrels 80 to 140	4400 to 7700 gals	Closed Van Ocean Vessel	1 1/2
Dinitrochloro Benzene - Poison	50 lb bags Palletized	40,000 to 60,000 lbs	Closed Van Ocean Vessel	1 1/2
Monochloracetic Acid Corrosive	50 lb bags Palletized	40,000 to 60,000 lbs	Closed Van Ocean Vessel	1 1/2
2-Methox 4-2-3 Dyhydro 4-H Inflammable Liquid	55 gal/barrels 80 to 140	4400 to 7700 gals	Closed Van Ocean Vessel	1 1/2
Ortho-Phenylenediamine Poison	50 lb bags Palletized	40,000 to 60,000 lbs	Closed Van Ocean Vessel	1 1/2
Chloro Benzo Tri Floride Inflammable Liquid	55 gal/barrels 80 to 140	4400 to 7700 gals	Closed Van Ocean Vessel	1 1/2
Caustic Alkali Liquid Corrosive	55 gal/barrels 80 to 140	4400 to 7700 gals	Closed Van Ocean Vessel	1 1/2
Thionyl Chloride Corrosive	55 gal/barrels 80 to 140	4400 to 7700 gals	Closed Van Ocean Vessel	1 1/2
Gasoline, No. 6 oil, diesel oil, No. 2 oil	Steel tanks 8 compartments	168,000 gal ea 1,300,000 total	Barge	1 1/2
Phenol	Steel tanks 2 compartments	1325 tons ea 2650 total	Barge	1 1/2
Oleum	Steel tanks 2 compartments	1500 tons ea 3000 total	Barge	1 1/2
Sulfur (Liquid @ 260°F to 275°F)	Steel tanks 2 compartments	10,000 tons ea 20,000 total	Barge	1 1/2

Table 2.2-2 (SHEET 2 OF 2)
CHEMICAL COMPOUNDS SHIPPED ON THE JAMES RIVER

Chemical	Site Container	Quantity Per Unit	Type Container	Distance Miles[a]
Liquid Fertilizer (Uran)	Steel tanks 2 compartments	5000 tons ea 10,000 total	Barge	1 1/2
Ammonium Sulfate	50 lb bags Palletized	1500 to 12,000 tons	Barge	1 1/2
Ammonium Sulfate	50 lb bags Palletized	8000 to 25,000 tons	Closed Van Ocean Vessel	1 1/2

Data Source: Survey by NUS Corporation, Rockville, MD, 1981.

a. Distance refers to minimum separation between the Surry Power Station Control Room and the midpoint of the James River. The ISFSI is approximately 1 mile further away.

Table 2.2-3
CHEMICAL COMPOUNDS TRANSPORTED BY TRUCK ON VIRGINIA HIGHWAY 10

Chemical	Size Container	Quantity Per Unit	Type Container	Distance Miles
Sulfuric Acid	25-Ton Truck Tank	3300 gals	Metal Tank	4 1/2
Nitric Acid	25-Ton Truck Tank	4000 gals	Metal Tank	4 1/2
Muratic Acid	25-Ton Truck Tank	5000 gals	Metal Tank	4 1/2
Petroleums Gasoline, Oil	25-Ton Truck Tank	8500 gals	Metal Tank	4 1/2

Data Source: Survey by NUS Corporation, Rockville, MD, 1981.

Table 2.2-4
CHEMICAL COMPOUNDS USED AND/OR STORED NEAR SURRY

Chemical	Size Container	Quantity Per Unit	Type Container	Distance Miles	Berm
Acrylonitrile	50,000 gal (5000 gal)	1 4 ea	Metal Tank	4.9	50'x30'x4.5' (30'x15'x4.5')
Methyl Acrylate	25,000 gal (5000 gal)	1 1	Metal Tank	4.9	30'x20'x5.5' (30'x15'x4.5')
Sulfuric Acid	5000 gal	3 ea	Metal Tank	4.9	40'x20'x2'
Hydrochloric Acid	5000 gal	3 ea	Metal Tank	4.9	40'x20'x2'

Data Source: Survey by NUS Corporation, Rockville, MD, 1981

Table 2.2-5
PIPELINE DATA

Company	Product Carried	Number of Lines	Diameter (inch)	Operating Pressure (psi) Max	Operating Pressure (psi) Normal
Commonwealth Natural Gas	Natural Gas	2	8[a]	600	150
		1	10[a]	600	150
		1	12-3/4[a,b]	600	150
		1	12[a,c]	600	150

Table 2.2-5
PIPELINE DATA

Company	Product Carried	Number of Lines	Diameter (inch)	Operating Pressure (psi) Max	Operating Pressure (psi) Normal
Colonial Pipeline	Petroleum Products[d]	1	14[e]	1181	500

NOTES:

a. These lines run under the James River bed at a depth of 3 to 4 feet. The pipelines remain buried 30 to 36 inches below grade after emerging from the river (Reference 14).
b. This lines does not cross Surry Power Station property.
c. This line runs from the lo-inch line to the Surry Plant combustion turbine and is used seasonally.
d. These include leaded and unleaded gasoline, aviation fuel, kerosene, and No. 2 fuel oil.
e. This line is buried approximately 20 feet below the river bed while crossing the James River. It remains buried 30 to 36 inches below grade after emerging from the river (Reference 15).

Table 2.2-6
AIRPORTS WITHIN 25 MILES OF THE SITE

Airport	Distance (mi)	Sector	Number of Movements	Type of Airport
Felker AAF	5	SE	81,500 (Reference 11)	F, M (30)
Melville	6	SW	---	E, R (29)
Williamsburg-Jamestown	5	NNW	45,000 (Reference 11)	E, P (32)
Patrick Henry	11	ESE	172,000 (Reference 13)	F, C (80)
Langley AFB	19	ESE	---	F, M (100)
NAS Norfolk	24	SE	---	F, M (37)

F- Aerodromes with facilities (land)
E- Aerodromes with emergency or no facilities (land)
P- Public use
C- Civil
M- Military
R - Restricted
( )- Length of longest runway in hundreds of feet

Data Source: Section 2.2 of the PSAR for Units 3 and 4 of Surry Station.

Figure 2.2-1
ROADS WITHIN 10 MILES OF THE SITE

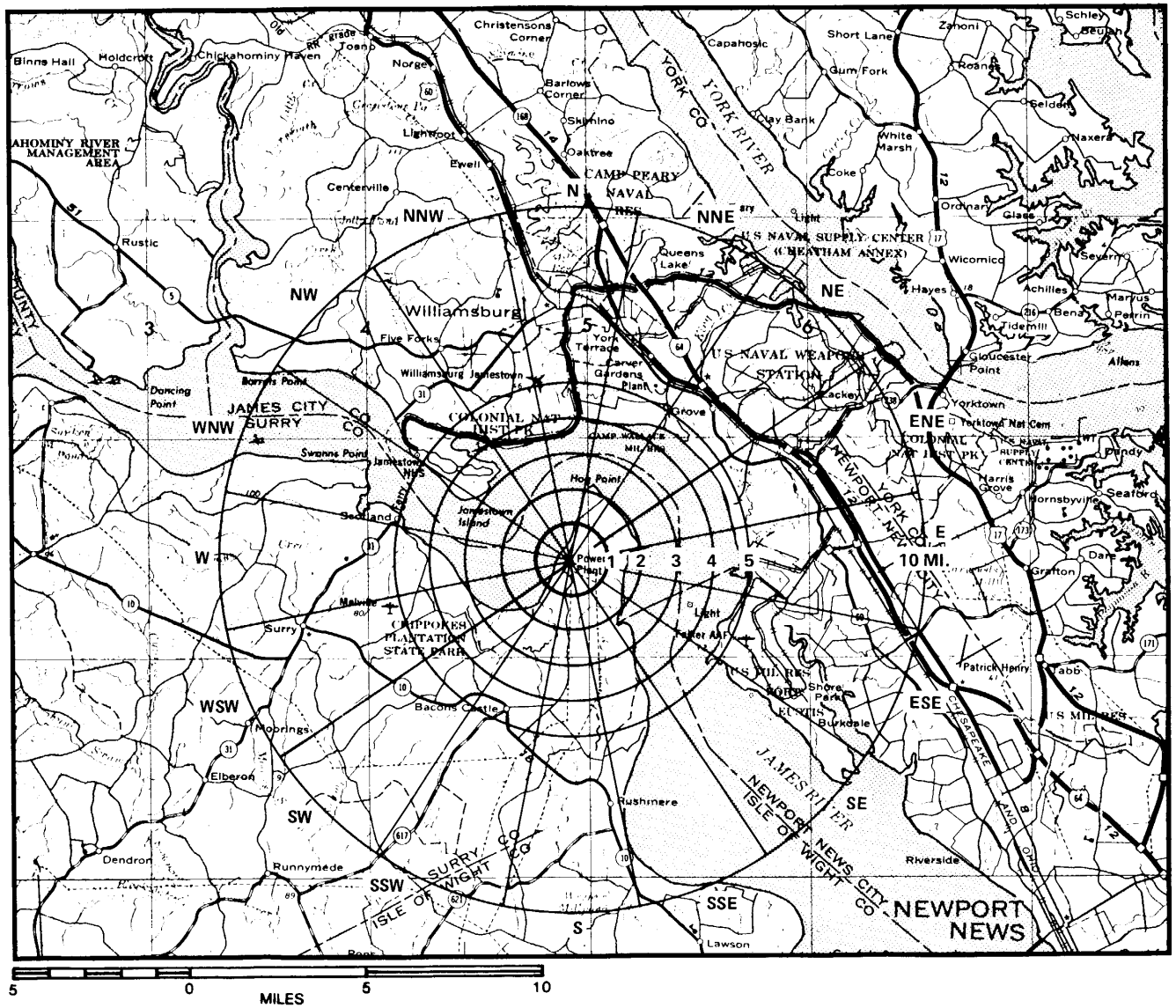


Figure 2.2-2
AIRPORTS WITHIN 10 MILES OF PLANT SITE

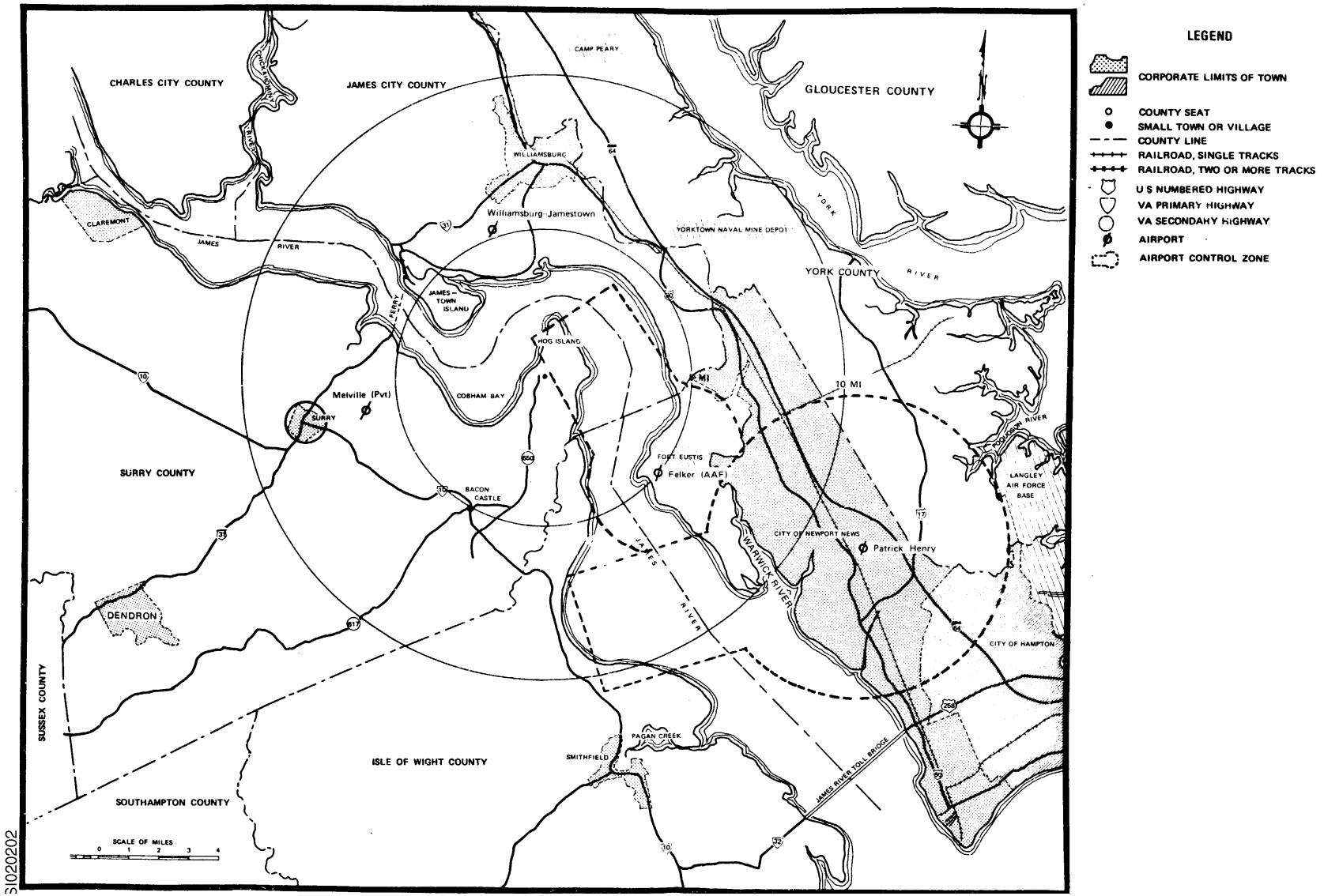


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Figure 2.2-3
NATURAL GAS PIPE LINES WITHIN 10 MILES OF PLANT SITE

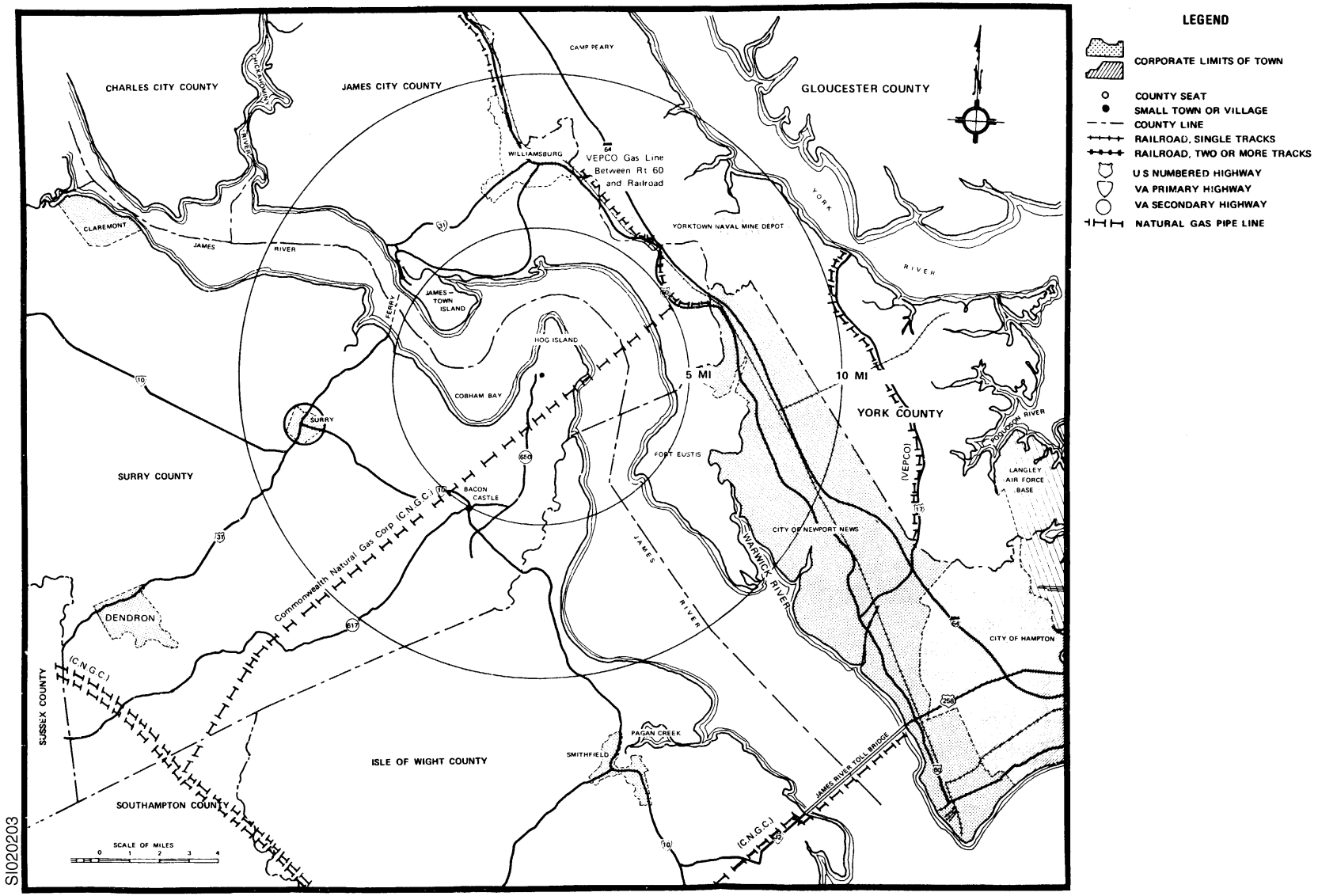
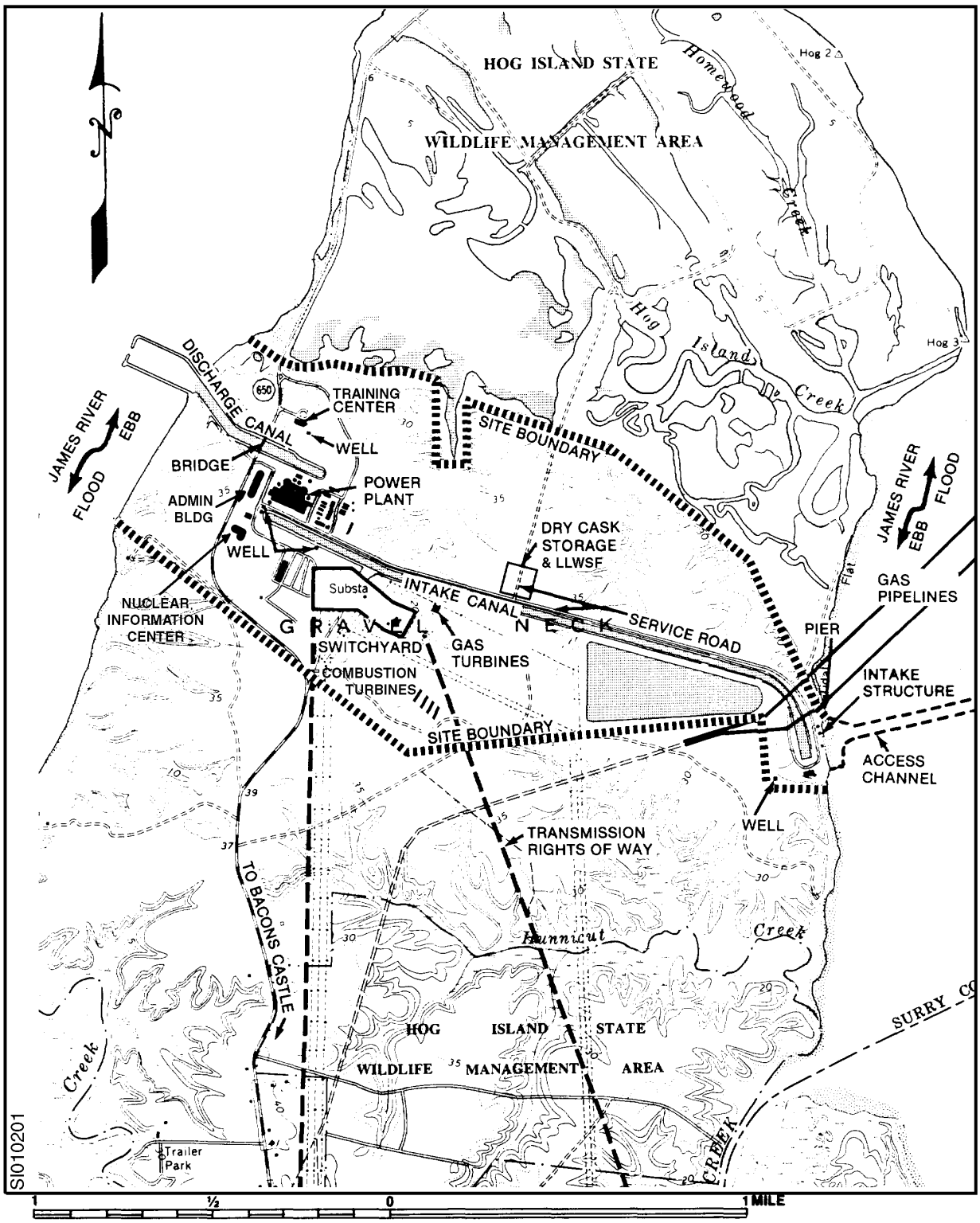


Figure 2.2-4
PIPELINES



2.3 METEOROLOGY

2.3.1 Regional Climatology

2.3.1.1 Data Sources

Data acquired by the National Weather Service (NWS) and summarized by the Environmental Data Service (EDS) were used to determine the regional climatology pertinent to the Surry site. References 1 and 2 were used to determine the climatological characteristics of Richmond and Norfolk, Virginia and Reference 3 for the climatological characteristics of the region.

Extreme wind data were obtained from studies by Thom (Reference 4) and Huss (Reference 5). Severe weather data were obtained from a variety of sources. Severe storm, tornado, and hurricane data were obtained from References 6, 7, 8, 9, and 10.

Data for meteorological extremes were obtained for Richmond and Norfolk from References 1 and 2 and temperature and precipitation extremes for selected meteorological stations in the site region were obtained from References 11, 12, 13, and 14. Monthly storm data (Reference 6) were used to compute the number of occurrences of hail and ice storms. Climatological data for restrictive dilution conditions were obtained from a variety of sources dealing with stagnating conditions in the United States (References 15, 16, 17 & 18).

2.3.1.2 General Climate

The Surry site is situated in a humid subtropical climate which is characterized by warm humid summers and mild winters. During the summer months this region is dominated by tropical maritime air masses while during the winter season this area is in a transitional zone between polar continental and tropical maritime air masses.

The climatic characteristics of the site region are influenced by the Atlantic Ocean and the Appalachian Mountains. The Atlantic Ocean has a moderating effect on the temperature for the Surry region whereas the Appalachians act as a barrier to deflect midwest winter storms to the northeast of the Surry region.

Snow is not common during winter in the Tidewater area of Virginia. (The Tidewater area is defined as the Coastal Plain area of Virginia extending west to the fall line). A snowfall of 10 inches or more a month in the Tidewater area is expected to occur once every 4 years. In general, the total accumulated snow for the Tidewater area is approximately 10 inches per year. Precipitation occurs mostly as rain in the site area. The summer months are usually associated with the greatest amount of precipitation. However, great amounts of rainfall have occurred during the fall season associated with the passages of tropical storms or hurricanes.

The Bermuda high that develops off the coast of the United States during the spring and summer seasons results in a moist southerly flow of air from the Caribbean and South Atlantic to the Surry region. During the fall and winter seasons a semipermanent high-pressure cell develops

over the midwest region of the United States resulting in a prevailing north-westerly flow of air into the Surry region. The mean annual wind speed for the Norfolk area is 10.5 mph (Reference 2). The mean annual wind speed for Richmond is 7.5 mph (Reference 1).

The annual mean number of days with heavy fog is 22 and 29 in the Norfolk and Richmond areas, respectively. Thunderstorms are frequent during the summer months with the greatest occurrence during the month of July (8 for Norfolk and 9 for Richmond). Only a small percentage of these can be classified as severe. Approximately four tornados are reported in Virginia each year, with the majority occurring east of the Blue Ridge Mountains.

An average of two hurricanes each year come close enough to the coast to affect Virginia. These hurricanes usually bring torrential rainfall to the Tidewater area, and high tides result in flood conditions for low lying areas along the coast. However, less than one hurricane (0.6 per year) actually crosses the state. A recent hurricane to affect the Tidewater area was Hurricane Dennis (August 1981) which brought 2.4 inches of rainfall to the Norfolk area and 0.25 inch to the Richmond area.

2.3.1.3 **Severe Weather**

2.3.1.3.1 Extreme Winds

According to Thom (Reference 4), the extreme 1 mile wind speed at 30 feet above the ground for a 100-year recurrence interval for the Surry region is 105 mph. Based on a gustiness factor of 1.3 according to Huss (Reference 5), the highest instantaneous gust expected once in 100 years is 137 mph.

The fastest mile wind recorded at Norfolk based on the 1953 to 1980 period of record was a southerly wind with a speed of 78 mph (Reference 2). The fastest mile wind recorded at Richmond based on the 1951 to 1980 period of record was a southeasterly wind with a speed of 68 mph (Reference 1). Both of these extreme wind speeds occurred during the passage of Hurricane Hazel in October 1954 (References 1, 2 & 3).

2.3.1.3.2 Tornados

During the period of January 1951 through December 1981 a total of 30 tornados on land have been reported within a 50 mile radius of the Surry site for an average of 0.9 tornado per year within this radius.

The probability of a tornado striking a point within a given area may be estimated as follows (Reference 8):

$$P = \frac{\bar{z}\dot{t}}{A}$$

Where:

P = the mean probability per year

z = the geometric mean tornado path area

$\dot{t}$ = the mean number of tornados per year observed in the area of concern A

For the region surrounding the Surry site, the computed geometric mean tornado path length was about 1.6 miles and the computed geometric mean path width reported was about 118 yards based on examination of reported tornado statistics (Reference 6). These values yield a z of 0.106 square miles based on tornado data for the period of January 1951 through December 1981. Using a 50-mile radius as a basis for A (excluding the Chesapeake Bay) and a value of 0.9 tornado per year for $\dot{t}$ yields a probability of 1.2×10^{-5} per year, or a recurrence interval of about 80,000 years.

2.3.1.3.3 Tropical Storms and Hurricanes

Since 1871 (when more complete weather record keeping began) through 1981, a total of 52 tropical storms or hurricane centers passed within 100 nautical miles of the Surry site (References 6 & 9). After 1885, weather records differentiated between tropical storms (<73 mph) and hurricanes (>73 mph). From 1886 through 1981, there have been 32 passages of tropical storms and 8 hurricanes have passed within 100 nautical miles of the site. The last tropical storm to affect the site was Hurricane Dennis, which occurred from August 19 through August 21, 1981. The center of maximum rainfall during this storm was located in extreme southeastern Virginia. The rainfall amounts were 2.40 inches for Norfolk and 0.25 inch for Richmond.

2.3.1.3.4 Precipitation Extremes

Table 2.3-1 lists some extremes of meteorological measurements for selected National Weather Service stations in the Surry region. The maximum amount of precipitation recorded at Norfolk for a 24-hour period was 11.4 inches which occurred in August of 1964 (Reference 2). The maximum amount of precipitation recorded at Richmond for a 24-hour period was 8.79 in August 1955 (Reference 1). The maximum monthly snowfall measured in the Norfolk area was 18.9 inches in February 1980, and the maximum monthly snowfall measured in Richmond was 28.5 inches in January 1940 (Reference 1). The maximum 24-hour snowfalls observed at Richmond were 21.6 inches in January of 1940 (Reference 1) and 12.4 inches at Norfolk in February 1980 (Reference 2).

2.3.1.3.5 Hail and Ice Storms

Hail can occasionally occur at the Surry site (associated with well developed thunderstorms) and at times may be intense. A review of data for the 30-year period, 1951 to 1981, indicates that there were 15 reported cases of hail in Surry County and the immediate surrounding counties (Reference 6). There was one reported case of hailstones with diameters of 1.75 inches, and one case of hailstones 1.5 inches in diameter.

An examination of the 20-year period, 1962 to 1981, indicates that there were only five documented cases of ice storms in Surry County and the immediate surrounding counties (Reference 6). Of these, only one was reported to have caused major damage.

2.3.1.3.6 Thunderstorms

Norfolk and Richmond both average 37 thunderstorm days a year. The highest frequency of occurrence of thunderstorms, 8 days (Reference 2) for Norfolk and 9 days (Reference 1) for Richmond, is in July.

2.3.1.3.7 Restrictive Dilution Conditions

The frequency of occurrence of low level inversions or isothermal layers based at or below a 500-foot elevation in the site region is approximately 25 percent of the total hours on an annual basis (Reference 15).

Seasonally, the greatest frequencies of inversions occur during the fall (31 percent) and winter (26 percent). The lowest inversion frequencies occur during the spring (24 percent) and summer (25 percent). The majority of these inversions occur nocturnally.

The mean maximum mixing depth (MMMD) is another restriction to atmospheric dilution. By definition, the MMMD is the thickness of the atmospheric layer, measured from the surface upward, in which convective overturning is taking place caused by the daytime heating at the surface (Reference 19). The mixing depth is usually shallowest during the early morning hours just after sunrise when the nocturnal inversion is being modified by solar heating at the surface. The mixing layer is at its greatest depth during the latter part of the afternoon when the maximum surface temperature of the day is reached. The annual afternoon MMMD for the site region according to Holzworth (Reference 16) is approximately 4600 feet. Seasonal afternoon MMMD values are 3000 feet (winter), 5000 feet (spring), 5000 feet (summer), and 4600 feet (fall) (Reference 16).

Periods of high air pollution potential are usually related to a stagnating anticyclone with an average wind speed <9.0 mph (4.0 m/s), no precipitation, and a shallow mixing depth (<1600 feet or 500 meters) (Reference 17).

The greatest air pollution potential in the site region occurs during the fall and winter seasons when the tendency is greatest for a quasi-stationary anticyclone to develop in association with wind speed ≤5 mph and a shallow mixing depth.

There was a total of 227 cases of days when a stagnating high occurred for 4 or more days during the period 1936 to 1965 (Reference 18).

2.3.2 Local Meteorology

2.3.2.1 Data Sources

Data acquired by the National Weather Service and summarized by the Environmental Data Service were utilized to determine the normals, means, and extremes of temperature, precipitation, relative humidity, and fog applicable to the Surry Power Station site region.

The 1980 Richmond and Norfolk LCDs (References 1 & 2) provide detailed climatological data for these first order observation stations. References 11, 12, 13, and 14 provide data for other stations in the area, although not as complete as for Norfolk and Richmond. Site data were obtained from meteorological instrumentation located at the plant site and summarized for the period March 3, 1974 to December 31, 1981.

Data from the Surry Station were taken from a Westinghouse magnetic tape from pulses every 15 minutes for all meteorological parameters. The data were assembled into a data base and quality ensured before being entered on the universal data base (UDB).

In general, for determination of meteorological design basis parameters, long-term climatological data collected at nearby representative weather stations, such as at Norfolk and Richmond, rather than short-term onsite data are used. Meteorological data measured at the Richmond and Norfolk NWS Stations can be considered representative of the region including the Surry site because both NWS Stations as well as the Surry site fall within the same NWS-defined climatic region: Tidewater. The Climate of Virginia publication (Reference 3) defines Tidewater Virginia as a region which extends westward from the Atlantic Coast and west shore of the Chesapeake Bay to the Fall Line. The Fall Line extends from Great Falls in the north, southward through Richmond to Emporia. The region is divided into peninsulas by four principal rivers and by numerous estuaries that open into the Chesapeake Bay. The climate of this flat to gently rolling, at times swampy, Tidewater region is influenced by the ocean and other nearby water bodies. Due to the varying proximities to the moderating ocean, extremes recorded in Richmond, which is a more inland station, are expected to be more pronounced than those recorded at the coastal city, Norfolk. However, due to the small variations in terrain elevation, ranging from 300 feet to sea level, the weather pattern from one side of the region to the other cannot be significantly different.

Land use, terrain, and the proximity of the ocean or other large bodies of water are the dominant factors related to an area’s peculiar micro-meteorological conditions. For the ISFSI site to have unique micro-meteorological conditions as compared to the Norfolk and Richmond NWS Stations, the site would have to have decidedly unique land use, terrain, or ocean exposure. The ISFSI site is in a predominantly rural area characterized by coastal lowland farms interspersed with marshy areas near the James River. The site is within 10 miles of an urban area, Newport News. However, the site is not close enough to the urban area to be influenced by the urban heat island effect, i.e., warmer than normal ambient temperatures and the reduced frequency of nocturnal stable conditions. The valley associated with the James River is broad and shallow and,

therefore, will probably not encourage down-valley drainage flows. The James River itself is not large enough to promote “sea breeze circulations” or moderate the temperatures significantly.

Both the Richmond and Norfolk NWS Stations, like the ISFSI site, are located in rural areas outside of the urban centers along the James River Valley. The Norfolk Station more directly borders an urban area and consequently it feels more urban heating effects, i.e., warmer than normal ambient temperatures and the reduced frequency of nocturnal stable conditions than Richmond or the Surry site. However, these heating effects are tempered only slightly by Norfolk’s proximity to the Atlantic Ocean and its moderating breezes. The net effect of these competing influences is that the urban heat island effects cannot be considered a significant meteorological phenomenon in Norfolk.

As Richmond, Norfolk, and the ISFSI site all possess similar land use, terrain, and ocean exposure, the ISFSI site is not expected to experience temperatures and other meteorological conditions significantly different from these two stations.

Also, a statistical analysis of temperature records for January and July 1977 from the site and the Norfolk and Richmond NWS Stations has been performed using data from References 20 and 21. In July 1977, a record high temperature, 105°F, was measured at the Richmond Station. In January 1977, a record low, 5°F, was recorded at the Norfolk Station. The analysis shows that there is a strong correlation and similarity between onsite temperatures and temperatures measured at these nearby NWS stations. A summary of the analysis results is given in Table 2.3-9. Furthermore, the three stations’ daily maximum and minimum temperatures are in good agreement as indicated in Table 2.3-10. As expected, the Surry site temperatures are bracketed by the two NWS stations with one exception: the Norfolk daily maximum mean temperature for July is 2 degrees higher than the corresponding Surry temperatures.

2.3.2.1.1 Local Climatological Data

Climatological extremes for selected meteorological stations in the region are presented in Table 2.3-1. Normals and extremes of temperature, precipitation, relative humidity, and fog are presented for Richmond and Norfolk in Tables 2.3-2, 2.3-3, and 2.3-4.

The closest available fog data for Surry site are from the National Weather Service observation stations at Byrd Field, Richmond and Regional Airport, Norfolk, Virginia. The Local Climatological Data (1980) for Richmond indicates an average of 29 days per year of heavy fog based on 51 years of records and 22 days per year of heavy fog based on 32 years of Norfolk data. Heavy fog is defined by the National Weather Service as fog which reduces visibility to l/4 of a mile or less (Reference 1). The frequency of fog conditions reported at Surry is expected to be more similar to the annual average of heavy fog reported at Richmond than to Norfolk (References 1 & 2). Surry is in close proximity to the James River and has a rural environment (i.e., land use characteristics favorable for rapid radiation cooling of the ambient air with high specific humidity due to the close proximity of the river). The occurrence of heavy fog in the

Norfolk area (Reference 2) is less than Richmond (Reference 1) due to the moderating influence of the Atlantic Ocean.

2.3.2.1.2 Wind Direction and Speed

The distribution of wind direction and speed is an important consideration when evaluating transport conditions relevant to site diffusion climatology. There are no significant topographic features that would have any major influence on wind direction distribution.

Seasonal and annual distributions of wind direction recorded at the Surry site meteorological tower are presented on Figures 2.3-1 through 2.3-10. Measurements at 147.4-foot and 30.3-foot levels were made on the tower.

On an annual basis the predominant wind direction at both the upper and lower level is from the southwest and south-southwest direction.

Seasonal variations in average wind speed, are presented in Table 2.3-5. The annual average wind speeds at Surry (5.8 mph) lower level and (9.8 mph) upper level are comparable to average wind speeds of 10.5 mph at Norfolk for the period 1949 to 1980 and of 7.5 mph at Richmond for the period 1949 to 1980.

Calms are defined in this report as winds less than or equal to 0.75 mph, commensurate with data reduction limitations for onsite data. Lower wind speeds and an increased frequency of calms are expected at a lower sampling height.

2.3.2.1.3 Wind Direction Persistence

Wind persistence is extremely important when considering potential effects from any radiological release. Wind persistence is defined as a continuous flow from a given direction or range of directions.

Periods of maximum wind persistence in 22-l/2 degree sectors recorded at the Surry site meteorological tower are presented on Figures 2.3-11 through 2.3-20. The maximum persistence period at the 147.4-foot level was for 28 hours from the south. At the 30.3-foot level the maximum persistence period was for 30 hours from the west-southwest.

2.3.2.1.4 Atmospheric Stability

Atmospheric stability refers to the degree of wind turbulence. Stable conditions are associated with low turbulence and poor diffusion capability. Unstable conditions are associated with a high degree of turbulence and favorable diffusion characteristics. The standard deviation of horizontal wind direction (σ_θ) for a 15 minute sample per hour is used to determine atmospheric stability from onsite data in this report. The classification of σ_θ data utilized is summarized in Table 2.3-6.

The seasonal and annual frequency of σ_θ stability classes and associated wind speeds for the Surry site are presented in Table 2.3-7. These distributions indicate that the 147.4-foot level stability data are more stable than the 30.3-foot level data. Seasonal variations of the stability distribution presented are minor. Stable conditions were recorded 37 percent of the time at the upper level and 9 percent at the lower level and unstable conditions 22 percent and 61 percent, respectively.

2.3.2.1.5 Temperature

For the Surry ISFSI site region, a record high temperature, 105°F, was measured at the Richmond Station and a record low, 5°F, was recorded at the Norfolk Station.

The frequency of hot periods can be described by the annual mean number of days with temperatures at or above 90°F. Norfolk, near the moderating ocean, experiences an average of 31 “plus 90” days (Reference 22). Farther inland, Richmond experiences 42 “plus 90” days. The ISFSI site, located between these two stations, probably experiences between 31 and 42 “plus 90” days annually.

The distribution of temperatures at or above 90°F for these two NWS stations is given in Table 2.3-1. These temperatures represent only 3 percent of the hourly temperature observations per year. As shown from the table, the majority (70 percent or more) of these temperature observations fall within the range of 90°F to 94°F. Temperatures in excess of 100°F represent less than 5 percent of the total. No temperatures higher than 104°F were recorded for the stations during the period in which temperature observations have been made (References 22, 23, 24, & 25).

The recurrence interval of maximum temperatures for southeastern Virginia, which includes the ISFSI site, is as follows (Reference 26):

Return Period (years)	Temperature (°F)
2	98
50	105
100	107

The extreme temperature used as the design criteria for the ISFSI casks, 115°F, was selected because it exceeds the extreme temperatures recorded at the Norfolk and Richmond Stations as well as exceeds the 100-year maximum temperature for southeastern Virginia.

2.3.2.1.6 Lightning

The Surry Power Station (SPS) does not routinely record information concerning onsite lightning strikes. As the newer power stations and accompanying switchyards have become less susceptible to damage from lightning strikes, the importance of maintaining such information has decreased.

No SPS onsite data relating to the frequency of thunderstorms is available. However, the expected annual frequency of thunderstorms at the Surry ISFSI can be expressed in terms of the mean number of thunderstorm days experienced annually at Norfolk (45 miles, SE) and Richmond, Virginia (50 miles, NW). As discussed in Section 2.3.2.1, meteorological data measured at these nearby National Weather Service Stations can be considered representative for the region which includes the ISFSI site.

Both Norfolk and Richmond experience an average of 37 thunderstorm days a year (References 22 & 23). The term thunderstorm day is defined as an observational day during which thunder is heard at the station. Precipitation need not occur (Reference 27).

Information concerning the correlation of frequency and intensity of both single and multiple lightning strikes associated with regional thunderstorms is unavailable. However, a probability distribution of crest currents in lightning strikes has been compiled from measurements made in the United States and Europe. Figure 2.3-28, derived from these measurements, illustrates the relationship between crest currents and frequency of occurrence. (Reference 28).

This figure represents the best available information concerning the correlation of frequency and intensity of lightning strikes. However, there was no differentiation of whether the crest current is from single or multiple lightning strikes.

2.3.2.1.7 Solar Radiation

At the Surry ISFSI site, the normal daily total solar radiation (June 21) is 500 g-cal/cm^2 and the normal daily hours of sunshine during summer is 10 hours (Reference 29). During winter, the sunshine exposure period is shorter and consequently, the daily insolation value is lower. To encompass this, a daily total solar radiation value of 800 g-cal/cm^2 (10-hour exposure) was chosen as the design solar heat burden at the Surry ISFSI site. This maximum insolation value represents about 90 percent of the solar radiation incident at the top of the atmosphere at the ISFSI latitude (Reference 30). The 90 percent assumption refers to a 0.9 transmissivity factor which is representative of a conservative clear sky transmissivity (Reference 31), i.e., the percent of solar radiation at the top of the atmosphere which makes it to the ground after absorption or scattering by atmospheric constituents other than clouds. The length of the exposure period has been provided for information only; it does not enter into the calculation of the daily maximum insolation.

Regulatory Guide 7.8 (Reference 32) describes maximum insolation data as part of the general and initial conditions to be used for both normal and hypothetical accident conditions for shipping casks. The Regulatory Guide defines the maximum insolation for horizontally transported casks as 800 g-cal/cm^2 per day. For stationary and vertically stored casks, which are more representative of the ISFSI casks, the Regulatory Guide defines the design insolation as 400 g-cal/cm^2. Consequently, the ISFSI cask design insolation of 800 g-cal/cm is conservative.

2.3.2.2 **Topography**

The Surry site is situated in the Tidewater area of Virginia. This area is typical of Coastal Plain topography. Elevations in the site region range from 0 feet mean sea level (msl) at the James River to approximately 200 feet msl at Richmond (fall line). In general, the area is fairly flat with no distinctive relief features within 50 miles of the station.

The ISFSI is located in the flood plain of the James River. Elevations generally range from 0 feet msl at the James River to 35 feet msl further inland. Some channeling of winds associated with cold air drainage that would occur would be very minimal. Figures 2.3-21 through 2.3-24 illustrate the topographic profile of the site region out to 10 miles from the ISFSI site. Figure 2.3-25, presents a general topographic view of the site region for a 5-mile radius and Figure 2.3-26 for a 50-mile radius.

2.3.3 On-Site Meteorological Measurements Program

2.3.3.1 **General Program Description**

The onsite meteorological measurements program for the Surry Power Station will be used as the onsite meteorological measurements program for the Surry ISFSI. There are two towers installed on the Surry site. Their locations are illustrated on Figure 2.3-27. The primary tower is 147.4 feet high and the backup tower is 30.3 feet high. At the primary site monitoring of wind direction and wind speed at two levels of the tower, ambient air temperature at the lower tower level, differential air temperature between tower levels, horizontal wind direction fluctuation (σ_θ) at both tower levels, dew point temperature at the lower tower level, and rainfall at the base of the tower is performed. At the backup site, wind direction, wind speed, and horizontal wind direction fluctuation (σ_θ) are monitored at an elevation of 30.3 feet.

2.3.3.2 **Location, Elevation, and Exposure of Instruments**

The location of the meteorological towers is shown on the topographic map, Figure 2.3-27. The nearest structures are 500 feet north-northwest and 150 feet northwest of the primary and backup sites, respectively. At the primary site, the nearest tree is approximately 50 feet south of the tower, as is the nearest continuous tree line. Tree heights are 40 to 50 feet. At the backup site, a 5-foot tree stands 5 feet south-southeast of the tower. The nearest tree line, with trees 10 to 15 feet high, is located approximately 200 feet north-northeast of the tower.

Ground cover at the location is characteristically native grasses. Comparable cover will be maintained at the bases of the towers.

The primary tower is a guyed, triaxial, open-latticed structure (Rohn 90 series). The lower level instrumentation is at 30.3 feet above ground level (agl). The upper instrumentation is at approximately 147.4 feet above the finished plant grade of 26.5 feet. The backup tower is a freestanding, triaxial, open-latticed structure (Rohn 25 series). The instrumentation is at 30.3 feet agl.

The wind sensors are positioned such that the towers do not influence the prevailing south-southwest wind flow detected by the sensors.

On the primary tower, the wind speed, wind direction, and σ_θ sensors are mounted on booms longer than one and one half times the tower face width. The sensor is postmounted on top of the backup tower.

Temperature, differential temperature, and dew point temperature sensors are housed in motor aspirated shields to insulate them from thermal radiation from the tower, and solar and terrestrial radiation. (See Table 2.3-8 for aspirated shield performance characteristics.)

2.3.3.3 **Meteorological Sensors - Type and Performance Specifications**

2.3.3.3.1 General Description

Wind speed, wind direction, and σ_θ are measured by an MRI 1074-22 sensor at the 147.4-foot level of the primary tower, and at the 30.3-foot level of the primary tower and on the backup tower. The MRI 1074-22 is a combined anemometer cup and vane sensor. The wind speed signal is generated by a light emitting diode-photo-Darlington assembly and light chopper mechanically linked to the anemometer cup shaft.

The sensor provides for a dual output of direction signal. The 0° to 540° wind direction for strip chart recording and data transmission is generated by a ganged two section potentiometer. Sine/cosine function potentiometers, mechanically geared along with the 540° pot to the vane shaft, also generate wind direction signals for historical data files. The σ_θ is electronically calculated from the analog voltages produced by the 540° pot and associated circuitry.

Temperature is measured at the 30.3-foot level and differential temperature is measured between the 30.3-foot and 147.4-foot level use Rosemont 104MB 12 ADCA sensors. The Rosemont system consists of one single element high precision platinum resistance temperature sensor located at the 147.4-foot level for measuring part of the differential temperature, and one single element precision platinum resistance sensor located at the 30.3-foot level for measuring ambient temperature and the other part of differential temperature. Compensating resistance loops are used to compensate for the probe signal cable resistance. Endevco 4473.2 Signal Conditioners convert the probe resistances to analog signals.

Dew point temperature, as measured at the 30.3-foot level of the primary tower, uses either an EG&G 110(S)M or Model 220 sensor. The EG&G sensor is a thermoelectric chilled mirror with optical sensing bridge for condensation. The mirror temperature is measured by a platinum resistance temperature sensor tied to a temperature transmitter/control unit.

2.3.3.3.2 Instrument Performance Specifications

Performance specifications for the Met towers' instrumentation are provided in Table 2.3-8.

2.3.3.4 **Instrument and Maintenance**

The meteorological monitoring installations are calibrated quarterly. Inspection, service, and maintenance are performed as required to ensure not less than 90 percent data recovery. A body of instrument technicians with the requisite expertise to service and, in the event of a system failure, repair the monitoring equipment is maintained by an environmental services support organization.

An inventory of spare sensors and parts is maintained for replacement of major components in the event of a system outage. Redundant recording systems are incorporated into the program to further minimize data loss due to recorder failure.

2.3.3.5 **Data Recording Systems**

Control Room Systems

Temperature, differential temperature, and wind speed and wind direction from both the 30.3-foot and 147.4-foot primary tower level sensors are displayed on strip chart recorders in the control room, as are wind speed, wind direction, and σ_θ from the 30.3-foot backup tower.

Tower Base Shelter Systems

A nominally 8- by 18- by 8-foot shelter is located at the base of each tower. The shelters have thermostatically controlled heat and air conditioning to maintain an interior temperature within a range appropriate for proper equipment operation. The enclosures are located to minimize any micrometeorological effects on the tower instrumentation.

Equipment and circuitry for two separate data recording systems are housed in instrument racks mounted in the shelters. Esterline Angus Models E1102R and A601R strip chart recorders are utilized as a visual display of the data and as a backup collection medium. The recorders' specifications are listed in Table 2.3-8.

A Westinghouse magnetic tape pulse metering system is the primary method of data acquisition for the offsite historical files. The sensor analog signals are coverted through the system circuitry to pulse trains linearly proportional to the input signal. The pulse trains are recorded continuously with time hacks entered every 15 minutes. The tapes are translated, initially reducing the data to 30-minute average pulse totals. This 30-minute data base is then directly converted to the meteorological units of the parameters.

The Westinghouse pulse recorder tapes have a rated acceptance density of approximately 1500 pulses per 15 minutes period. The applicant has conducted independent evaluations of these systems by applying constant known analog signals to the system circuitry. Maximum three interval average deviation from calculated pulse totals has been found to be less than ±0.5 percent with typical performance at ±1 pulse per interval or ±0.07 percent deviation at full acceptance density.

The instruments and recorders as detailed herein are consistent with the current level of technology for meteorological monitoring and the accuracies of the components are adequate to ensure system accuracy in accordance with Regulatory Guide 1.23, Onsite Meteorological Programs, February 1972.

2.3.3.6 **Impact of ISFSI Operation on Meteorological Instrument Performance**

As illustrated by Figure 2.3-27, distances from the primary and backup site meteorological towers to the ISFSI are approximately 1880 and 820 feet, respectively. Since the casks are a continuous source of heat, the potential heat impact of the casks on meteorological measurements made at the towers has been evaluated. The assumptions, methodology and conclusions of this evaluation are as follows:

1. Assumptions

   Two parallel rows of 14 casks are placed on each of three, 230- by 32-foot concrete pads as shown on Figure 4.1-1. An approximate 8-foot surface-to-surface separation is provided between casks. Each cask is approximately 8 feet in diameter and 16 feet in height. The maximum cask surface temperature is assumed to be a constant 260°F.

   Furthermore, the heat generated by the 28 casks in one pad was conservatively assumed to be equivalent to a heated block with dimensions 216 feet by 24 feet by 16 feet which has a surface temperature of 260°F. This is equivalent to assuming that all the air between casks within the imaginary block is at a temperature of 260°F.

   An ambient temperature of 115°F was used in the calculation. Note that the maximum temperature recorded for the area is 105°F as shown on Table 2.3-1. Therefore, the selected ambient temperature of 115°F is an extremely conservative value.

   Heat loss by the casks to the immediate environment will be from conduction, convection, and radiation. Thermal conductivity for air at 115°F is less than 0.02 Btu/hr-ft-°F, (33) and the heat transfer coefficient for air under free convection is between 1 to 5 Btu/hr-ft^2-°F (Reference 33). Since the closest meteorological tower is 820 feet away, the heat impact from heat conduction and convection from the casks to the tower is judged to be negligible based on the above stated thermal conductivity and free convection heat transfer coefficient for air.

   Emissivity of steel varies from 0.066 for a polished surface at 212°F to 0.80 for a strong, rough, oxidized surface at 75°F (Reference 33). For the casks, a conservative emissivity of 0.8 is assumed. Using the same reference, an emissivity of 0.1 is assumed for the meteorological instruments which are made mostly of aluminum with brush finished surfaces.

2. Methodology

   A simplified heat balance calculation for meteorological instruments on the towers was performed. The methodology used is described below.

At equilibrium, the heat gain by the instrument is equal to the heat loss of the instrument. Heat gain was determined by the casks' radiant heat flux intercepted by the instrument. Heat loss was approximated by the convective heat loss and radiative heat loss of the instrument. Conductive heat loss of the instrument was neglected.

Cask radiant heat flux was calculated using the Stefan-Boltzman Law of thermal radiation. All the radiant energy was assumed to be distributed evenly on the surface of a hemisphere with a radius equal to the specified distance of interest, i.e., 820 feet or 1880 feet. Heat gain by the instrument was calculated by using a heat transfer coefficient, h_c, which is a function of the instrument length (L) and the temperature differential (ΔT) between the equilibrium temperature of the instrument (Tm) and the ambient temperature (Ta), and the driving force T. The expression of the h_c used is:

$$h_c = 0.27\left(\frac{Tm - Ta}{L}\right)^{0.25}$$ (Reference 33)

The radiative heat loss of the instrument to the environment was calculated by using the Stefan-Boltzman Law of thermal radiation.

Conclusions

The maximum estimated rise in temperature of the meteorological instruments located at 820 feet and 1880 feet away is calculated to be 2.0°F and 0.5°F, respectively. These are conservative estimates based on the conservative assumptions used in the calculation. The separation of the cask and the tower is defined as the distance between the tower and the closest cask pad. The estimated temperature rise caused by casks further away on the other pads will be lower. Furthermore, due to the quantity of fuel which can be stored on the pads, it will be an extended period of time before the second pad is filled. At that time, the cask surface temperature on the first pad will have decayed considerably. Therefore, the final temperature rise due to the existence of casks on three pads (28 by 3 casks) is not expected to be more than twice the estimates for one pad, i.e., no more than 4.0°F and 1.0°F.

Based on instrument performance specifications given in Table 2.3-8 and the above estimated temperature rises, the increase in temperature will not cause the instrument to exceed its design operating range, and no degradation of instrument performance is expected. As described in Section 2.3.3.1, no temperature measurements are made at the backup meteorological tower. The ambient temperature and dew point are measured at the primary tower which is 1880 feet from the facility. The maximum estimated temperature rise of 1.0°F at the primary tower location is comparable with the system accuracy as required by Regulatory Guide 1.23, Onsite Meteorological Programs (Safety Guide 23), for the instrument used on the tower. For the differential air temperature (ΔT) measurements, since the temperature rise at the upper level of the tower is the same as at the lower level, the net difference in ΔT measurement will remain unchanged. Therefore, the operation of the ISFSI will cause no significant measurable impact and will not affect the operation of the Surry Power Station meteorological towers.

2.3.4 Diffusion Estimates

2.3.4.1 General

Atmospheric dilution estimates at the Exclusion Area Boundary (EAB) and population centers out to 50 miles from the Surry ISFSI site are required in Chapter 8 to evaluate the radiological consequences of postulated accident. These atmospheric dilution factors χ/Q values, were calculated using the bivariate normal or Gaussian diffusion model (Regulatory Guide 1.145, Rev. 1) assuming ground level releases.

2.3.4.1.1 Hourly Average χ/Q Estimates

Hourly average χ/Q values for the l-hour (representative of the 0- to 2-hour period) accident period were calculated using equations 1 through 3.

For neutral (D) and stable (E, F, and G) stability conditions, when the wind speed is less than 6 meters per second, χ/Q values were calculated using equation 1.

$$\chi/Q = (U_{33}\pi\Sigma_y\sigma_z)^{-1} \quad (1)$$

where:

χ/Q = Relative Concentration (sec/m^2)

U_{33} = Wind speed at 33 feet above plant grade (m/sec)

π = 3.14159...

Σ_y = Lateral plume spread with meander and building effects

$\Sigma_y = M\sigma_y$ for distances up to 800 m

$\Sigma_y = (M-1)\sigma_y$ 800 m + σ_y for distances beyond 800 m

σ_y, σ_z = Lateral and vertical plume spread (m)

Figure 2.3-29 depicts the functional relationship of M (meander factor) with respect to wind speed and atmospheric stability.

If the χ/Q value calculated in equation 1 is less than the greater χ/Q value of either of the following equations, it is retained; otherwise, the applicable χ/Q value which is the greater of those calculated by equations 2 and 3 becomes limiting.

$$\chi/Q = [U_{33}(\pi\sigma_y\sigma_z + A/2)]^{-1} \quad (2)$$

$$\chi/Q = [U_{33}(3\pi\sigma_y\sigma_z)]^{-1} \quad (3)$$

where:

A = The smallest vertical plan cross-sectional building area (m). For ISFSI releases, credit due to the effects of building wake were not considered.

For all unstable (A, B, and C) stability conditions and for D, E, F, and G stability conditions when the wind speed is greater than or equal to 6 meters per second, the greater of the two χ/Q values calculated from equations 2 and 3 becomes limiting.

2.3.4.1.2 Annual Average χ/Q Estimates

The calculation of the annual average χ/Q value for each downwind sector centered at the cask was determined using equation 4, which is based on Regulatory Guide 1.111, Revision 1.

$$(\chi/Q)_{k,\,l} = \sum_{j=1}^{n_l} \frac{2.032\Omega}{N\bar{U}_{33}x(\sigma_{z_k}^2 + ch_b^2/\pi)^{1/2}} \qquad (4)$$

where:

n = Number of hours of wind in a particular 22.5 degree sector

l = Index for a particular 22.5 degree sector

k = Index for a particular receptor distance

j = Index for a number of hours

$2.032 = (2/\pi)^{1/2}(2\pi/16)^{-1}$

π = 3.14159 . . .

Ω = Terrain recirculation factor (obtained by using Figure 2 of the Regulatory Guide 1.111, Rev. 0, March 1976)

N = Total number of hours of wind in all sectors for applicable averaging period

$\bar{U}_{33}$ = Average wind speed at 33 feet above plant grade (m/sec)

x = Downwind receptor distance (m)

σ_z = Vertical dispersion coefficient (m)

h_b = Building height (m) (set equal to 0.0)

c = Building shape factor = 0.5

2.3.4.2 **Calculations**

Meteorological input parameters were determined from onsite meteorological data acquired during the January 1, 1976 through December 31, 1982 (7-year) time period. The parameters

included hourly average values (based on 15-minute averages) of wind speed and wind direction at the 30-foot level, and atmospheric stability determined from the temperature differences measured at 30.3- and 147.4-foot levels. Atmospheric stability was classified according to the temperature gradient values for the various Pasquill stability categories (A through G).

Each valid hour of the data period was used for the calculation. An hour of data was considered valid if recovery of the wind speed, wind direction, and temperature difference (ΔT) were simultaneously accomplished. For each valid hour of meteorological data, a χ/Q value was calculated as described in Section 2.3.4.1, where the wind direction determined the applicable downwind sector. The EAB and population midpoint distances were used (along with the stability class), to determine magnitudes of σ_y and σ_z.

For the hours with calm wind speeds, a wind speed of 0.75 miles per hour was assigned. The wind directions during these calm conditions were assigned in proportion to the directional distribution of the noncalm through 3.4-mile-per-hour wind speed condition. Regulatory Guide 1.145 states noncalm wind speeds below 3.4 miles per hour provide a reasonable method for defining the distribution of wind directions during light winds.

For each downwind section, χ/Q values were stored and arranged in descending order and 0.5-percent χ/Q values during the total time period were chosen. These values were compared and the sector with the largest χ/Q value determined the 0.5-percent χ/Q for the 0- to 2-hour time period.

For time periods greater than 2 hours, χ/Q values were determined graphically by techniques outlined in Regulatory Guide 1.145. The 0.5-percent value for the 0- to 2-hour period was plotted at the 2-hour time period on logarithmic versus time coordinates, while the annual average χ/Q value for the same sector was plotted at 8760 hours. Logarithmic interpolation was applied to locate values for the time periods corresponding to 0 to 8 hours, 8 to 24 hours, 1 to 4 days, and 4 to 30 days following an accidental release. For overall site χ/Q calculation, the maximum of the 16 annual average χ/Q values was used along with the 5 percent 2-hour χ/Q value to determine χ/Q values for the intermediate time periods by logarithmic interpolation. The 5 percent overall site χ/Q value was also compared with the maximum sector dependent χ/Q values and the higher set of values was selected.

Resultant accident χ/Q values (sector dependent) at the EAB (503 m) and various population receptors are presented in Tables 2.3-12 through 2.3-24. The maximum 0- to 2-hour χ/Q value at the EAB is 1.07×10^{-3} sec/m^3. As can be shown from these tables, maximum sector χ/Q values occur at the north sector of the ISFSI site. These values, as a function of downwind distance, are summarized in Table 2.3-25.

The following hypothetical accident diffusion meteorology, Pasquill F (stable) stability condition and 1 m/sec wind speed, was used in Chapter 8 to evaluate the radiological consequences of a postulated loss of the confinement barrier. This analysis produced a χ/Q of 1.56×10^{-3} (sec/m^3) at the nearest site boundary to the ISFSI, 629 meters away.

For ground level releases, i.e., the postulated dry cask release and a given meteorological condition, the resulting χ/Q values decrease as the distance from the release point increases. A comparison of the maximum calculated 0- to 2-hour χ/Q value at the EAB (503 m), 1.07×10^{-3} sec/m^3 (using onsite meteorological data), with the χ/Q value at the nearest site boundary (629 m), 1.56×10^{-3} sec/m^3 (using the hypothetical meteorology), shows that the χ/Q value used in Chapter 8 radiological consequences evaluation is conservative.

There are no long-term (routine) airborne releases associated with the operation of the ISFSI facility; therefore, no long-term diffusion estimate is reported.

2.3.5 References

1. *Richmond, Virginia, 1980, Local Climatological Data, Annual Summary with Comparative Data,* National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, North Carolina.
2. *Norfolk, Virginia, 1980, Local Climatological Data, Annual Summary with Comparative Data,* National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, North Carolina.
3. *Climates of the States, Climate of Virginia, Climatography of the United States No. 60-44,* U.S. Department of Commerce, Washington, D.C., 1971.
4. Thom, H. C. S., *New Distribution of Extreme Mile Winds in the United States,* ASCE Environmental Engineering Conference, Dallas Texas, February 1967.
5. Huss, P. O., *Relation Between Gusts and Average Wind Speed,* David Guggenheim Airship Institute, Report 140, Cleveland, Ohio, 1946.
6. *Storm Data,* National Weather Records Center, National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, North Carolina.
7. *Climatological Data - National Summary,* U.S. Department of Commerce, Weather Bureau, 1951-1958.
8. Thom, H. C. S, Tornado Probabilities, *Monthly Weather Review 91,* pp. 730-736 (1963).
9. Cry, G. W., Tropical Cyclones of the North Atlantic Ocean, National Oceanic and Atmospheric Administration, *Technical Paper No. 55,* Washington, D.C., 1965.
10. *Climatological Data, Virginia, June 1972,* National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, North Carolina.
11. *Climatological Data, Virginia, Annual Summary, 1971,* National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, North Carolina, 1972.
12. Crockett, C. W., *Climatological Summaries for Selected Stations in Virginia - Holland,* Water Resources Research Center, Virginia Polytechnic Institute and State University, “53,” Blacksburg, Virginia, 1972.

13. Crockett, C. W., *Climatological Summaries for Selected Stations in Virginia - Hopewell,* Water Resources Research Center, Virginia Polytechnic Institute and State University, "53," Blacksburg, Virginia, 1972.

14. Crockett, C. W., *Climatological Summaries for Selected Stations in Virginia - Williamsburg,* Water Resources Research Center, Virginia Polytechnic Institute and State University, "53," Blacksburg, Virginia, 1972.

15. Hosler, C. R., Low-Level Inversion Frequency in the Contiguous United States, *Monthly Weather Review 89,* pp. 319-332, 1961.

16. Holzworth, G. C., *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States,* Preliminary Document, Environmental Protection Agency, May 1971.

17. Stackpole, J. D., The Air Pollution Potential Forecast Program, National Meteorological Center, Weather Bureau Technical Memo, *NMC-43,* Suitland, Maryland, 1967.

18. Korshover, J., Climatology of Stagnating Anticyclones East of the Rocky Mountains, 1936-1965, U.S. Department of Health, Education, and Welfare, *999-AP-34,* Cincinnati, Ohio, 1967.

19. Schaefer, V. J. (Chairman), *Glossary of Terms Frequently Used in Air Pollution,* American Meteorological Society, Boston, p. 34, 1968.

20. *Local Climatological Data Monthly Summary,* Norfolk, Virginia, January and July 1977, U.S. Department of Commerce, 1978.

21. *Local Climatological Data Monthly Summary,* Richmond, Virginia, January and July 1977, U.S. Department of Commerce, 1978.

22. *Local Climatological Data Annual Summary,* Norfolk, Virginia, 1981, U.S. Department of Commerce, 1982.

23. *Local Climatological Data Annual Summary,* Richmond, Virginia, 1981, U.S. Department of Commerce, 1982.

24. *Climatography of the United States No. 30-44, Summary of Hourly Observations,* Richmond, Virginia, U.S. Department of Commerce.

25. *Climatography of the United States No. 82-44, Decennial Census of United States Climate - Summary of Hourly Observations,* Norfolk, Virginia, 1951-1960, U.S. Department of Commerce.

26. NUREG/CR-1390, *Probability Estimates of Temperature Extremes for the Contiguous United States,* USNRC, May 1980.

27. R. E. Huske, ed., *Glossary of Meteorology,* AMS, Boston, Massachusetts, 1959.

28. Sunde, E. D., *Bell System Technical Journal 24,* April 1945.

29. Visher, S. S., *Climatic Atlas of the United States,* Harvard University Press, 1966.

30. List, R. J., ed., *Meteorological Tables,* 6th ed., Smithsonian Institute, 1951, p. 417.

31. Wallace, John M. and Peter V. Hobbs, *Atmospheric Science,* Academic Press, 1977.

32. U.S. NRC Regulatory Guide 7.8, *Load Combinations for Structural Analysis of Shipping Casks,* May 1977.

33. Holman, J. P., *Heat Transfer,* 3rd edition, McGraw-Hill Book Company, N.Y., 1972.

Table 2.3-1
SELECTED NATIONAL WEATHER SERVICE STATIONS FOR METEOROLOGICAL EXTREMES IN THE SURRY SITE REGION (DATE OF OCCURRENCE)

	Norfolk		Richmond	
Maximum temperature	104°F	(8/80)	105°F	(7/77)
Miminum temperature	5°F	(l/77)	-12°F	(l/40)
Maximum monthly rainfall	13.80 in.	(9/79)	18.87 in.	(7/45)
Maximum monthly snowfall	18.9 in.	(2/80)	28.5 in.	(l/40)
Maximum 24-hour rainfall	11.4 in.	(8/64)	8.79 in.	(8/55)
Maximum 24-hour snowfall	12.4 in.	(2/80)	21.6 in.	(l/40)
Fastest mile wind	78 mph S	(10/54)	68 mph SE	(10/54)

Table 2.3-2
RICHMOND METEOROLOGICAL NORMALS, MEANS, AND EXTREMES
(REFERENCE 1)

Month	Temperature °F							Normal Degree days Base 65 °F		Precipitation in Inches										
	Normal			Extremes						Water equivalent							Snow, ice pellets			
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				51		51					43		43		43		43		43	
J	47.4	27.6	37.5	80	1950	-12	1940	853	0	2.86	7.97	1978	1.08	1951	3.31	1962	28.5	1940	21.6	1940
F	49.9	28.8	39.4	83	1932	-10	1936	717	0	3.01	5.97	1979	0.48	1978	2.67	1979	19.5	1979	10.9	1979
M	58.2	35.5	46.9	93	1938	11	1960	569	8	3.38	8.04	1975	0.94	1966	2.04	1942	19.7	1960	12.1	1962
A	70.3	45.2	57.8	96	1976	25	1977	226	10	2.77	5.32	1952	0.64	1963	2.60	1978	2.0	1940	2.0	1940
M	78.5	54.5	66.5	100	1941	31	1956	64	111	3.42	8.87	1972	0.87	1965	2.53	1972	0.0		0.0	
J	85.4	62.9	74.2	104	1952	40	1967	0	276	3.52	9.24	1938	0.38	1980	4.61	1963	0.0		0.0	
J	88.2	67.5	77.9	105	1977	51	1965	0	400	5.63	18.87	1945	0.52	1963	5.73	1969	0.0		0.0	
A	86.6	65.9	76.3	102	1953	46	1934	0	350	5.06	14.10	1955	0.52	1943	8.79	1955	0.0		0.0	
S	80.9	59.0	70.0	103	1954	35	1974	21	171	3.58	10.98	1975	0.26	1978	3.82	1955	0.0		0.0	
O	71.2	47.4	59.3	99	1941	21	1962	203	27	2.94	9.39	1971	0.30	1963	6.50	1961	T	1979	T	1979
N	60.6	37.3	49.0	86	1974	10	1933	480	0	3.20	7.64	1959	0.36	1965	4.07	1956	7.3	1953	7.3	1953
D	49.1	28.8	39.0	80	1971	-1	1942	806	0	3.22	7.07	1973	0.40	1980	3.16	1958	12.5	1958	7.5	1966
					JUL		JAN					JUL		SEP		AUG		JAN		JAN
YR	68.8	46.7	57.8	105	1977	-17	1940	3939	1353	42.59	18.87	1945	0.26	1978	8.79	1955	28.5	1940	21.6	1940

Month	Relative humidity pct. (Local time)				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days										Average station pressure mb.
							Fastest mile					Sunrise to sunset						Temperature °F Max.		Min.		
	01 Hour	07 Hour	13 Hour	19 Hour	Mean speed mph	Prevailing direction	Speed mph	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	(b) 90° and above	32° and below	32° and below	0° and below	Elev. 177 feet msl
(a)	46	46	46	46	32	15	30	30		30	35	35	35	35	43	43	43	51	51	51	51	51	8
J	77	81	57	69	8.0	S	43	NW	1971	51	6.5	8	7	16	11	1	*	3	0	3	21	*	1012.2
F	74	79	52	62	8.5	NNE	45	SW	1951	57	6.1	9	6	13	9	1	*	2	0	2	19	*	1017.6
M	74	78	49	59	8.9	W	42	SE	1952	59	6.2	8	8	15	11	1	1	2	*	*	10	0	1010.8
A	74	76	45	55	8.8	S	40	NW	1972	64	6.0	8	9	13	9	*	2	2	1	0	2	0	1009.7
M	84	80	51	65	7.7	SSW	45	N	1962	64	6.3	7	11	13	11	0	6	2	3	0	*	0	1008.8
J	87	82	54	68	7.2	S	52	NW	1952	68	6.0	7	12	11	9	0	7	2	9	0	0	0	1015.6
J	89	85	56	71	6.6	SSW	56	NW	1955	66	6.1	7	12	12	11	0	9	2	13	0	0	0	1010.1
A	90	89	57	76	6.3	S	54	W	1964	65	6.0	7	12	12	10	0	7	3	11	0	0	0	1011.6
S	90	90	57	79	6.6	S	45	SE	1952	64	5.8	9	9	12	8	0	3	3	5	0	0	0	1011.7
O	87	90	53	77	6.8	NNE	68	SE	1954	60	5.3	12	7	12	7	0	1	3	*	0	2	0	1012.5
N	80	84	50	70	7.4	S	38	NW	1977	56	5.7	10	8	12	8	*	1	2	0	*	10	0	1013.3
D	78	81	55	70	7.5	SW	40	SW	1968	52	6.1	10	6	15	9	1	*	3	0	2	21	*	1012.9
									OCT														
YR	82	83	53	69	7.5	S	68	SE	1954	61	6.0	102	107	156	113	4	37	29	42	6	86	1	1011.3

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: highest temperature 107 in August 1918; minimum monthly precipitation 0.11 in November 1890 and eariler.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS — Based on record for the 1941-1970 periods.
DATE OF AN EXTREME — The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION — Record through 1963.
WIND DIRECTION — Numerals indicate tens of degrees clockwise from true north. 00 indicate calm.
FASTEST MILE WIND — Speed is fastest observed 1-minute value when the direction is in tens of degrees.

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Table 2.3-3
NORFOLK METEOROLOGICAL NORMALS, MEANS, AND EXTREMES
(REFERENCE 2)

Month	Temperature °F							Normal Degree days Base 65 °F		Precipitation in Inches										
	Normal			Extremes						Water equivalent							Snow, ice pellets			
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				32		32					32		32		32		32		32	
J	48.8	32.2	40.5	78	1970	5	1977	760	0	3.35	6.47	1979	1.60	1949	3.80	1967	14.2	1966	9.1	1973
F	50.0	32.7	41.4	81	1976	8	1965	661	0	3.31	5.72	1956	0.86	1950	1.87	1970	18.9	1980	12.4	1980
M	57.3	38.9	48.1	85	1968	18	1980	532	8	3.42	7.80	1978	1.34	1967	3.18	1958	13.7	1980	9.9	1980
A	67.7	47.9	57.8	97	1960	28	1964	226	10	2.71	7.00	1979	0.99	1976	2.76	1979	1.2	1964	1.2	1964
M	76.2	57.2	66.7	97	1956	36	1966	53	106	3.34	10.12	1979	1.48	1965	3.41	1980	0.0		0.0	
J	83.5	65.5	74.5	101	1964	45	1967	0	285	3.62	9.72	1963	0.37	1954	6.85	1963	0.0		0.0	
J	86.6	69.9	78.3	103	1952	54	1979	0	412	5.70	13.73	1975	1.69	1961	5.64	1969	0.0		0.0	
A	84.9	68.9	76.9	104	1980	52	1965	0	369	5.92	11.19	1967	0.74	1975	11.40	1964	0.0		0.0	
S	79.6	63.9	71.8	98	1954	45	1967	0	213	4.20	13.80	1979	0.36	1958	6.79	1959	0.0		0.0	
O	70.1	53.3	61.7	95	1954	27	1976	141	38	3.06	10.12	1971	0.93	1967	4.38	1971	0.0		0.0	
N	60.5	42.6	51.6	86	1974	20	1950	402	0	2.94	7.01	1951	0.49	1965	3.35	1952	0.6	1950	0.6	1950
D	50.6	34.0	42.3	80	1978	14	1980	704	0	3.11	5.83	1973	0.98	1979	2.12	1958	14.7	1958	11.4	1958
					AUG		JAN					SEP		SEP		AUG		FEB		FEB
YR	68.0	50.6	59.3	104	1980	5	1977	3438	1441	44.68	13.80	1979	0.36	1958	11.40	1964	18.9	1980	12.4	1980

Month	Relative humidity pct.				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days										Average station pressure mb.
							Fastest mile †					Sunrise to sunset							Temperature °F Max.		Temperature °F Min.		
	01 Hour	07 Hour	13 Hour	19 Hour	Mean speed mph	Prevailing direction	Speed mph	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	(b) 90° and above	32° and below	32° and below	0° and below	
	(Local time)																					Elev. 30 feet msl
(a)	32	32	32	32	32	15	8	8		21	32	32	32	32	32	32	32	32	32	32	32	8
J	73	75	59	68	11.6	SW	39	23	1978	56	6.3	9	6	16	11	1	*	2	0	3	17	0	1017.9
F	72	74	56	65	12.0	NNE	44	36	1973	59	6.1	9	5	14	10	1	1	3	0	1	15	0	1017.6
M	72	74	54	62	12.3	SW	46	22	1973	63	6.1	9	7	15	11	*	2	2	0	*	6	0	1016.5
A	73	73	50	61	11.7	SW	39	06	1978	66	5.8	9	9	12	10	*	3	1	1	0	*	0	1015.4
M	81	78	56	67	10.2	SW	38	02	1979	65	6.1	8	10	13	10	0	5	2	1	0	0	0	1014.4
J	83	79	57	67	9.2	SW	46	30	1977	68	5.8	8	11	11	9	0	6	1	6	0	0	0	1015.6
J	85	82	59	71	8.9	SW	46	34	1973	65	5.9	8	11	12	11	0	8	1	11	0	0	0	1015.6
A	86	84	61	74	8.8	SW	46	35	1979	65	5.7	8	12	11	10	0	7	1	9	0	0	0	1017.2
S	84	84	61	76	9.6	NE	30	06	1979	64	5.7	9	10	11	8	0	3	1	3	0	0	0	1017.0
O	82	83	60	75	10.4	NE	32	23	1980	60	5.3	12	7	12	8	0	1	2	*	0	*	0	1017.9
N	76	79	56	69	10.6	SW	32	21	1973	59	5.3	11	8	11	8	0	1	2	0	0	3	0	1018.8
D	73	75	58	68	11.0	SW	35	35	1980	57	6.0	10	7	14	9	*	*	2	0	1	14	0	1018.4
									AUG														
YR	78	78	57	69	10.5	SW	46	35	1979	63	5.8	110	103	152	115	2	37	22	31	5	55	0	1016.9

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
† 1973 to date.

NORMALS — Based on record for the 1941-1970 periods.
DATE OF AN EXTREME — The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION — Record through 1963.
WIND DIRECTION — Numerals indicate tens of degrees clockwise from true north. 00 indicate calm.
FASTEST MILE WIND — Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:

Temperature
Highest: 105 in Aug. 1918
Lowest: 2 in Feb. 1895.

Precipitation
Maximum monthly: 15.61 in Aug. 1942.
Minimum monthly: 0.04 in Oct. 1874.

Fastest Mile Wind
Highest: 80 mph W in Jun. 1925.

Snowfall
Maximum in 24 hours: 17.7 in Dec. 1892.

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Table 2.3-4
MONTHLY METEOROLOGICAL MEANS FOR TEMPERATURE AND PRECIPITATION FOR STATIONS IN THE SURRY SITE REGION

Month	Norfolk	Richmond
January		
Temp	41.4°F	37.6°F
Precip	3.32 in.	3.20 in.
February		
Temp	42.1°F	39.1°F
Precip	3.33 in.	2.96 in.
March		
Temp	48.9°F	47.2°F
Precip	3.78 in.	3.52 in.
April		
Temp	57.5°F	57.1°F
Precip	3.20 in.	2.88 in.
May		
Temp	66.7°F	66.2°F
Precip	3.73 in.	3.68 in.
June		
Temp	74.6°F	73.9°F
Precip	4.01 in.	3.67 in.
July		
Temp	78.6°F	77.7°F
Precip	5.70 in.	5.57 in.
August		
Temp	77.6°F	76.4°F
Precip	5.33 in.	4.98 in.
September		
Temp	72.5°F	70.2°F
Precip	3.89 in.	3.67 in.
October		
Temp	62.1°F	58.7°F
Precip	3.13 in.	3.42 in.
November		
Temp	52.1°F	48.8°F
Precip	2.62 in.	3.19 in.
December		
Temp	43.6°F	39.7°F
Precip	3.19 in.	3.17 in.

Table 2.3-5
SURRY SEASONAL AND ANNUAL MEAN WIND SPEED SUMMARY (mph)
(March 3, 1974 - December 31, 1981)

	147.4-foot Level	30.3-foot Level
Spring (Mar, Apr, May)	10.7	6.8
Summer (June, July, Aug)	8.9	5.1
Fall (Sept, Oct, Nov)	9.4	5.3
Winter (Dec, Jan, Feb)	10.3	6.3
Annual	9.8	5.8

Table 2.3-6
σ_θ STABILITY CATEGORIES

Range of Standard Deviation, (Degrees)		Turbulence Type
A = Extremely Unstable	$\sigma_\theta \geq 22.5$	
B = Moderately Unstable	$22.5 > \sigma_\theta \geq 17.5$	High Atmospheric Turbulence
C = Slightly Unstable	$17.5 > \sigma_\theta \geq 12.5$	
D = Neutral	$12.5 > \sigma_\theta \geq 7.5$	Moderate Atmospheric Turbulence
E = Slightly Stable	$7.5 > \sigma_\theta \geq 3.8$	
F = Moderately Stable	$3.8 > \sigma_\theta \geq 2.1$	Low Atmospheric Turbulence
G = Extremely Stable	$\sigma_\theta < 2.1$	

Table 2.3-7
SEASONAL AND ANNUAL STABILITY AND WIND SPEED DISTRIBUTION

	σ_θ						
	A	B	C	D	E	F	G
Spring (Mar, Apr, May)							
147.4 Feet Frequency, %	4.13	4.50	14.17	44.21	27.90	4.26	.82
Wind Speed, mph	(5.3)	(7.0)	(9.2)	(11.66)	(10.8)	(8.9)	(7.4)
30.3 Feet Frequency, %	12.53	16.19	33.09	30.91	6.19	.47	.60
Wind Speed, mph	(4.5)	(6.2)	(7.3)	(7.4)	(4.7)	(2.2)	(1.1)
Summer (June, July, Aug)							
147.4 Feet Frequency, %	5.88	6.45	15.58	36.59	27.88	6.21	1.41
Wind Speed, mph	(5.1)	(6.3)	(8.0)	(9.4)	(8.9)	(8.0)	(6.6)
30.3 Feet Frequency, %	19.10	18.49	26.79	25.90	7.16	.98	1.58
Wind Speed, mph	(4.2)	(5.2)	(5.6)	(5.1)	(3.4)	(2.0)	(1.0)
Fall (Sept, Oct, Nov)							
147.4 Feet Frequency, %	3.37	3.82	13.30	40.56	30.29	7.01	1.64
Wind Speed, mph	(4.8)	(6.1)	(8.5)	(10.3)	(9.3)	(8.5)	(7.5)
30.3 Feet Frequency, %	13.53	17.29	30.74	28.28	7.87	.99	1.31
Wind Speed, mph	(4.3)	(5.5)	(5.9)	(5.6)	(3.6)	(2.4)	(.5)
Winter (Dec, Jan, Feb)							
147.4 Feet Frequency, %	2.77	3.14	9.86	45.65	32.65	5.39	.55
Wind Speed, mph	(4.3)	(5.8)	(8.3)	(11.4)	(10.4)	(8.7)	(7.8)
30.3 Feet Frequency, %	9.95	13.57	32.82	35.64	7.25	.49	.28
Wind Speed, mph	(3.8)	(5.7)	(6.6)	(7.2)	(4.3)	(3.3)	(.8)
Annual							
147.4 Feet Frequency, %	4.02	4.46	13.23	41.69	29.71	5.77	1.13
Wind Speed, mph	(5.0)	(6.3)	(8.5)	(10.7)	(9.9)	(8.5)	(7.2)
30.3 Feet Frequency, %	13.74	16.40	30.88	30.15	7.14	.74	.95
Wind Speed, mph	(4.3)	(5.6)	(6.4)	(6.4)	(4.0)	(2.4)	(.8)

Table 2.3-8 (SHEET 1 OF 2)
INSTRUMENT PERFORMANCE SPECIFICATIONS

MRJ 1074-22		
Wind Speed:		
Starting threshold	-	0.75 mph
Response distance	-	18' (63% recovery)
Flow coefficient	-	7.9'/rev
Accuracy	-	±0.25 mph
Range	-	125 mph maximum
Temperature range	-	40°C to +50°C
Humidity range	-	0% to 100% RH
0°-540° Direction:		
Starting threshold	-	0.75 mph
Delay Distance	-	4' (50% recovery)
Damping ratio	-	0.5 to 0.6
Accuracy	-	±2.5°
Range	-	540° (electrical)
	-	360° (mechanical)
Linearity	-	±0.25% of full scale with 4° open space
Sin/Cos Direction:		
Starting threshold	-	0.75 mph
Delay distance	-	4' (50% recovery)
Damping ratio	-	0.5 to 0.6
Accuracy	-	±3.6°
Range	-	360° (mechanical and electrical)
Linearity-not linear, conformity to function	-	±1% of full scale
Rosemont 104MB 12 ADCS probes and Endevco 4473.2 Signal Conditioner		
Accuracy (RSS)	-	±0.18°F (temperature)
	-	±0.13°F (differential temperature)
Range	-	10°F to +110°F (temperature)
	-	-6°F to +6°F (differential temperature)
Linearity	-	±0.1% (typical for resistance sensor)

Table 2.3-8 (SHEET 2 OF 2)
INSTRUMENT PERFORMANCE SPECIFICATIONS

EG&G 110(S)M or 220 with Aspirator Housing		
Range	-	-80°F to +160°F (overall, dependent on ambient temperature)
	-	-100°F to +160°F (for resistance temperature sensor)
	-	-30°F to +120°F (measurement range)
Relative humidity	-	<1% to 100% RH
Response	-	3°F to 5°F/sec (typical)
Sensitivity	-	±0.1°F
Dew point depression		0 to 100°F
Depression slow rate		4°F/sec maximum
System accuracy	-	±0.5°F (typical, accuracy analysis available from EG&G)
Teledyne Geotech 327B		
Motor Aspirated Solar Radiation Shield for Temperature and Differential Temperature Resistance Sensors		
Radiation shield	-	<0.2°F error at maximum solar radiation of 1.6 gm-cal/cm^2/sec
MRl 302		
Tipping bucket rain gage and heater		
Resolution	-	0.01 inches melted precipitation
Accuracy	-	±1% @ 3 inches/hour ±5% @ 10 inches/hour
Esterline Angus E11 and A6 series recorders		
Accuracy (DCV or milliamps)	-	±l% of full scale 0.5 sec. to record 99% of final value at critical damping
Temperature range	-	20°F to 120°F

Table 2.3-9
TEMPERATURE CORRELATION FACTOR

Daily Temperature		Site/Norfolk	Site/Richmond
January	Maximum	0.959	0.961
	Minimum	0.902	0.872
July	Maximum	0.952	0.924
	Minimum	0.861	0.914

Table 2.3-10
MONTHLY MEAN EXTERNAL TEMPERATURES

	Site[a]		Norfolk[b]		Richmond[c]	
Month	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
January	35.4	22.8	35.9	23.1	36.1	16.2
July	86.7	69.9	88.8	70.5	91.8	66.9

Note: Tmax = monthly mean of daily maximum temperatures (°F)
Tmin = monthly mean of daily minimum temperatures (°F)

a. Data source for onsite information - Meteorological Data Summary 1977 Surry Nuclear Power Station.
b. Source: Reference 20 of Section 2.3.2.1.
c. Source: Reference 21 of Section 2.3.2.1.

Table 2.3-11
DISTRIBUTION OF TEMPERATURES 90°F

Temperature Range (°F)	Richmond[a, b]	Norfolk[b, c]
104/100	12 (5%)	1 (1%)
99/85	59 (25%)	19 (12%)
94/90	163 (70%)	136 (87%)
Totals	234 (100%)	156 (100%)

a. Data period 3/50 - 2/55 (5 years)
b. (%) indicates percent of observation with temperature 90°F and above.
c. Data period l/51 - 12/60 (10 years)

Table 2.3-12
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-4}$ SEC/M^3) AT THE 0.313-MILE EXCLUSION AREA BOUNDARY 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	l-4 day	4-30 day
N	503	10.7	7.39	6.15	4.12	2.32
NNE	503	10.1	6.93	5.74	3.82	2.13
NE	503	9.56	6.28	5.09	3.22	1.67
ENE	503	7.27	4.68	3.75	2.32	1.17
E	503	4.85	3.19	2.59	1.64	0.856
ESE	503	3.52	2.35	1.92	1.24	0.661
SE	503	3.63	2.43	1.98	1.28	0.682
SSE	503	3.18	2.19	1.82	1.22	0.685
S	503	3.42	2.38	1.98	1.33	0.755
SSW	503	2.76	1.85	1.52	0.985	0.529
SW	503	2.62	1.76	1.45	0.942	0.509
WSW	503	2.35	1.56	1.27	0.814	0.429
W	503	3.03	2.04	1.67	1.09	0.589
WNW	503	4.43	2.96	2.42	1.56	0.834
NW	503	6.73	4.38	3.53	2.21	1.13
NNW	503	8.95	6.03	4.95	3.22	1.74

Five percent direction independent 8.65

Table 2.3-13
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-5}$ SEC/M^3) AT THE 0.5-MILE EXCLUSION AREA BOUNDARY 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	l-4 day	4-30 day
N	805	49.9	34.1	28.2	18.6	10.3
NNE	805	47.2	32.0	26.3	17.3	9.41
NE	805	44.7	28.9	23.3	14.5	7.40
ENE	805	34.0	21.6	17.2	10.5	5.16
E	805	22.2	14.4	11.6	7.31	3.75
ESE	805	15.8	10.5	8.53	5.45	2.86
SE	805	16.3	10.8	8.80	5.62	2.96
SSE	805	14.3	9.78	8.09	5.37	2.98
S	805	15.4	10.6	8.80	5.88	3.29
SSW	805	12.5	8.33	6.79	4.36	2.31
SW	805	11.8	7.86	6.42	4.15	2.21
WSW	805	10.7	7.00	5.66	3.58	1.85
W	805	13.7	9.15	7.47	4.81	2.56
WNW	805	20.1	13.3	10.8	6.92	3.64
NW	805	30.7	19.8	15.9	9.84	4.95
NNW	805	40.4	27.0	22.1	14.3	7.63

Five percent direction independent 40.2

Table 2.3-14
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-5}$ SEC/M^3) AT THE 1.5-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	l-4 day	4-30 day
N	2414	18.9	10.1	7.42	3.77	1.43
NNE	2414	17.8	9.49	6.92	3.49	1.31
NE	2414	16.9	8.59	6.12	2.94	1.02
ENE	2414	12.4	6.19	4.38	2.07	0.706
E	2414	7.51	3.90	2.81	1.38	0.498
ESE	2414	5.25	2.77	2.02	1.01	0.375
SE	2414	5.09	2.72	1.99	1.01	0.380
SSE	2414	4.46	2.47	1.84	0.967	0.385
S	2414	5.09	2.81	2.09	1.10	0.434
SSW	2414	3.84	2.07	1.52	0.778	0.297
SW	2414	3.34	1.83	1.36	0.706	0.277
WSW	2414	3.07	1.64	1.20	0.610	0.230
W	2414	4.25	2.29	1.68	0.858	0.327
WNW	2414	6.37	3.40	2.49	1.26	0.474
NW	2414	10.8	5.52	3.94	1.90	0.665
NNW	2414	15.3	8.03	5.81	2.89	1.06

Five percent direction independent 14.6

Table 2.3-15
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-5}$ SEC/M^3) AT THE 2.0-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	l-4 day	4-30 day
N	3218	14.7	7.39	5.24	2.49	0.851
NNE	3218	13.9	6.93	4.89	2.30	0.778
NE	3218	13.2	6.27	4.33	1.93	0.609
ENE	3218	9.31	4.40	3.02	1.34	0.416
E	3218	5.65	2.77	1.94	0.892	0.293
ESE	3218	3.95	1.97	1.39	0.653	0.220
SE	3218	3.83	1.93	1.37	0.651	0.224
SSE	3218	3.34	1.74	1.26	0.622	0.226
S	3218	3.82	1.99	1.43	0.705	0.255
SSW	3218	2.82	1.44	1.03	0.494	0.173
SW	3218	2.40	1.25	0.901	0.443	0.160
WSW	3218	2.24	1.13	0.806	0.386	0.134
W	3218	3.09	1.58	1.13	0.543	0.190
WNW	3218	4.66	2.35	1.67	0.798	0.276
NW	3218	8.15	3.92	2.72	1.23	0.392
NNW	3218	11.90	5.86	4.11	1.90	0.630

Five percent direction independent 11.4

Table 2.3-16
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-5}$ SEC/M^3) AT THE 2.5-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	l-4 day	4-30 day
N	4023	12.1	5.80	4.02	1.82	0.580
NNE	4023	11.4	5.43	3.75	1.68	0.530
NE	4023	10.8	4.91	3.32	1.41	0.414
ENE	4023	7.60	3.43	2.31	0.974	0.283
E	4023	4.46	2.10	1.44	0.637	0.197
ESE	4023	3.17	1.52	1.05	0.470	0.149
SE	4023	3.08	1.49	1.03	0.469	0.151
SSE	4023	2.68	1.34	0.950	0.448	0.152
S	4023	2.99	1.50	1.06	0.501	0.170
SSW	4023	2.21	1.08	0.758	0.350	0.115
SW	4023	1.87	0.935	0.662	0.313	0.107
WSW	4023	1.69	0.827	0.579	0.267	0.088
W	4023	2.40	1.18	0.827	0.383	0.127
WNW	4023	3.74	1.81	1.26	0.575	0.186
NW	4023	6.54	3.02	2.05	0.005	0.265
NNW	4023	9.77	4.59	3.15	1.39	0.430

Five percent direction independent 9.32

Table 2.3-17
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-6}$ SEC/M^3) AT THE 3.5-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	5633	88.6	40.1	27.0	11.5	3.34
NNE	5633	83.7	37.6	25.2	10.6	3.04
NE	5633	79.2	34.0	22.3	8.89	2.38
ENE	5633	55.8	23.7	15.5	6.13	1.62
E	5633	31.2	14.0	9.34	3.90	1.11
ESE	5633	22.7	10.3	6.90	2.91	0.845
SE	5633	21.4	9.82	6.65	2.86	0.848
SSE	5633	19.2	9.08	6.24	2.77	0.861
S	5633	21.3	10.1	6.94	3.08	0.962
SSW	5633	15.5	7.20	4.91	2.14	0.647
SW	5633	12.6	6.03	4.17	1.87	0.592
WSW	5633	11.4	5.32	3.64	1.60	0.489
W	5633	17.0	7.92	5.40	2.36	0.715
WNW	5633	26.2	12.1	8.17	3.52	1.05
NW	5633	46.8	20.4	13.5	5.49	1.51
NNW	5633	71.7	31.8	21.2	8.77	2.47

Five percent direction independent 68.1

Table 2.3-18
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-6}$ SEC/M^3) AT THE 4.5-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	7242	69.9	30.5	20.2	8.21	2.26
NNE	7242	66.0	28.6	18.8	7.58	2.05
NE	7242	62.6	25.8	16.6	6.36	1.61
ENE	7242	44.0	18.0	11.6	4.39	1.09
E	7242	24.2	10.4	6.86	2.76	0.745
ESE	7242	17.1	7.48	4.96	2.03	0.561
SE	7242	16.6	7.34	4.88	2.02	0.567
SSE	7242	14.9	6.78	4.58	1.98	0.574
S	7242	16.1	7.39	5.00	2.15	0.637
SSW	7242	11.5	5.21	3.50	1.47	0.426
SW	7242	9.33	4.33	2.95	1.28	0.574
WSW	7242	8.47	3.85	2.59	1.10	0.332
W	7242	12.7	5.74	3.86	1.63	0.472
WNW	7242	20.2	8.89	5.93	2.46	0.696
NW	7242	36.3	15.3	9.92	3.88	1.01
NNW	7242	56.6	24.2	15.8	6.28	1.67

Five percent direction independent 52.8

Table 2.3-19
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-6}$ SEC/M^3) AT THE 7.5-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	12070	43.1	17.7	11.4	4.34	1.09
NNE	12070	41.2	16.7	10.7	4.02	0.990
NE	12070	38.3	14.9	9.30	3.34	0.768
ENE	12070	27.4	10.6	6.56	2.33	0.527
E	12070	13.8	5.67	3.64	1.39	0.348
ESE	12070	10.1	4.20	2.71	1.04	0.265
SE	12070	9.57	4.02	2.61	1.02	0.264
SSE	12070	8.61	3.72	2.44	0.983	0.266
S	12070	9.57	4.14	2.72	1.10	0.297
SSW	12070	6.19	2.68	1.76	0.709	0.192
SW	12070	5.04	2.24	1.50	0.621	0.176
WSW	12070	4.54	1.98	1.31	0.531	0.146
W	12070	7.17	3.08	2.02	0.809	0.217
WNW	12070	11.5	4.85	3.15	1.23	0.322
NW	12070	21.5	8.59	5.43	2.00	0.478
NNW	12070	35.3	14.2	8.98	3.34	0.806

Five percent direction independent 32.2

Table 2.3-20
0.5 PERCENT GROUND LEVEL χ/Q VALUES ($\times 10^{-6}$ 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	l-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 ($\times 10^{-7}$ 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	l-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	l-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 ($\times 10^{-7}$ 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	l-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 Distance (m)	Time Averaging χ/Q				
	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

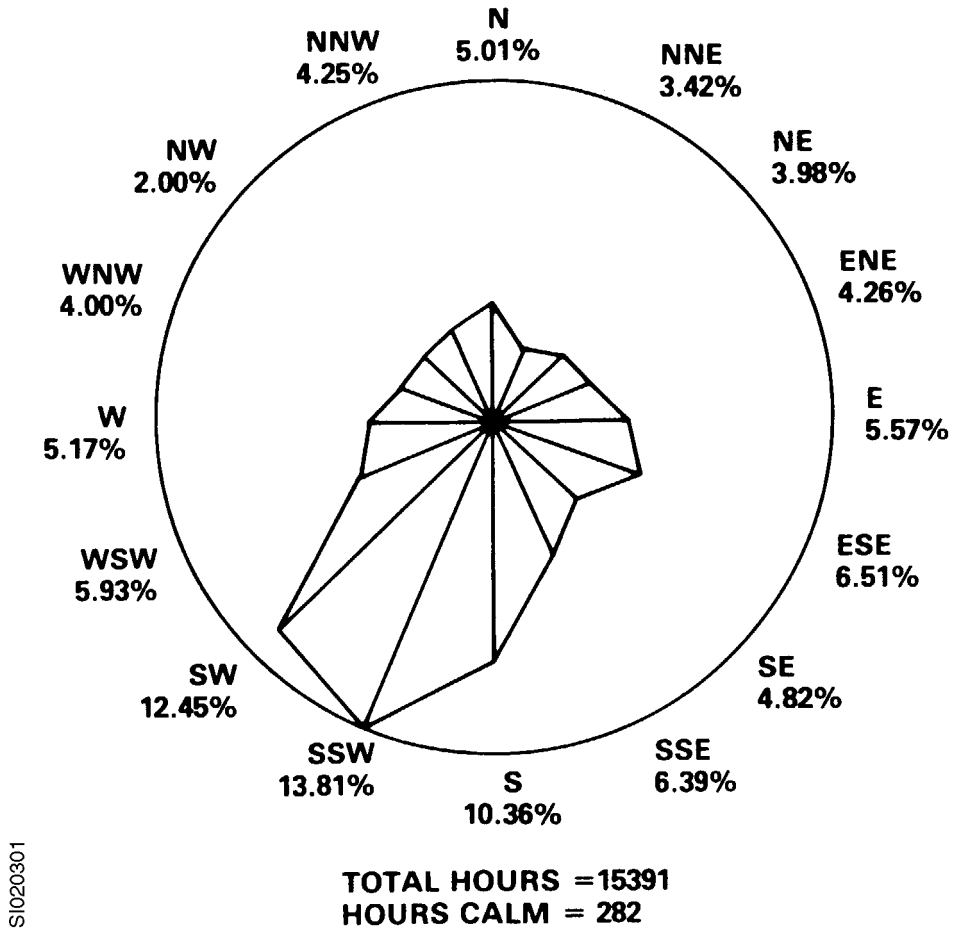


Figure 2.3-2
SURRY WIND DIRECTION ROSES (%); 1974-1981; LOW LEVEL;
SEASON = SUMMER

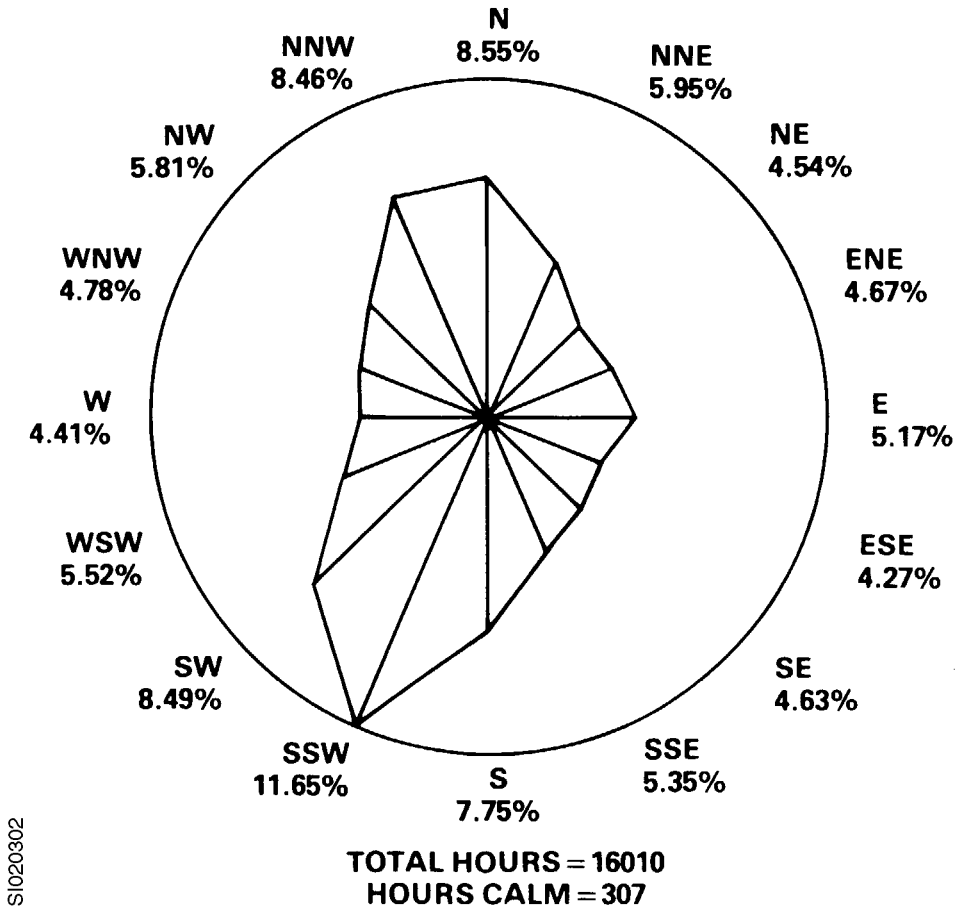


Figure 2.3-3
SURRY WIND DIRECTION ROSES (%); 1974-1981; LOW LEVEL;
SEASON = FALL

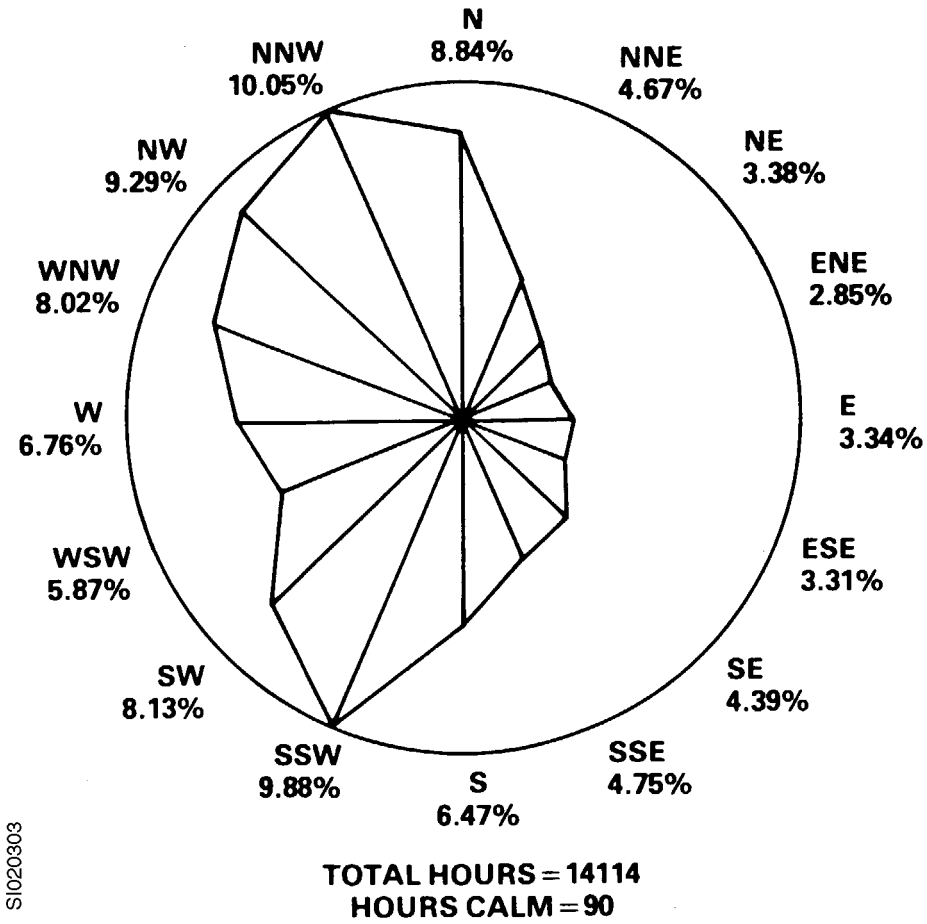


Figure 2.3-4
SURRY WIND DIRECTION ROSES (%); 1974-1981; LOW LEVEL;
SEASON = WINTER

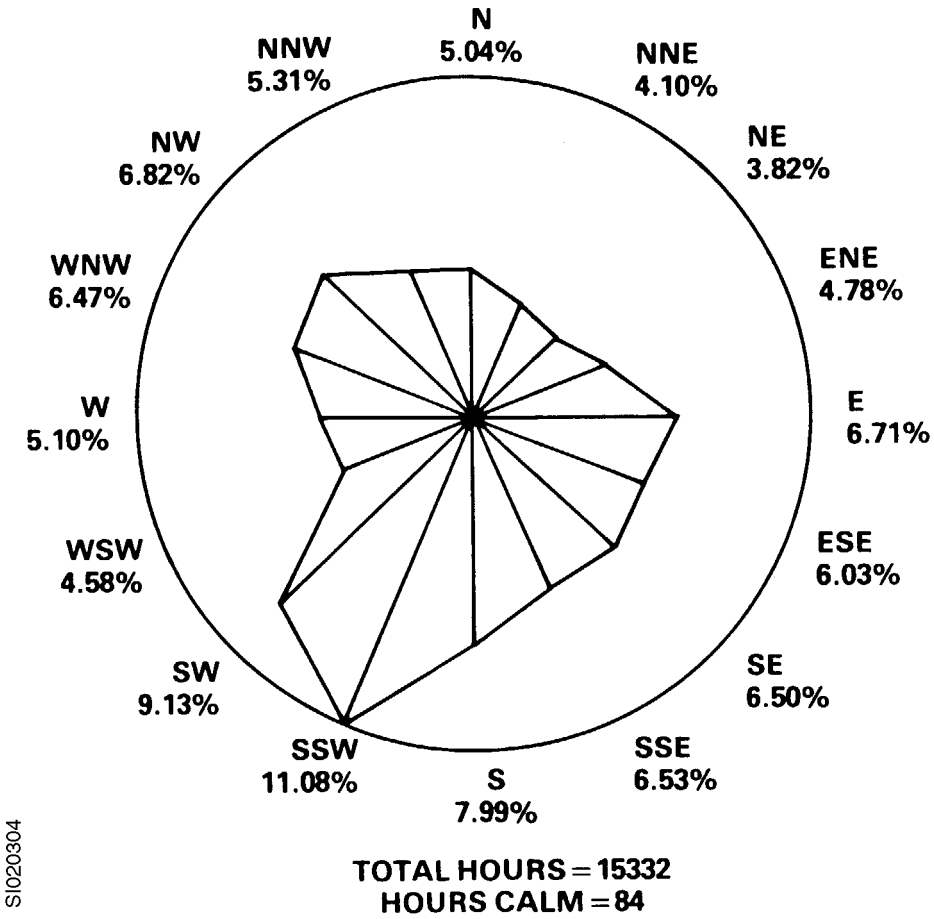


Figure 2.3-5
SURRY WIND DIRECTION ROSES (%); 1974-1981; LOW LEVEL; OVERALL

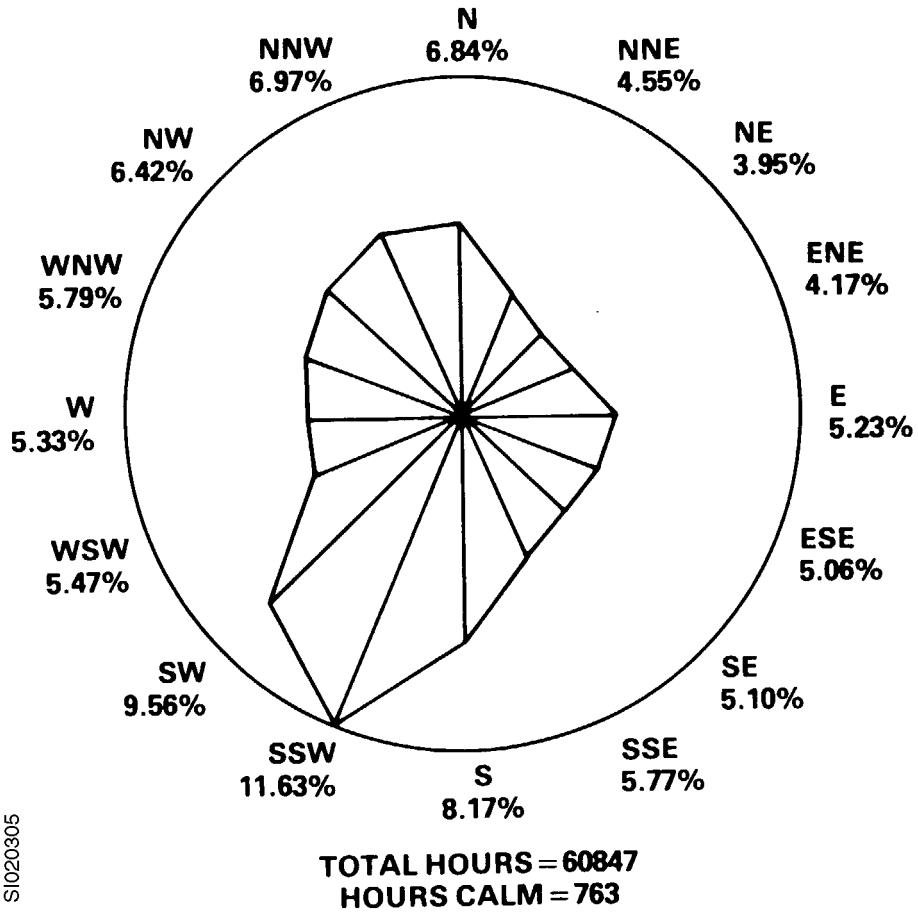


Figure 2.3-6
SURRY SEASONAL WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL;
SEASON = SPRING

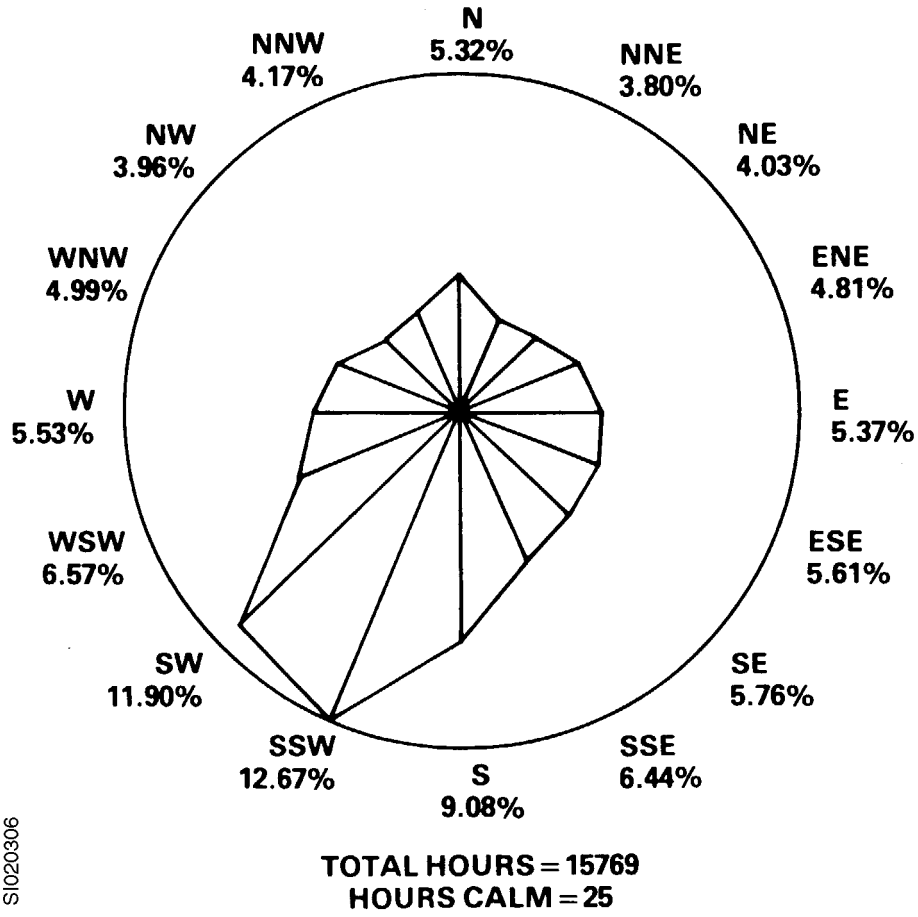


Figure 2.3-7
SURRY SEASONAL WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL;
SEASON = SUMMER

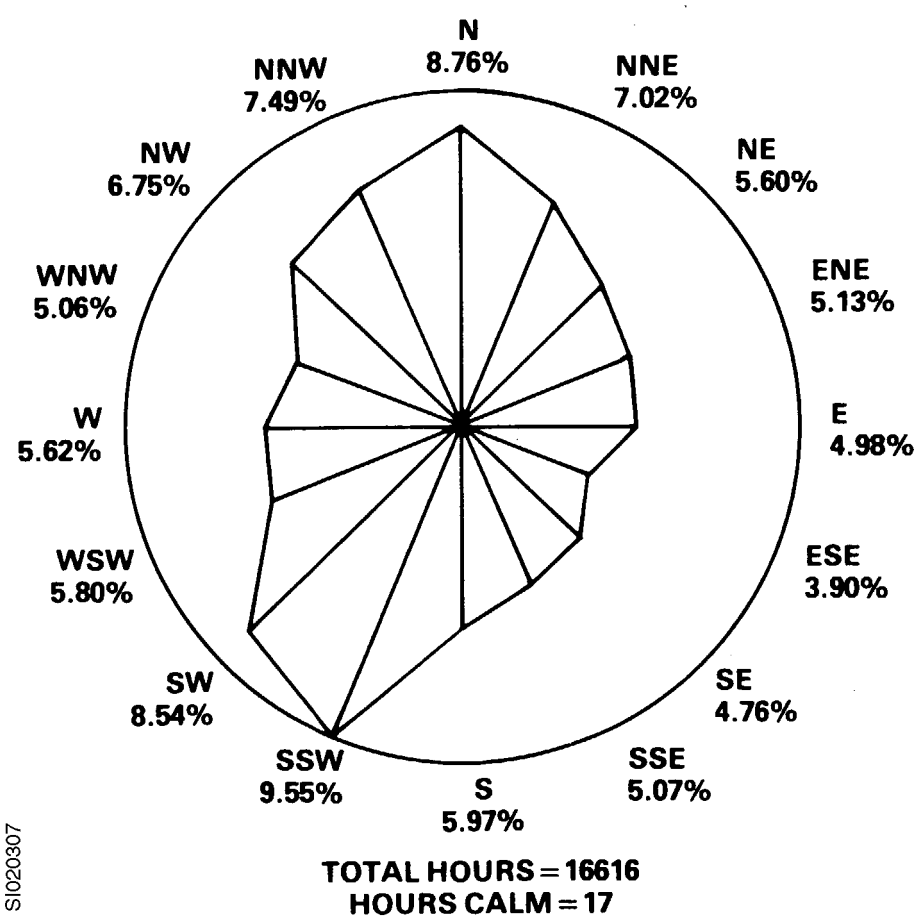


Figure 2.3-8
SURRY SEASONAL WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL;
SEASON = FALL

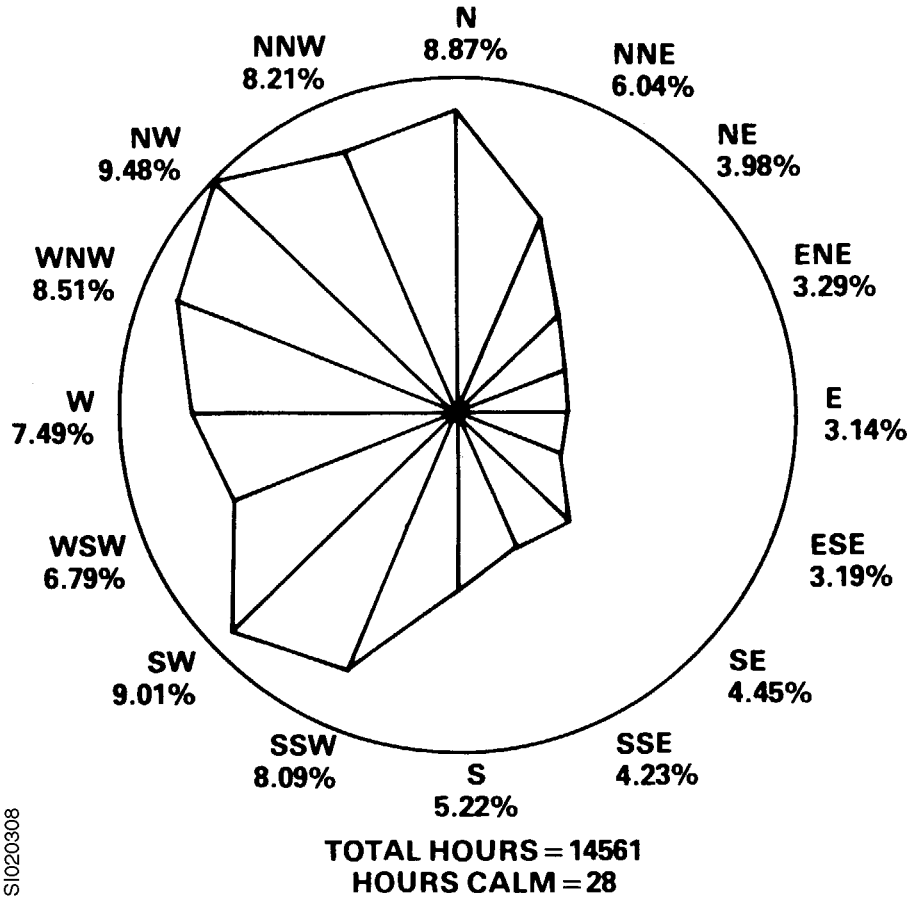


Figure 2.3-9
SURRY SEASONAL WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL;
SEASON = WINTER

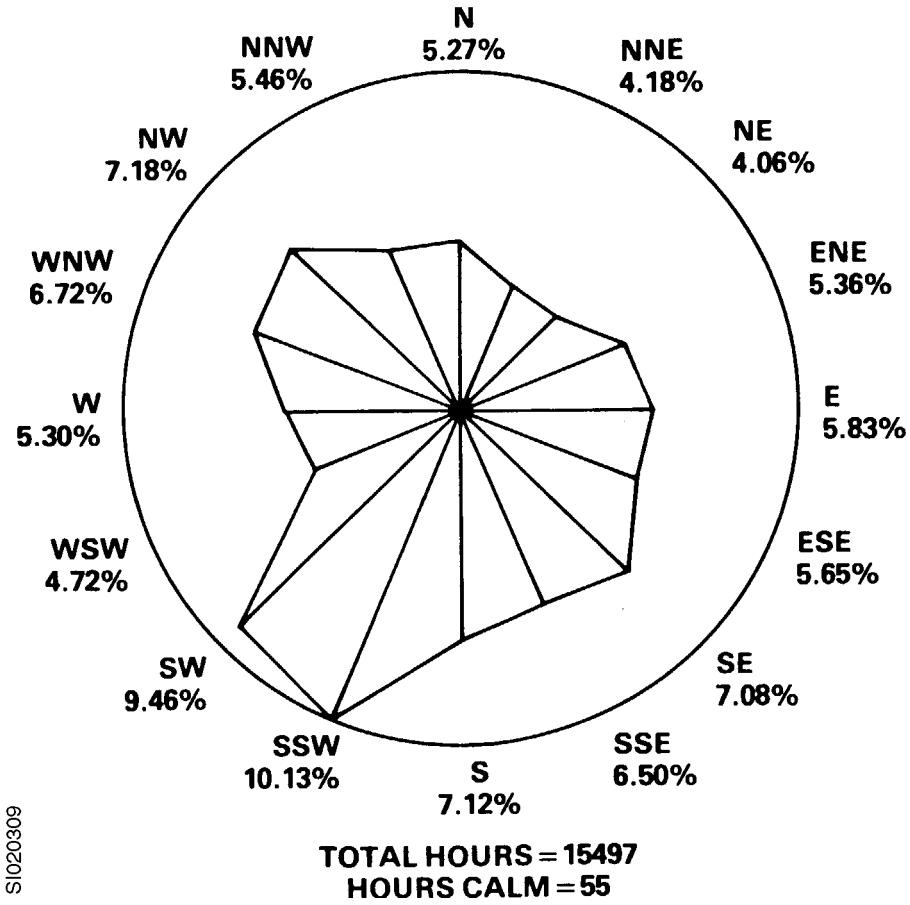


Figure 2.3-10
SURRY WIND DIRECTION ROSES (%); 1974-1981; HIGH LEVEL; OVERALL

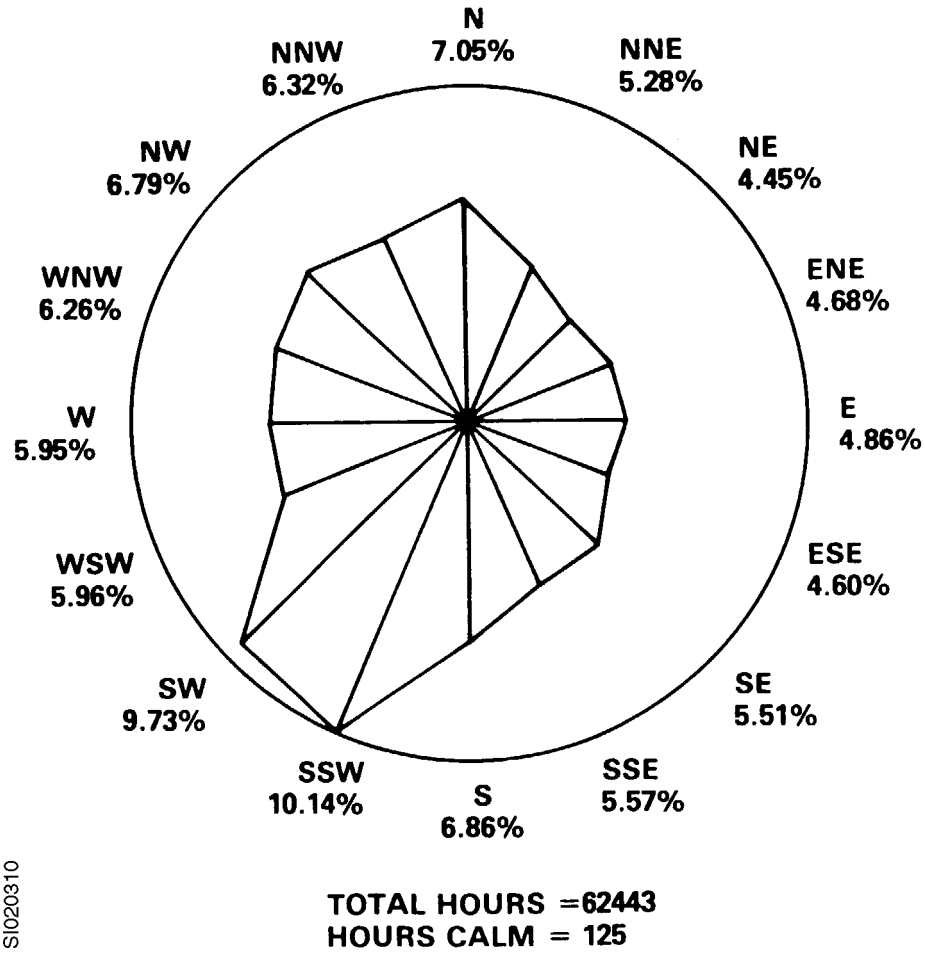


Figure 2.3-11
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL;
SEASON = SPRING

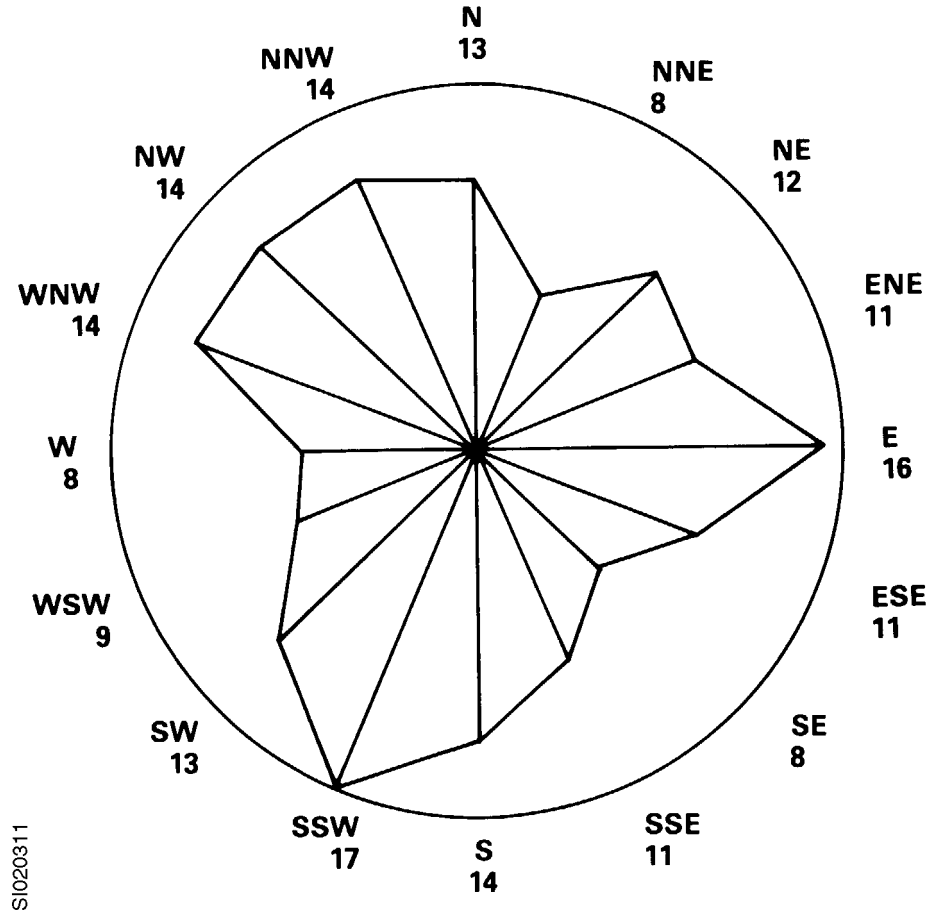


Figure 2.3-12
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL;
SEASON = SUMMER

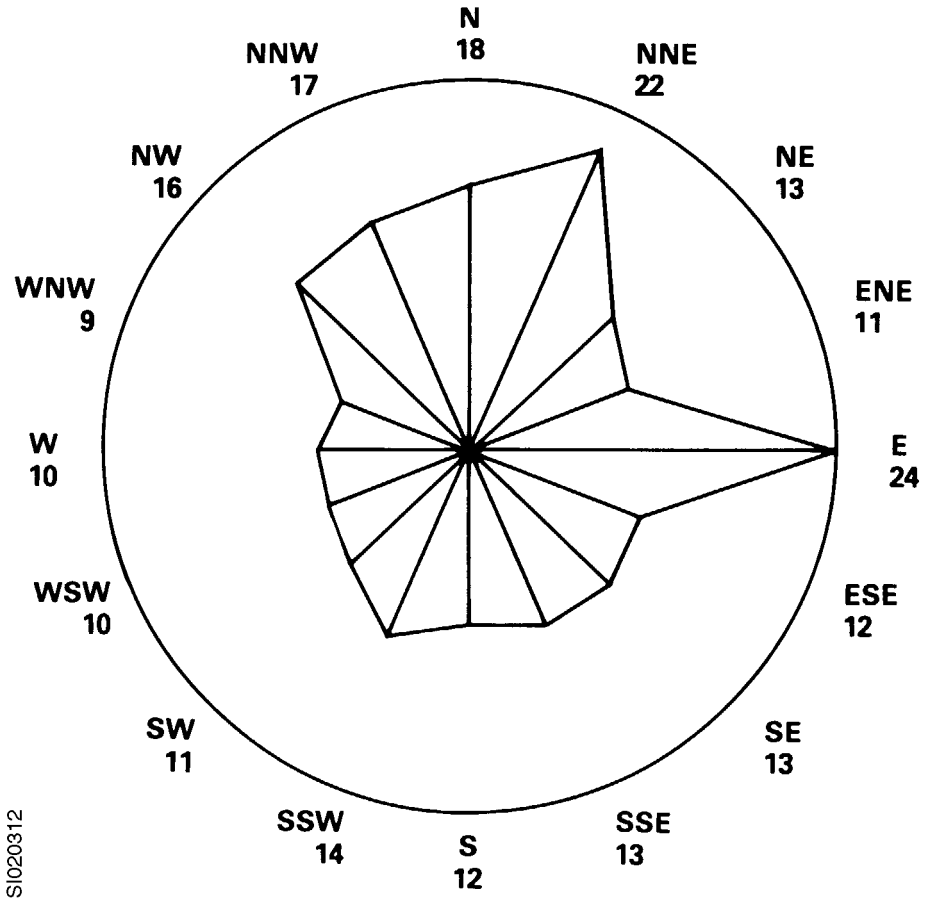


Figure 2.3-13
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL;
SEASON = WINTER

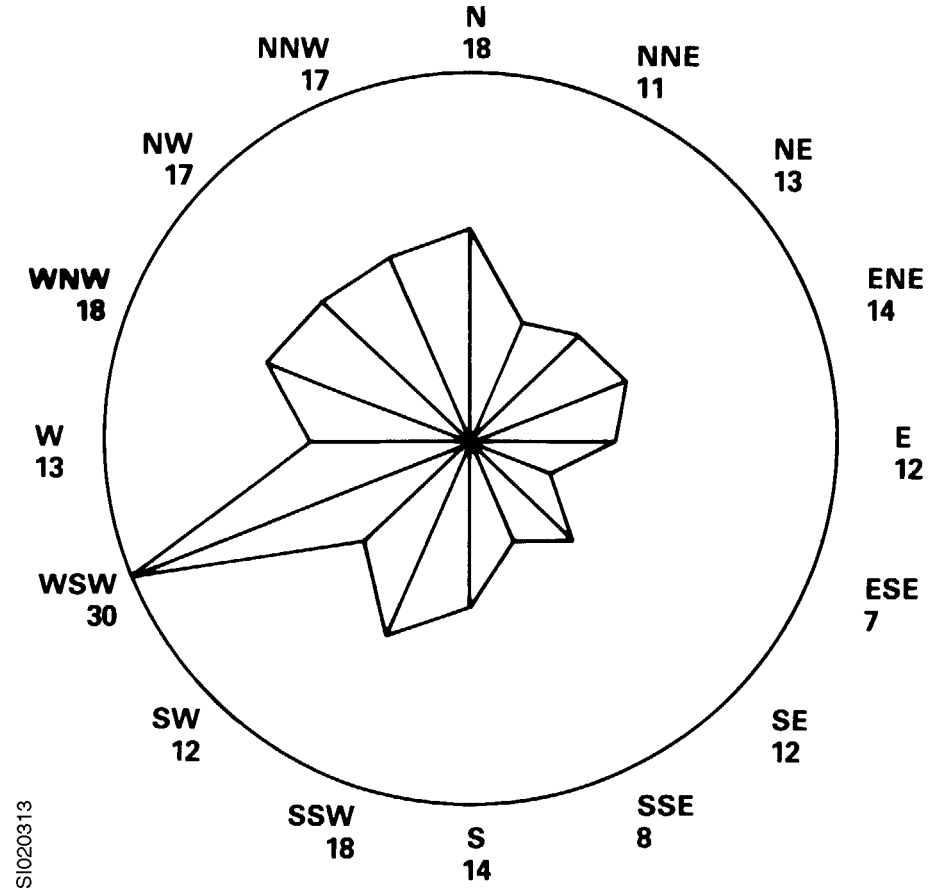


Figure 2.3-14
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL;
SEASON = FALL

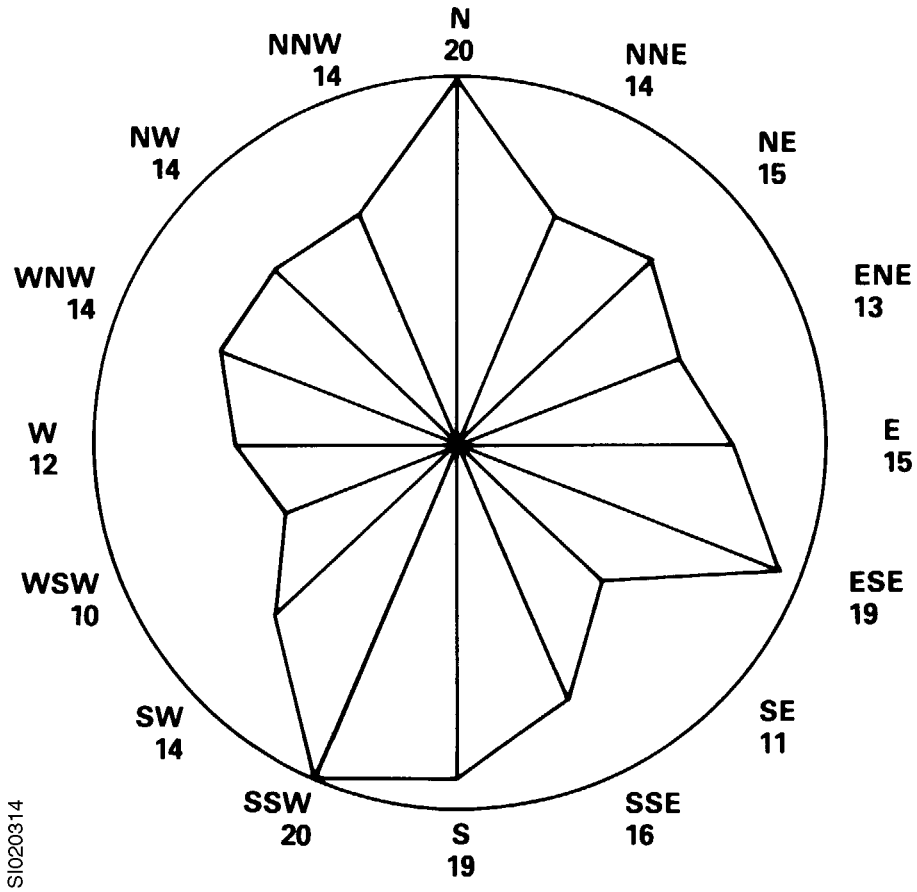


Figure 2.3-15
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; LOW LEVEL; OVERALL

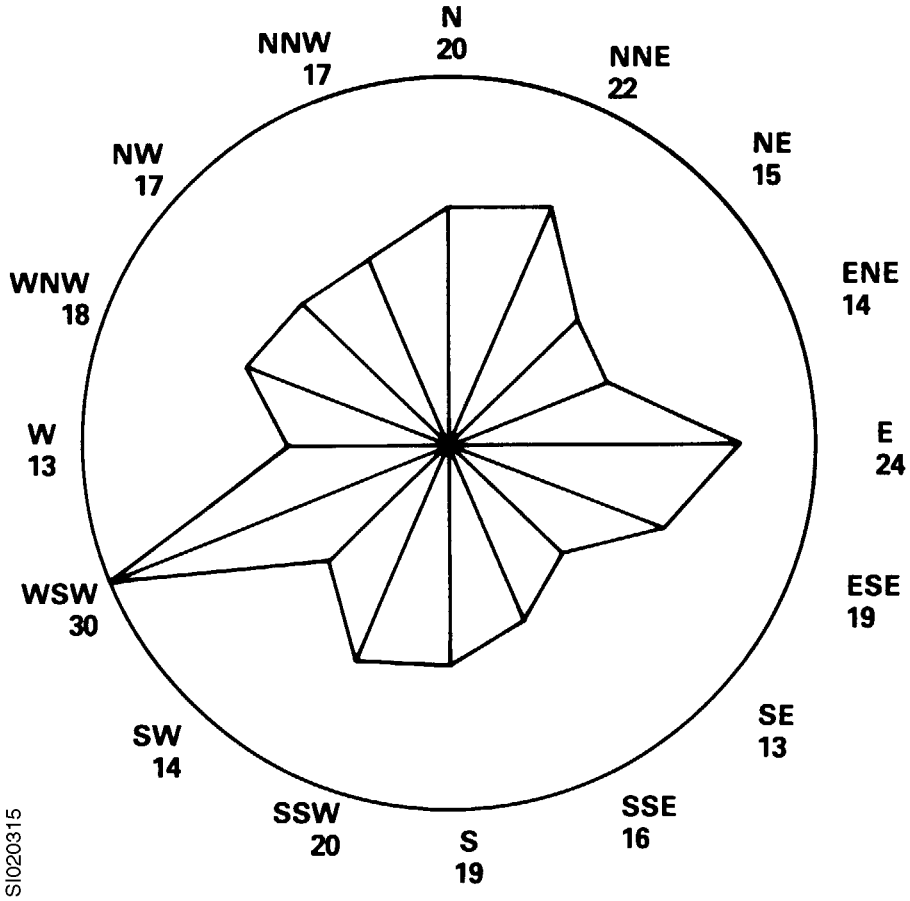


Figure 2.3-16
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL;
SEASON = SPRING

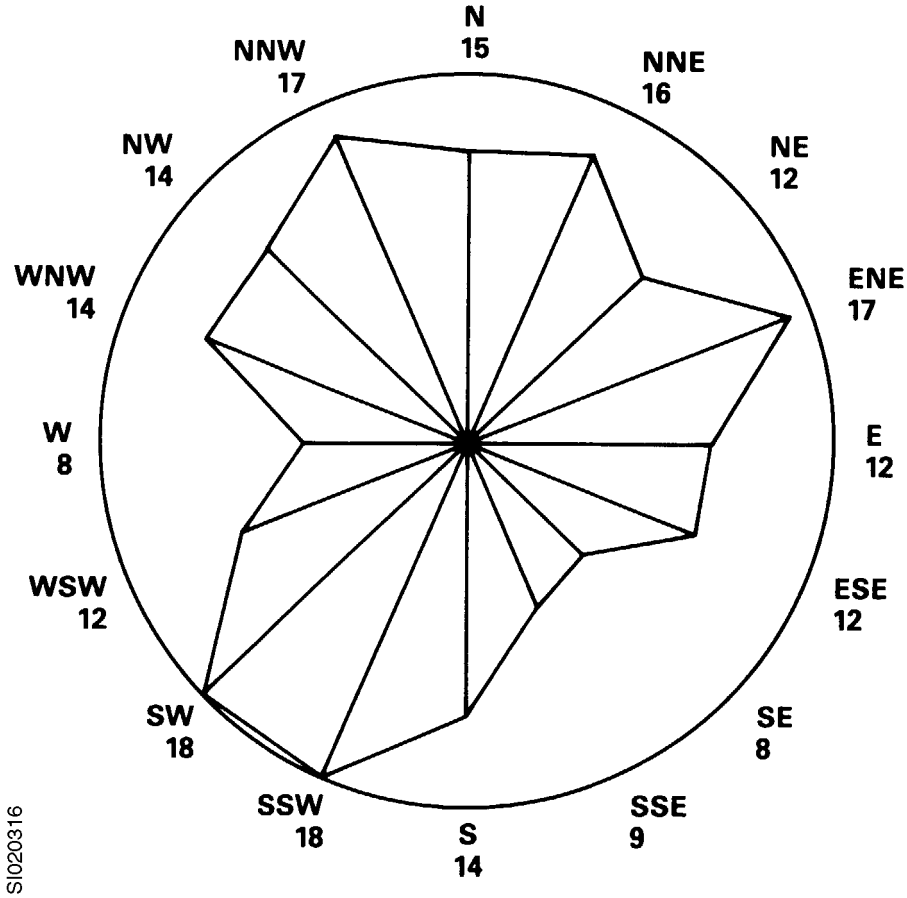


Figure 2.3-17
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL;
SEASON = SUMMER

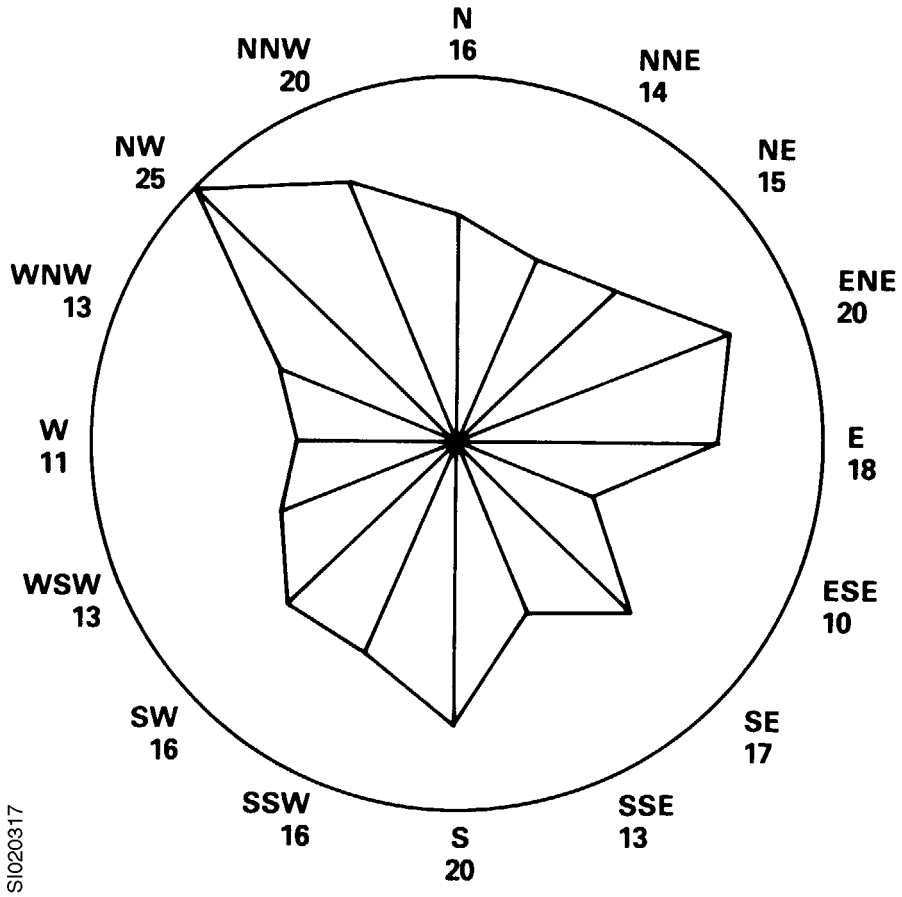


Figure 2.3-18
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL;
SEASON = FALL

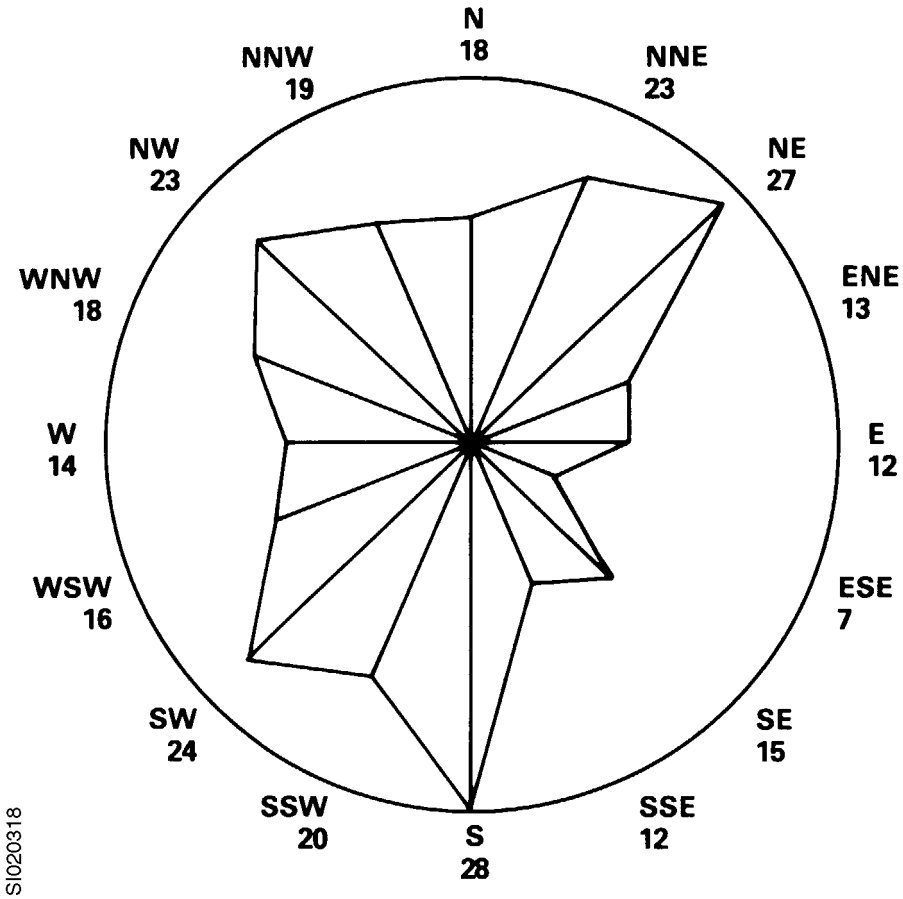


Figure 2.3-19
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL;
SEASON = WINTER

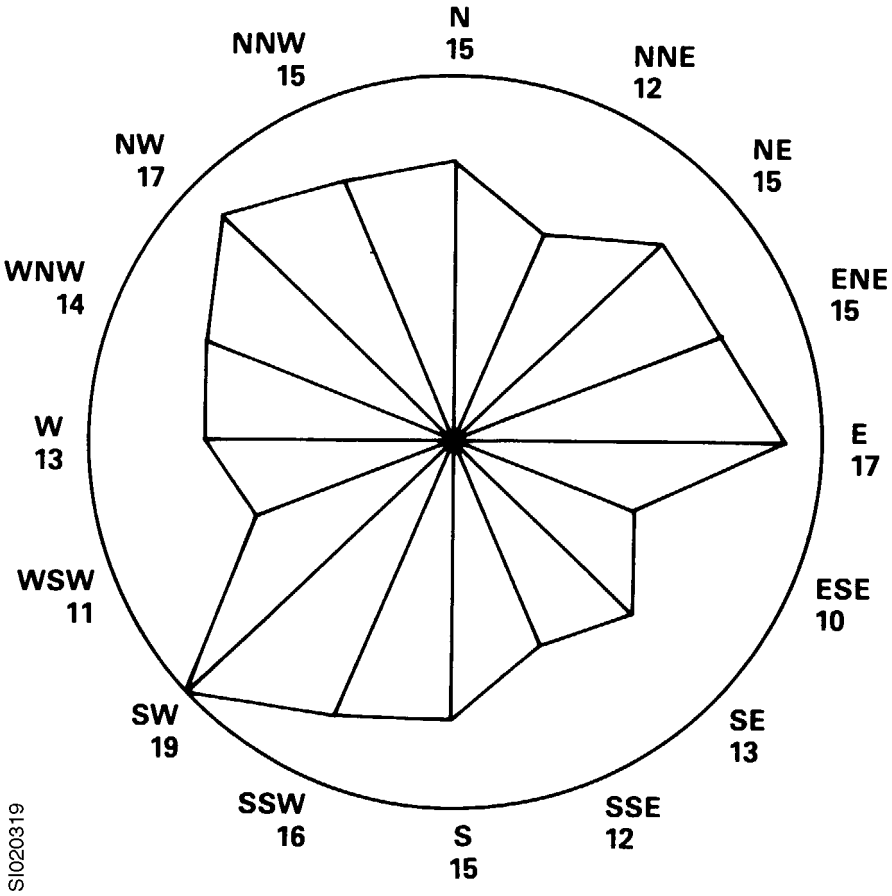


Figure 2.3-20
SURRY SEASONAL WIND PERSISTENCE ROSES; 1974-1981; HIGH LEVEL; OVERALL

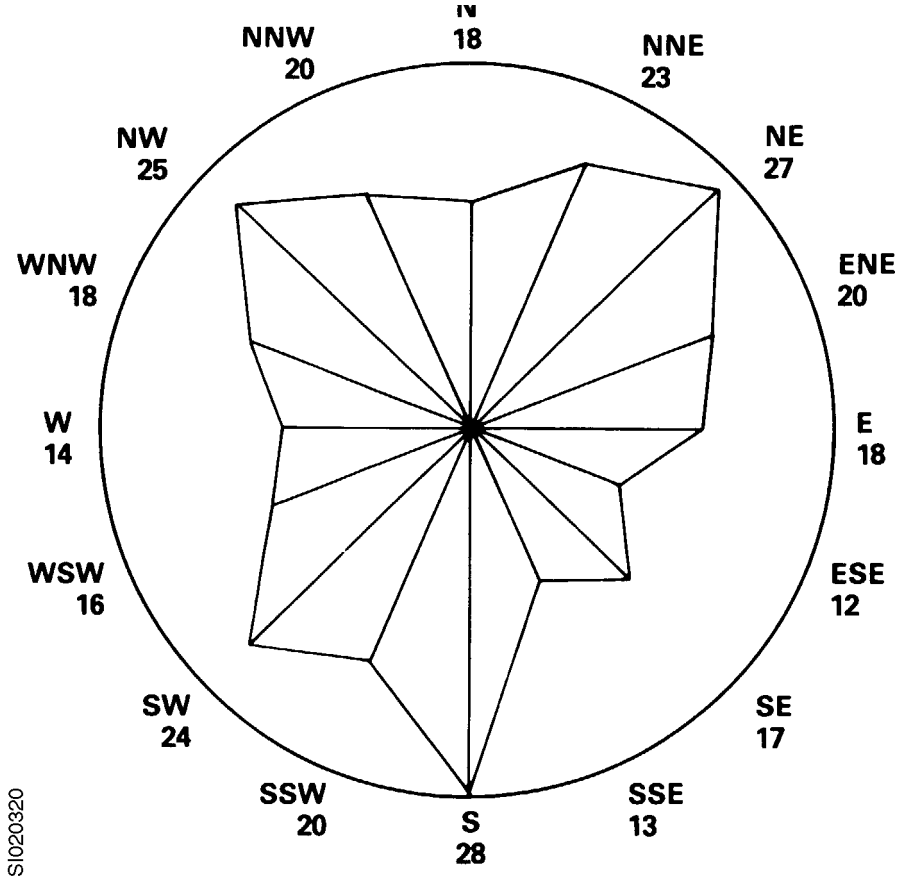
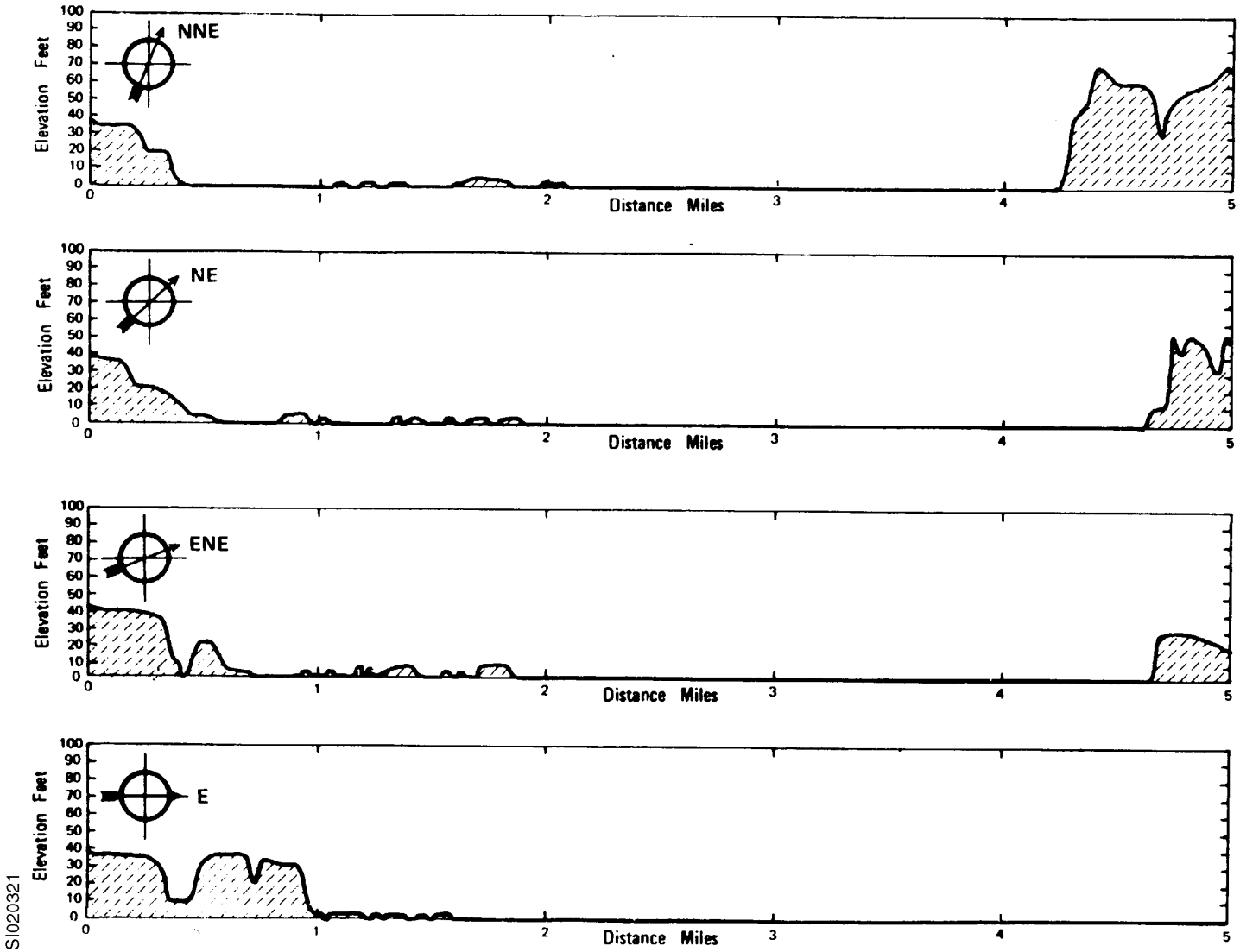
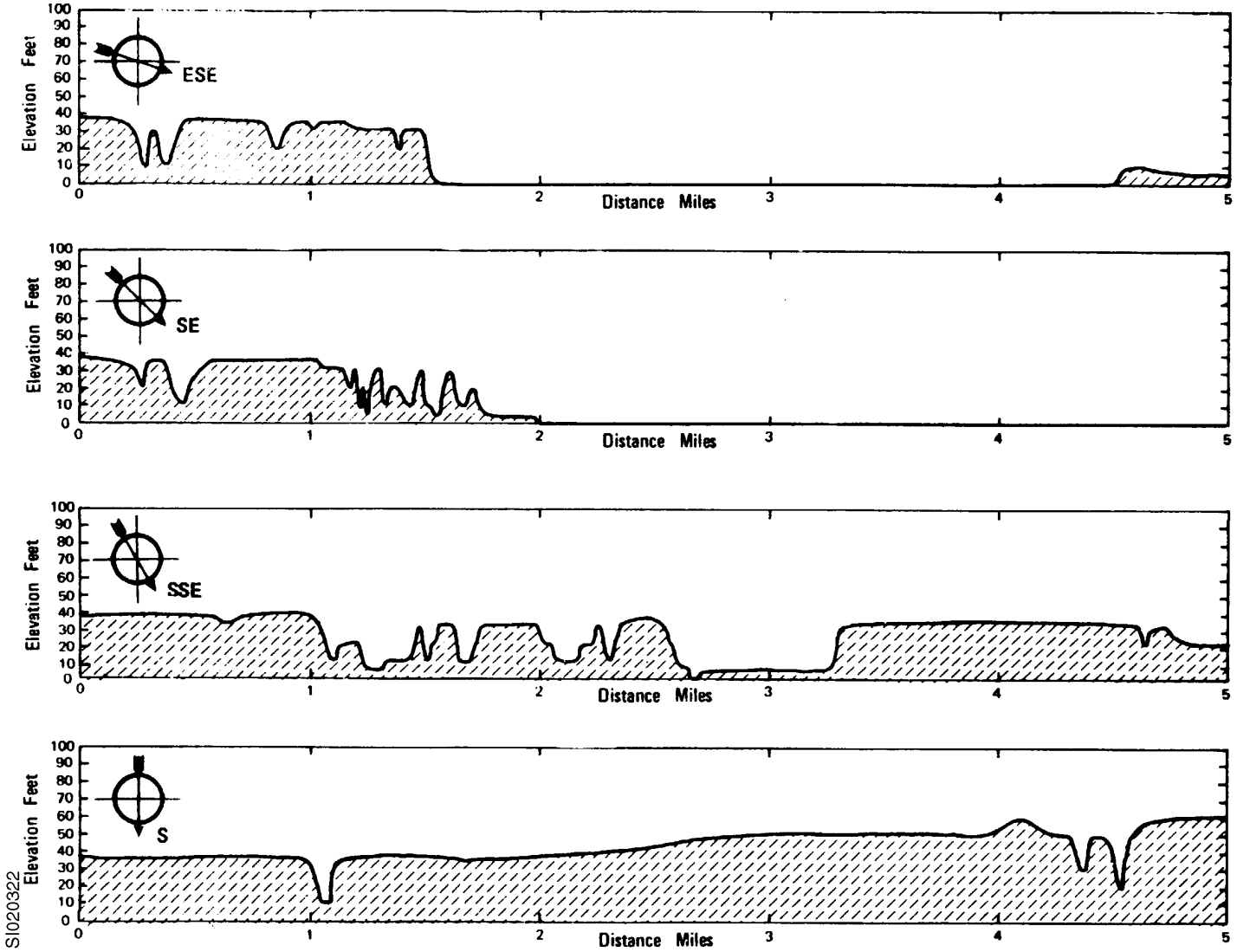


Figure 2.3-21
SURRY POWER STATION; TOPOGRAPHIC CROSS SECTIONS; (0-5 MILES FROM SURRY POWER STATION)



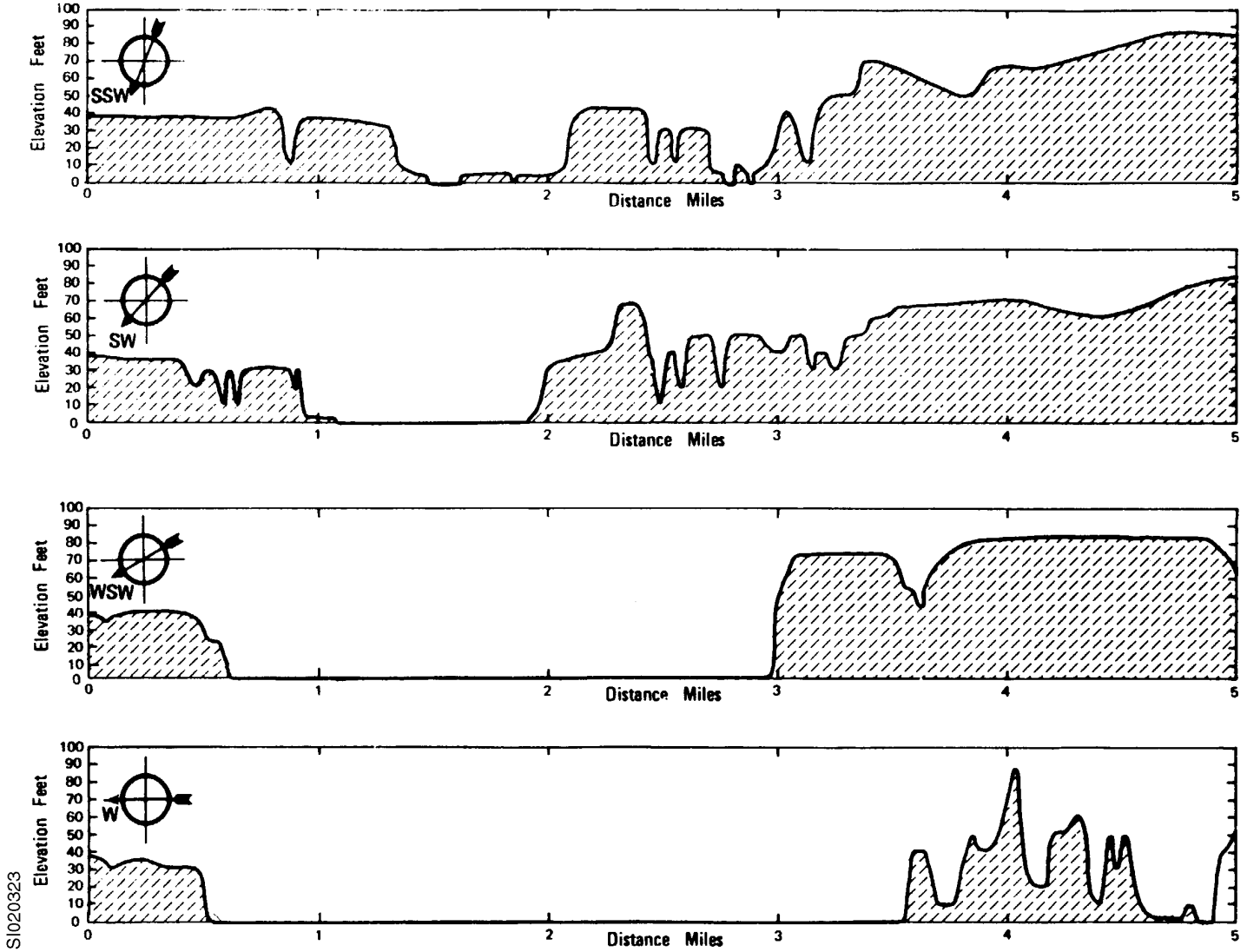
SI020321

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



SI020322

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



SI020323

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

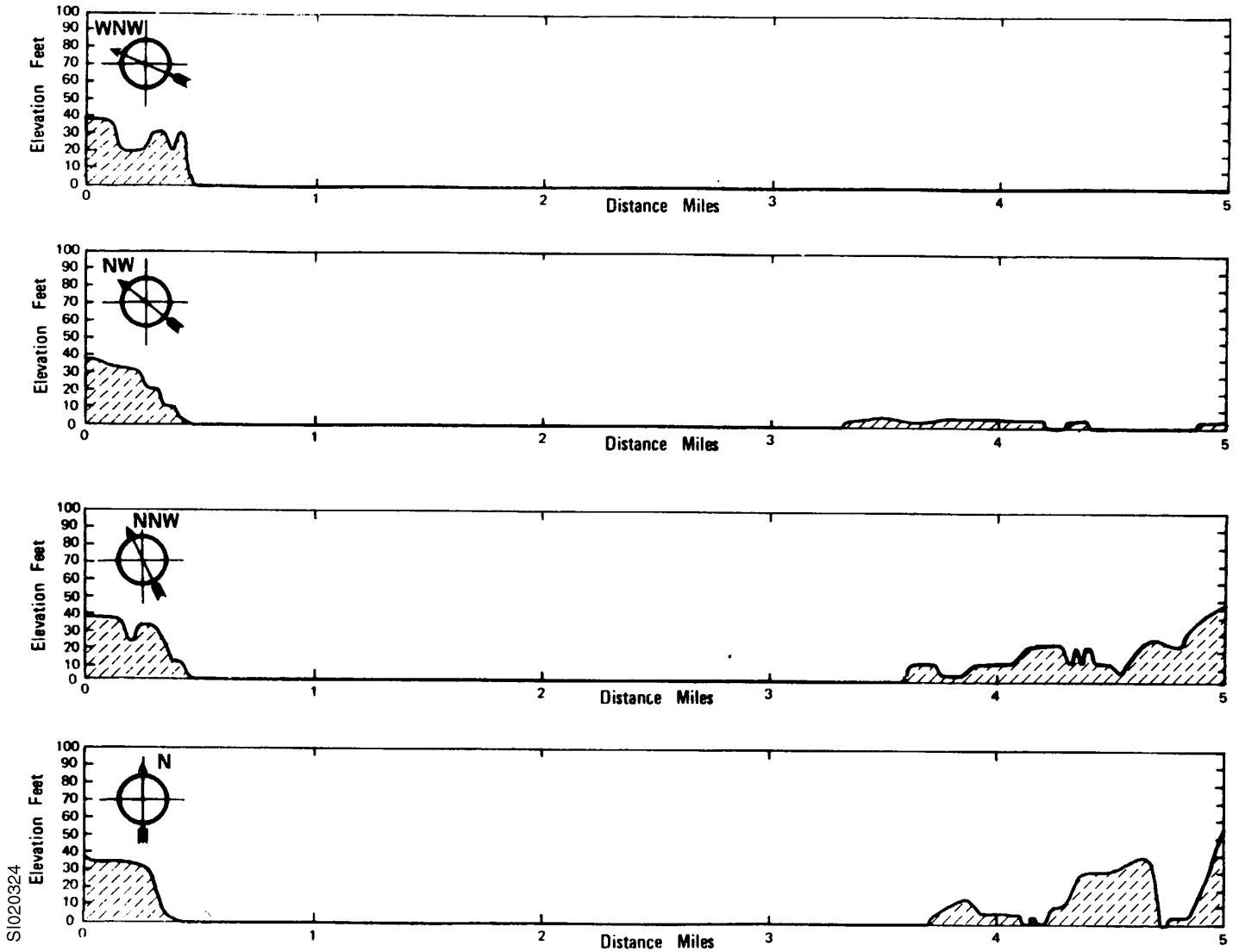


Figure 2.3-25
GENERAL TOPOGRAPHY; (5 MILES RADIUS OF THE SURRY POWER STATION)

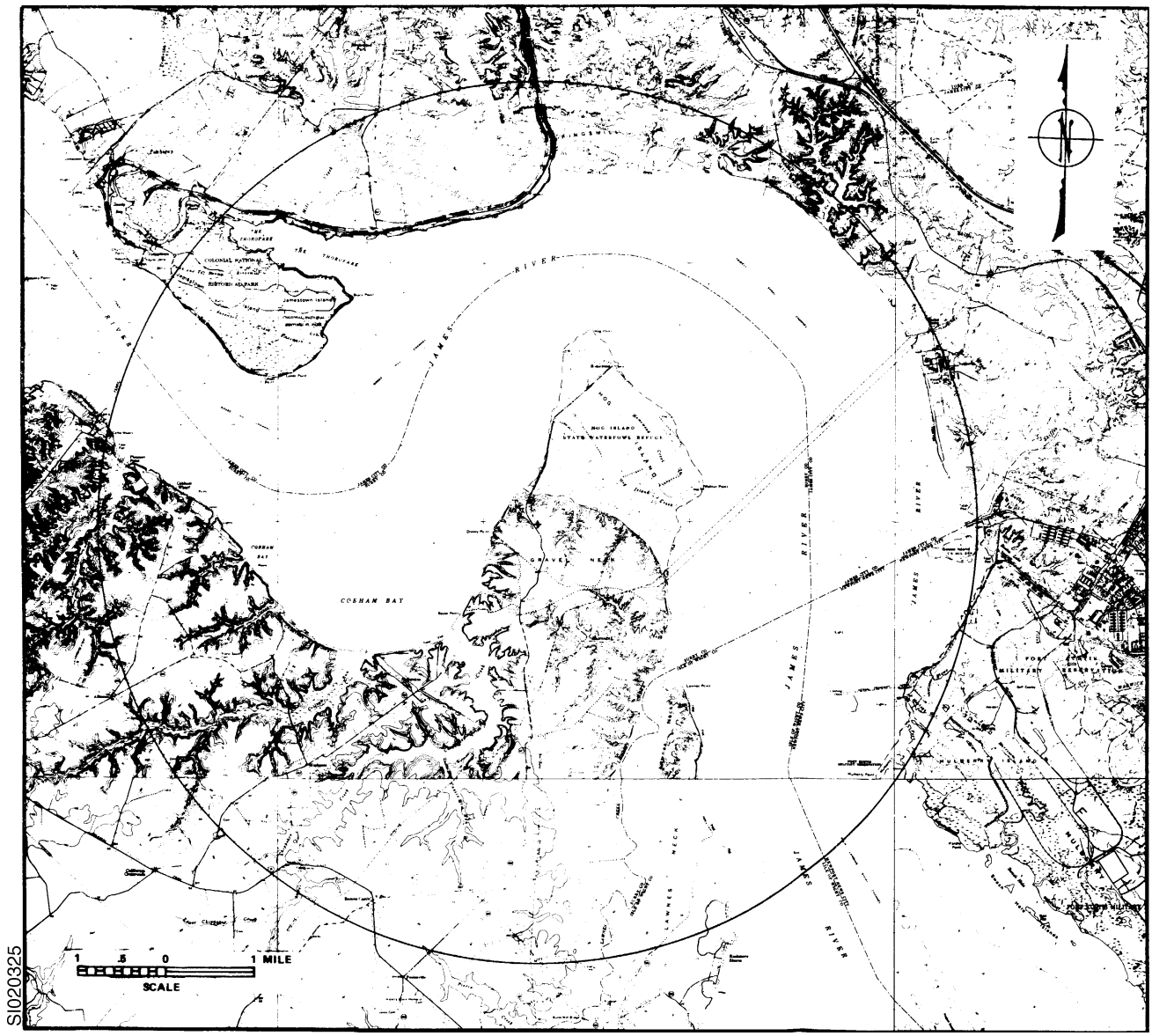


Figure 2.3-26
GENERAL TOPOGRAPHY; (50 MILES RADIUS OF THE SURRY POWER STATION)

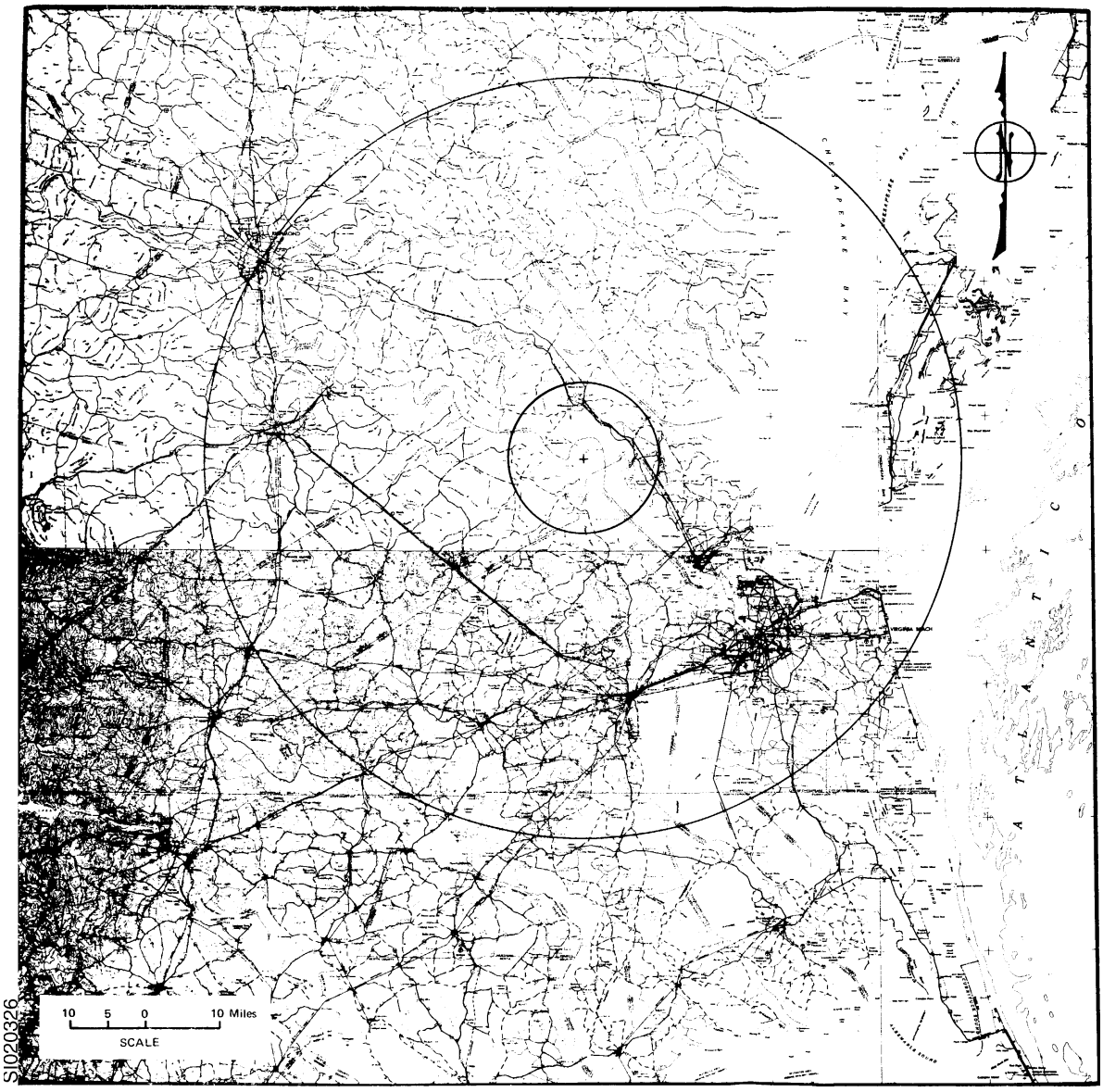


Figure 2.3-27
LOCATIONS OF METEOROLOGICAL TOWERS
SURRY POWER STATION

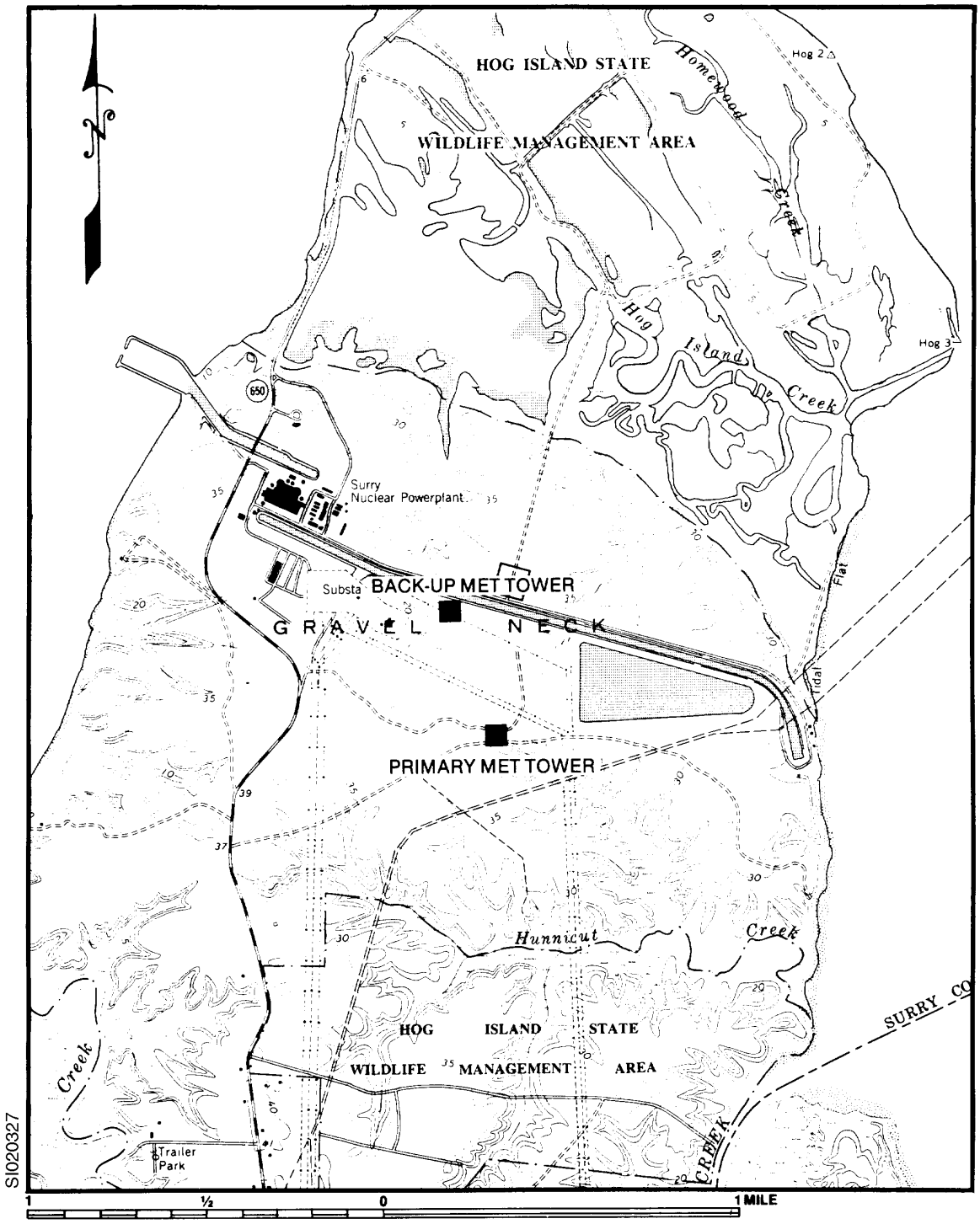
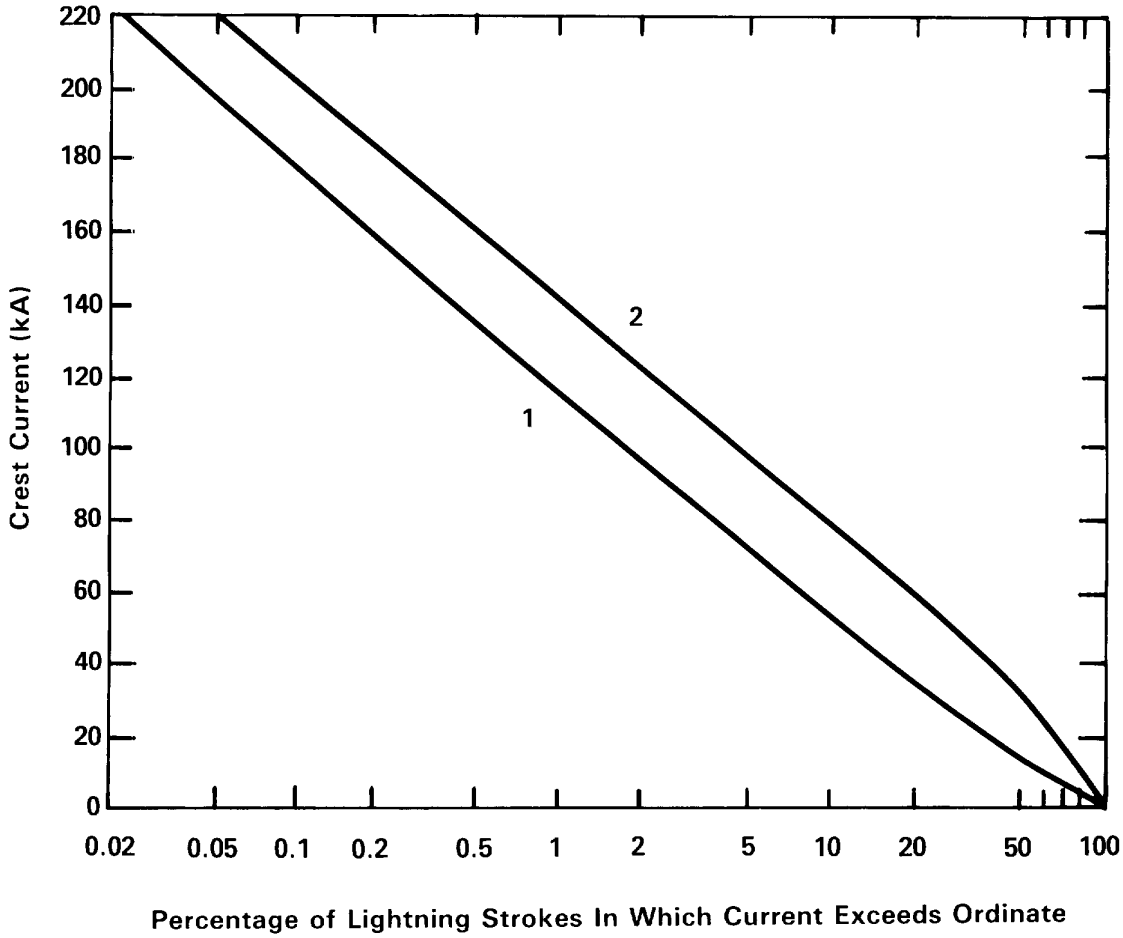


Figure 2.3-28
DISTRIBUTION OF CREST CURRENTS IN LIGHTNING STROKES (REF. 28)

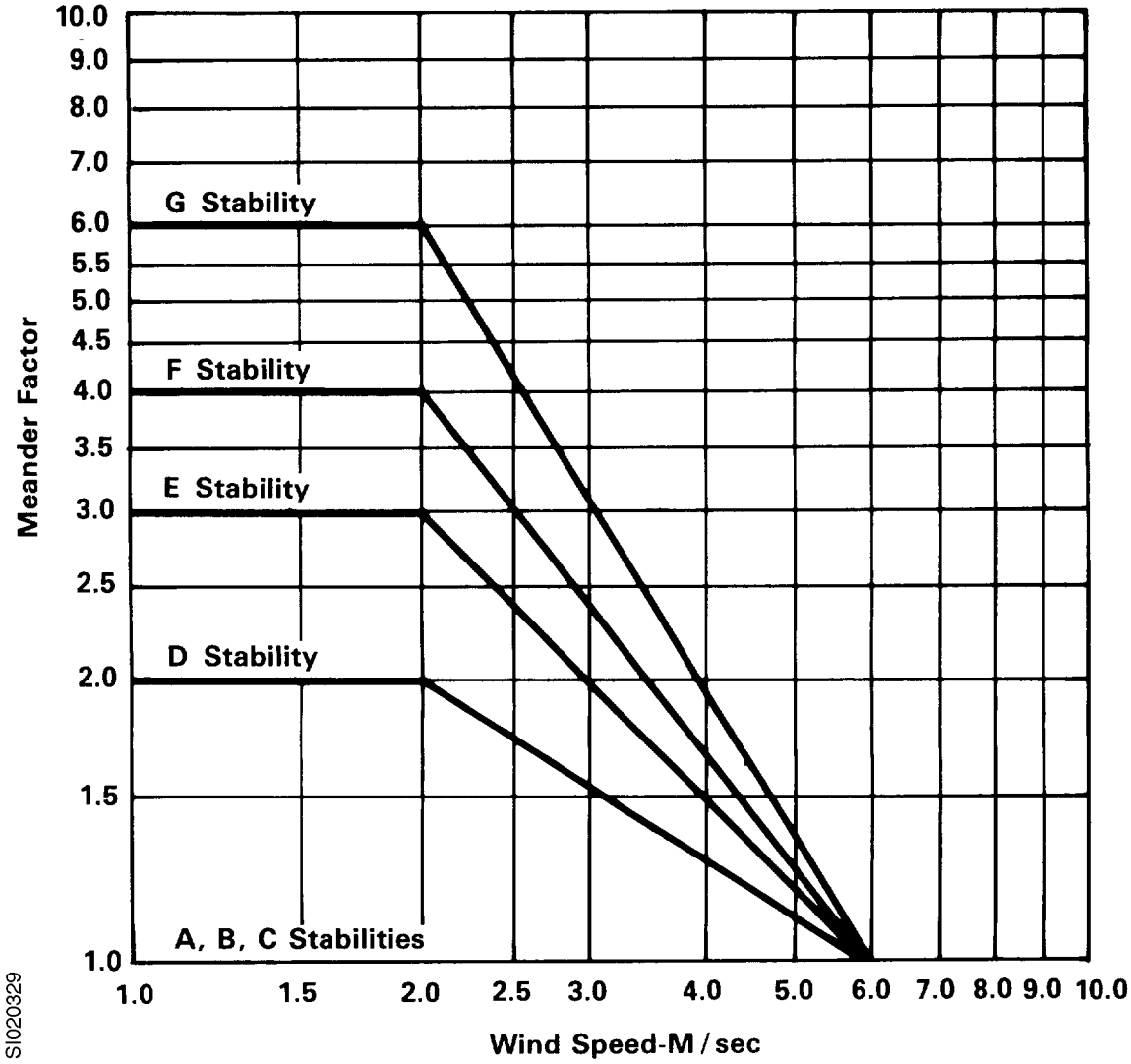


SI020328

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

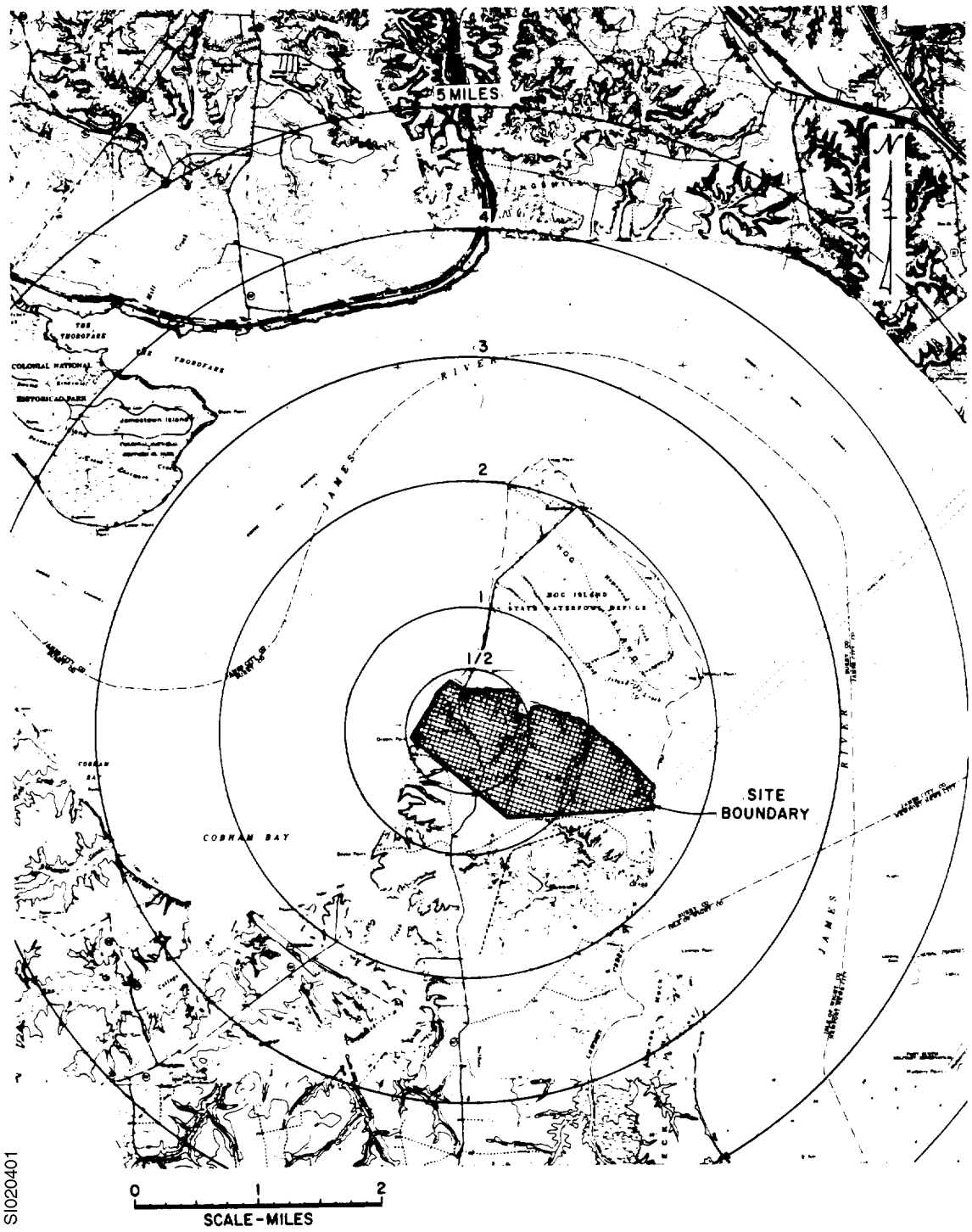
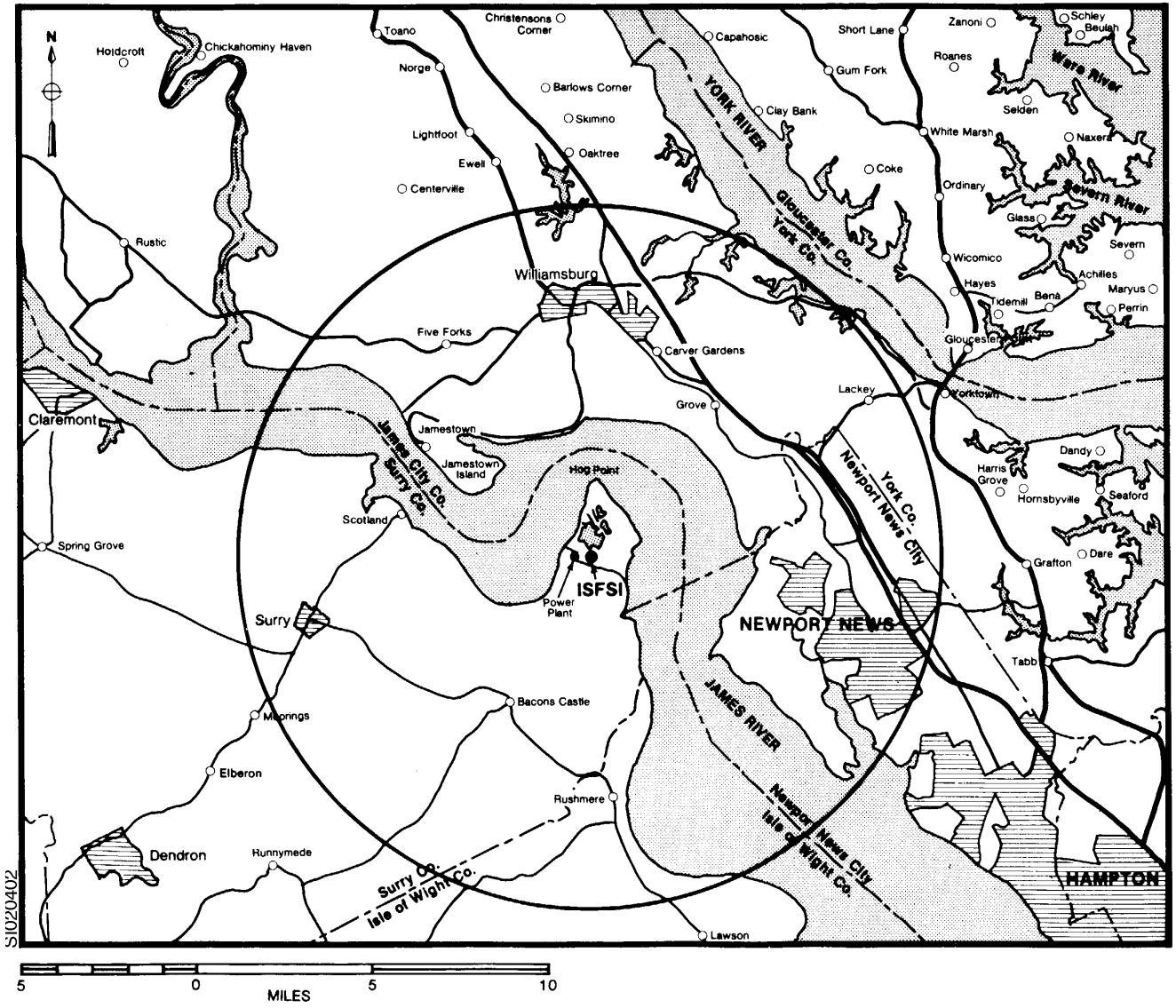


Figure 2.4-2
REGIONAL TOPOGRAPHY



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 Paleozic 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 (Reference 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.

2.6.6 References[1]

1. Virginia Electric & Power Co., 1971, Final Safety Analysis Report, Surry Power Station Units 1 and 2, Part B, Vol. 1, Sections 2.4 and 2.5.

2. Virginia Electric & Power Co., 1973, PSAR Surry Units 3 and 4, Vol. 1, Sections 2.4 and 2.5.

3. Fisher, G. W., Pettijohn, F. J., Reed, J. C. Jr., and Weaver, N. K., 1970, *Studies of Appalachian Geology Central and Southern,* Interscience, N.Y.(†)

4. Harris, D. L., 1970, Details of Thin-Skinned Tectonics in Parts of Valley and Ridge and Cumberland Plateau Provinces of the Southern Appalachians, Chapter 10, *Studies of Appalachian Geology Central and Southern.*(†)

1. References noted with an (†) indicate an original reference from Surry Power Station Units 3 and 4 PSAR.

5. Neuschel, S. K., 1970, *Correlation of Aeromagnetics and Aeroradio Activity with Lithology in the Spotsylvania Area,* Virginia, Geol Soc of Amer Bull. V. 81, pp. 3575-3582.(†)

6. Higgins, M. W., 1973, Personal Communications.(†)

7. Ownes, J. P., 1970, Post-Triassic Tectonic Movements in the Central and Southern Appalachians as Recorded by Sediments of the Atlantic Coastal Plain, Chap. 28, *Studies of Appalachian Geology Central and Southern,* 1970.(†)

8. .Meade, B. K., 1971, *Report of the Subcommission on Recent Crustal Movements in North America,* Paper presented at XV Gen Assembly of IUGG, Intn'l Assoc Geology, Moscow, USSR, Aug. 2-14, 1971, NOS, NOAA.(†)

9. Brown, P., Miller, and Swami, 1972, *Structural and Stratigraphic Framework, and Spatial Distribution of Permeability of the Atlantic Coastal Plain North Carolina to New York,* United States Geol Survey Prof Paper 796.(†)

10. Rogers, W. S., and Spencer, R. S., 1967, *The Pleistocene Geology of Princess Anne County,* Southeastern Geology, Vol. 9, pp. 101-114.(†)

11. Cederstrom, D. J., 1945, *Geology and Ground Water Resources of the Coastal Plain in Southeastern Virginia,* University of Virginia, Bulletin 63.(†)

12. Cederstrom, D. J., 1945, *Structural Geology of Southeastern Virginia,* American Association of Petroleum Geologists, Bulletin, Vol. 29, No. 1.(†)

13. Spangler, W. B., and Peterson, J. J., 1950, *Geology of the Atlantic Coastal Plain in New Jersey, Delaware, Maryland, and Virginia,* American Association of Petroleum Geologists, Bulletin, Vol. 34, No. 1.(†)

14. Ewing, M., Crary, A. B., Rutherford, M. M., and Miller, B., 1937 *Geophysical Investigations in the Emerged and Submerged Atlantic Coastal Plain, Part I,* Geological Society of America, Bulletin 48, pp. 735-801.(†)

15. Anderson, J. L., 1951, *Northeastern United States,* American Association of Petroleum Geologists, Vol. 35, pp. 421-437.(†)

16. Drake, C. L., Ewing, M., and Sutton, G. H., 1959, Continental Margins and Disciplines: The East Coast of North America North of Cape Hatteras, in *Physics and Chemistry of the Earth,* Vol. 3, L. H. Ahrems, Ed., Pergammon Press.(†)

17. Teifke, R. H., 1973, *Geological Studies, Coastal Plain of Virginia, Parts 1 and 2,* Virginia Division of Mineral Resources, Bulletin 83.(†)

18. Johnson, G., 1974, Personal Communication to M. Thonis 11 April 1974.(†)

19. Higgins, M. W. and Mixon, R., 1973, Personal Communications.(†)

20. Nelson, W. A., 1962, *Geology and Mineral Resources of Albemarle County,* Virginia Division of Mineral Resources, Bulletin 77.(†)

21. Dames & Moore, 1971, Report, *Site Environmental Studies, North Anna Nuclear Power Station, Proposed Units 3 and 4,* Louisa County, Virginia, Virginia Electric and Power Company, Aug. 18, 1971.(†)

22. Cederstrom, D. J., 1939, *Geology and Artesian Water Resources of a Part of the Southern Virginia Coastal Plain,* Virginia Geological Survey Bulletin SIE, pp. 123-136.(†)

23. Johnson, *G. H., 1972, Geology of the Yorktown, Poquoson West, and Poquosa East Quadrangles,* Virginia, Virginia Division of Mineral Resources, Report of Investigations 30.(†)

24. Cedarstrom, D. J., 1957, *Geology and Ground Water Resources of the York-James Peninsula, Virginia,* USGS Water Supply Paper 1361, 1957, 237 pp.(†)

25. Goodwin, B. K., 1970, *Geology of the Hylas and Medlothian Quadrangles, Virginia,* Report of Investigation 23, Virginia Division of Mineral Resources.(†)

26. Le Van, D. C. and R. F. Pharr, *A Magnetic Survey of the Coastal Plain in Virginia,* Virginia Division of Mineral Resources Rept. Inv. 4, 1963.(†)

27. Ewing, Maurice, George P. Woollard and A. C. Vine, Geophysical Investigations in the Emerged and Submerged Atlantic Coastal Plain, part III; Barnegat Bay, New Jersey, section *Geological Society of America,* Bulletin, Vol. 50, pp. 257-296, Feb. 1, 1939.(†)

28. Miller, Benjamin L., Geographical Investigations in the Emerged and Submerged Atlantic Coastal Plain, Part II, Geological Significance of the Geophysical Data; *Geological Society of America,* Bulletin, Vol. 48, June 1, 1937; pp 803-812.(†)

29. Taylor, Patrick T., Isidore Zietz, and Leonard S. Dennis, Geologic Implications of Aeromagnetic Data for the Eastern Continental Margin of the United States, *Geophysics,* Vol. 33, no. 5 (October 1968), pp. 755-780.(†)

30. Sabet, Mohammed, Oral Communication, August 27, 1973.(†)

31. Swick, C. H., *Gravitational Determination of Deep-Seated Crustal Structure of Continental Borders (Observations and Methods),* Transactions, American Geophysical Union, 1938, pp. 801-808.(†)

32. Woollard, George P, *A Comparison of Magnetic, Seismic, and Gravitational Profiles on Three Traverses Across the Atlantic Coastal Plain,* Transactions, American Geophysical Union, pp. 301-309, 1940.

33. Johnson, S.S., *Bouger Gravity in Northeastern Virginia and the Eastern Shore Peninsula,* Virginia Division of Mineral Resources Rept. Inv. 32, 1973.

34. Weston Geophysical Research Inc., *Seismic Analysis, Surry Nuclear Power Plant Site,* Virginia Electric Power Company, 1967.

35. Hopper, M. G., and Bollinger, G. A., *The Earthquake History of Virginia 1774 to 1900,* Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1971.

36. Bollinger, G. A., *Seismicity of the Central Appalachian States of Virginia, West Virginia, and Maryland - 1758 through 1968,* Bull of the Seism Soc of Amer, Vol. 59, No. 5., pp. 2103-2111, 1969.

37. Fuller, M. L., *The New Madrid Earthquake,* U.S. Geol Surv Bull 494, U. S. Government Printing Office, 1912.

38. MacCarthy, G. R., *Three Forgotten Earthquakes,* Bull of the Seism Soc of Amer, Vol. 53 No. 3, 1963. pp. 687-692.

39. MacCarthy, G. R., *A Note on the Virginia Earthquake of 1833,* Bull of the Seism Soc of Amer, Vol. 48, No. 2, 1948, pp. 177-180.

40. Taber, S., *The South Carolina Earthquake of July 1, 1913,* Bull of the Seism Soc of Amer, Vol. 3, 1913, pp. 6-13.

41. Dutton, C. E., *The Charleston Earthquake of August 31, 1886,* U. S. Geol. Surv., Ninth Annual Report, 1887-88, pp. 209-528.

42. MacCarthy, G. R., *A Descriptive List of Virginia Earthquakes through 1960,* Journal of the Elisha Mitchell Scientific Society, Vol. 8, No. 2, December 1964.

43. Cambell, M. R. *Earthquake Shocks in Giles County, Virginia,* Science, Vol. VII, New Series, No. 164, 1898, pp. 233-235.

44. Watson, T. L., *The Virginia Earthquake of April 9, 1918,* Bull of the Seism Soc of Amer, Vol. 8, No. 4, 1918, pp. 105-116.

45. Bollinger, G. A., *Virginia's Two Largest Earthquakes - December 22, 1875 and May 31, 1897,* Bull of the Seism Soc of Amer, Vol. 61, No. 4, 1971, pp. 1033-1039.

46. Bollinger G. A., 1973, *Seismicity of the Southeastern United States,* Bulletin of the Seismological Society of America, Vol. 63, No. 5, October 1973, pp. 1785-1808.

47. King P. B., *Systematic Pattern of Triassic Dike in the Appalachian Region,* Geological Survey Research, 1961.

48. Taylor, P. T., Zietz, I., and Dennis, L. S., *Geologic Implications of Aeromagnetic Data for the Eastern Continental Margin of the United States;* Geophysics, Vol. 33, No. 5, 1968.

49. Zietz, Isidore; Personnel Communications, 1973.

50. *Applied Technology Council, Tentative Provisions for the Development of Seismic Regulations for Buildings,* NBS spec publication 510, ATC publication ATC 3-06 and NSF publication 78-8, 1978.

51. Trifunac and Brady, *The Correlation of Seismic Intensity Scales with the Peaks of Recorded Strong Ground Motion,* Bulletin SS of A, Vol. 65, No. 1, pp 139-162, February 1975.

52. Bechtel Associates Professional Corporation (VA), *Subsurface Investigation and Foundation Report, Dry Cask Independent Spent Fuel Storage Installation,* August 1982.

53. Gibbs, H. J. and Holtz, W. G., *Research on Determining the Density of Sand by Spoon Penetration Testing,* Proc 4th Intl Conf on Soil Mechanics and Foundation Engineering, London, Vol. II, 1957.

54. Seed, H. B., Idriss, I. M., *Simplified Procedure for Evaluating Soil Liquefaction Potential,* Journal of the Soil Mechanics and Foundation Division ASCE, Vol. 97, No. SM9, September 1971.

55. Seed, H. B., Idriss, I. M., Arango, I., *Evaluation of Liquefaction Potential Using Field Performance Data,* Journal of Geotechnical Engineering ASCE, Vol. 109, No. 3, March 1983.

56. Bowles, J. E., *Foundation Analysis and Design,* 3rd Edition, McGraw- Hill Book Company, New York, New York, 1982.

57. Bollinger, G. A., *Reinterpretation of the Intensity Data for the 1886 Charleston, South Carolina, Earthquake,* Studies Related to Charleston, South Carolina, Earthquake of 1886 - A Preliminary Report, U.S.G.S. Professional Paper 1028, 1977.

58. *Uniform Building Code,* International Conference of Building Officials, Whittier, California, 1982.

59. Algermissen, S. T. and D. M. Perkins, *A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States,* U.S.G.S. Open-file Report 76-416, 1976.

60. Donovan, N. C., B. A. Bolt, and R. V. Whitman, *Development of Expectancy Maps and Risk Analysis,* Journal of the Structural Division, ASCE 104, ST8, Proc. Paper 13972, August 1978, pp. 1179-1192.

61. American National Standards Institute, Inc., *Minimum Design Loads for Buildings and Other Structures,* ANSI A58.1-1982, 1982.

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

	EIevation[a]	Basic Time Lag (min)		Permeability (x 10^{-1} ft/day)		
Boring No.	msl	Horizontal	Mean	Vertical	Horizontal	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			Clarke County, Va.	39.2	78.	-	156.5
			V	Boyse Section				
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:			37.8	77.4	3500	61.0
		39 2	V	Richmond, Va.				

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. 2	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		Atterberg Limits			Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
					Wet	Dry	LL	PL	PI				
B-l	0'-1.5' / -	Jar	Clayey silt, trace fine sand, with organic matter - tan (ML)	-	-	-	42	33	9	21.0	-	-	-
B-l	7.5'-9' / -	Jar	Silty clay, trace fine sand - brown (CL)	-	-	-	44	23	21	30.0	-	-	-
B-l	19'-20.5' / -	Jar	Fine to coarse sand, trace silt, with gravel - tan (SP-SM)	-	-	-	-	-	-	-	6	-	See Gradation Test Curve
B-l	29'-30.5' / -	Jar	Fine to coarse sand, trace silt, & fine gravel - tan (SP-SM)	-	-	-	-	-	-	-	5	-	See Gradation Test Curve
B-l	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-l	49'-50.5' / -	Jar	Fine sand, some silt, with shell fragments - gray (SM)	-	-	-	Nonplastic Fines			30.5	29	-	See Gradation Test Curve
B-l	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 Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
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
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

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-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		See Gradation Test Curve
B-4	14'-15.5' -	Jar	Fine sand, some silt - brown (SM)	-	-	-	-	-	-	-	34	-	See Gradation Test Curve
B-4	29'-30.5' -	Jar	Fine to coarse sand, trace silt, & fine gravel - tan (SP-SM)	-	-	-	-	-	-	-	5	-	See Gradation Test Curve
B-4	44'-45.5 -	Jar	Fine sand, some silt, with shell fragments - dark greenish gray (SM)	-	-	-	Nonplastic Fines			29.3	17	-	See Gradation 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	-	See Gradation Test Curve
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	-	See Gradation 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	14'-15.5' -	Jar	Fine sand, some silt - brown (SM)	-	-	-	-	-	-	-	15	-	See Gradation Test Curve
B-5	29'-30.5' -	Jar	Fine to coarse sand, some fine gravel, trace silt-brown (SW-SM)	-	-	-	-	-	-	-	5	-	See Gradation Test Curve
B-5	44'- 45.5' -	Jar	Fine sand, some silt, with shell fragments - gray (SM)	-	-	-	Nonplastic Fines			29.2	13	-	See Gradation 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
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

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-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
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	-	-	-

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	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	-	-	-
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	-	-	-

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	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	-	-	See Triaxial - 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	-	-	See Triaxial Test Curve
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	-	-	-

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 Wet	Natural Density pcf Dry	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Natural Moisture (%)	% Passing No. 200 Sieve	Specific Gravity	Remarks
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	$\tau^{(5)}/\sigma'_v$	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 l/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

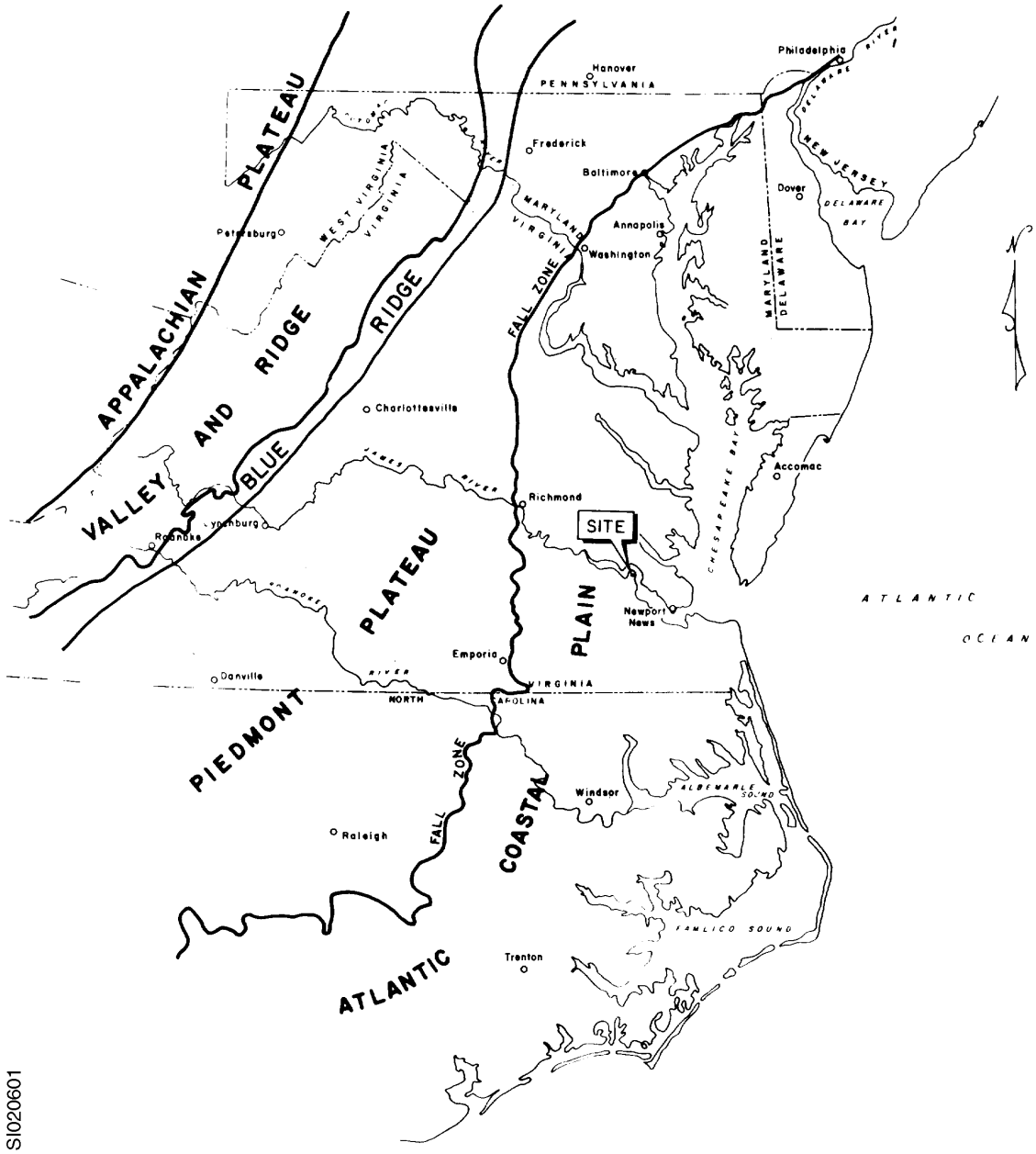


Figure 2.6-2
SITE TOPOGRAPHY

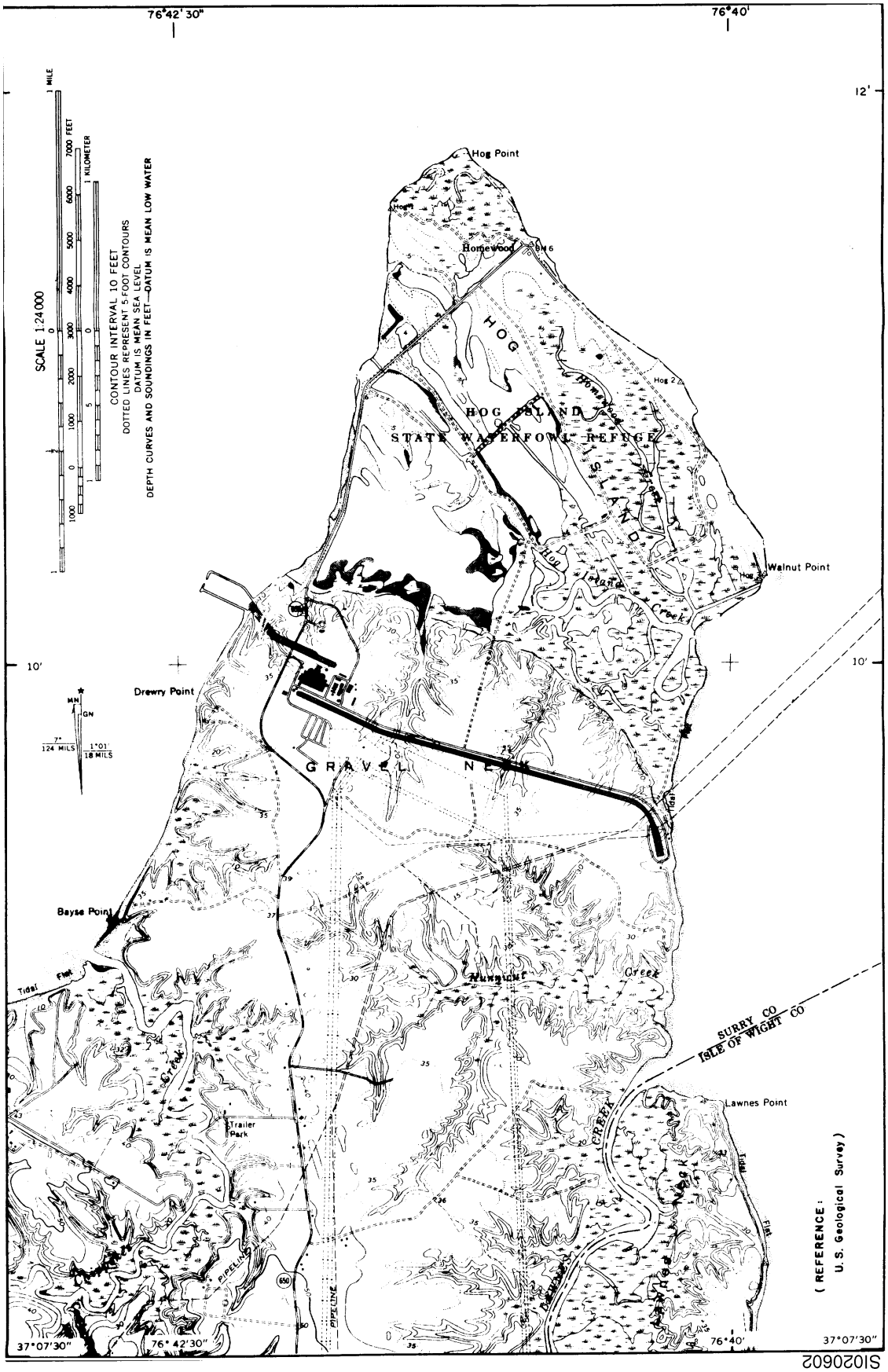


Figure 2.6-3
REGIONAL GEOLOGY

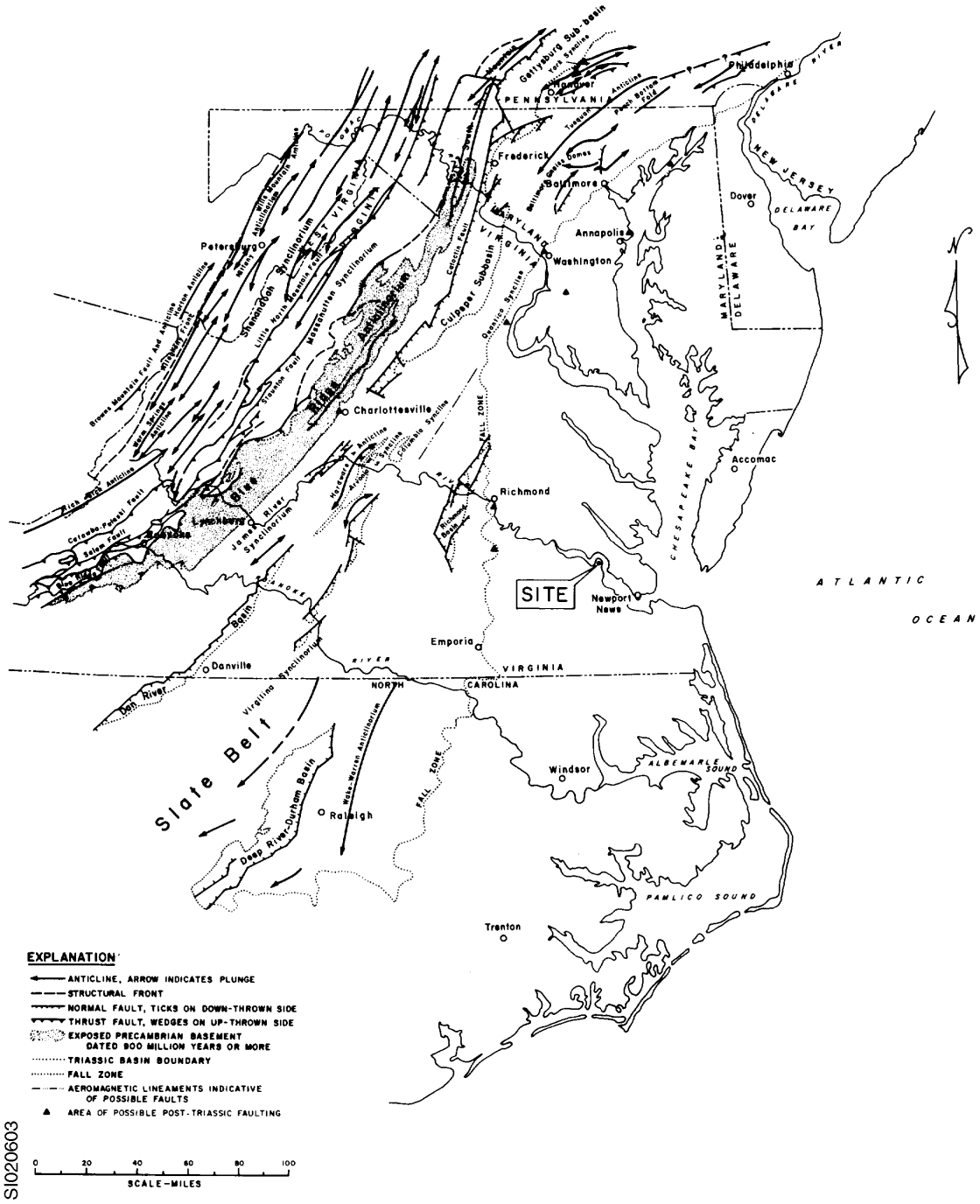


Figure 2.6-4
REGIONAL SUBSURFACE PROFILE

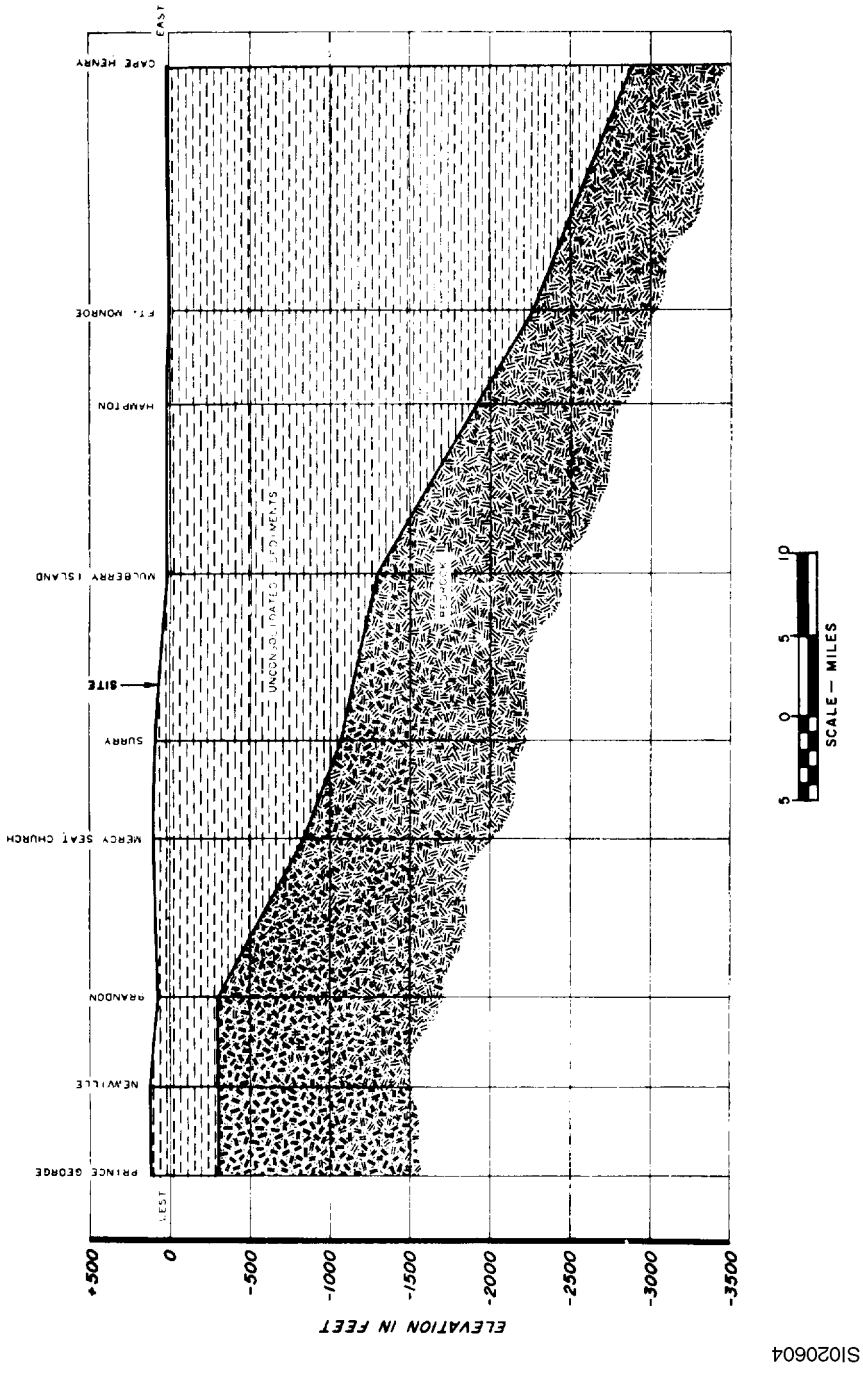


Figure 2.6-5
SITE STRATIGRAPHIC COLUMN

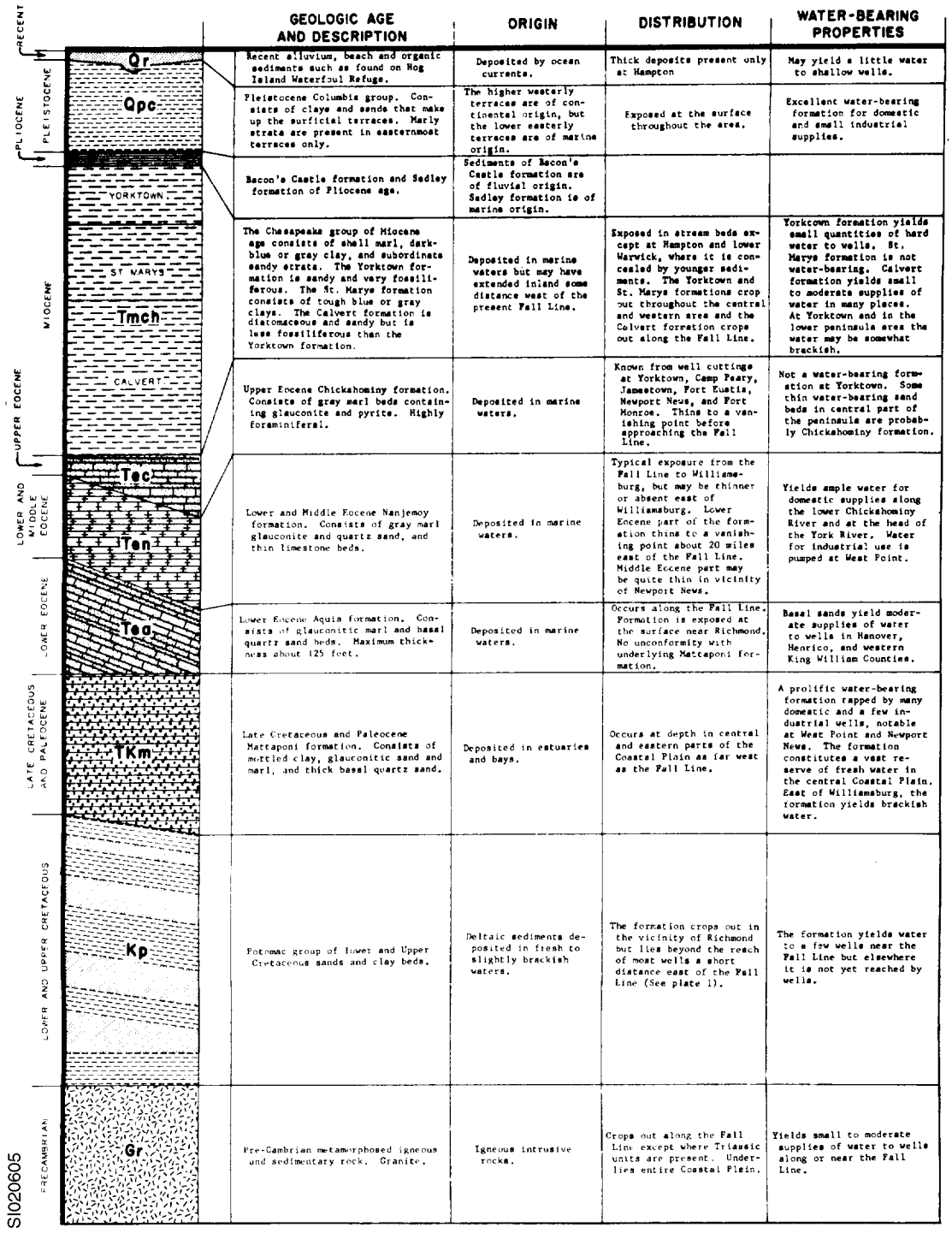
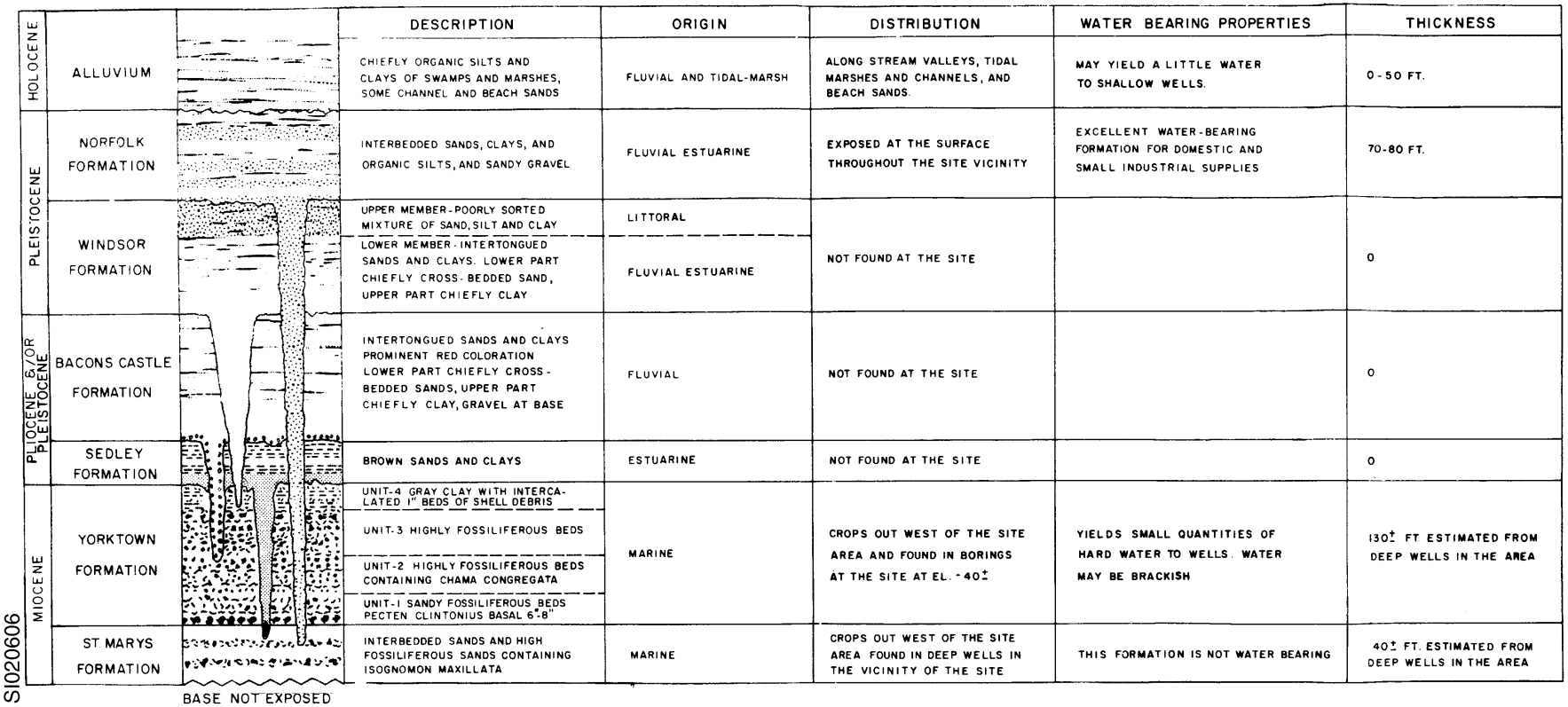


Figure 2.6-6
SITE STRATIGRAPHIC COLUMN OF QUATERNARY AND UPPER MIOCENE FORMATIONS



		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
	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"				
	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

Figure 2.6-7
GEOLOGIC MAP OF SITE AREA

Figure 2.6-8
REGIONAL TECTONICS

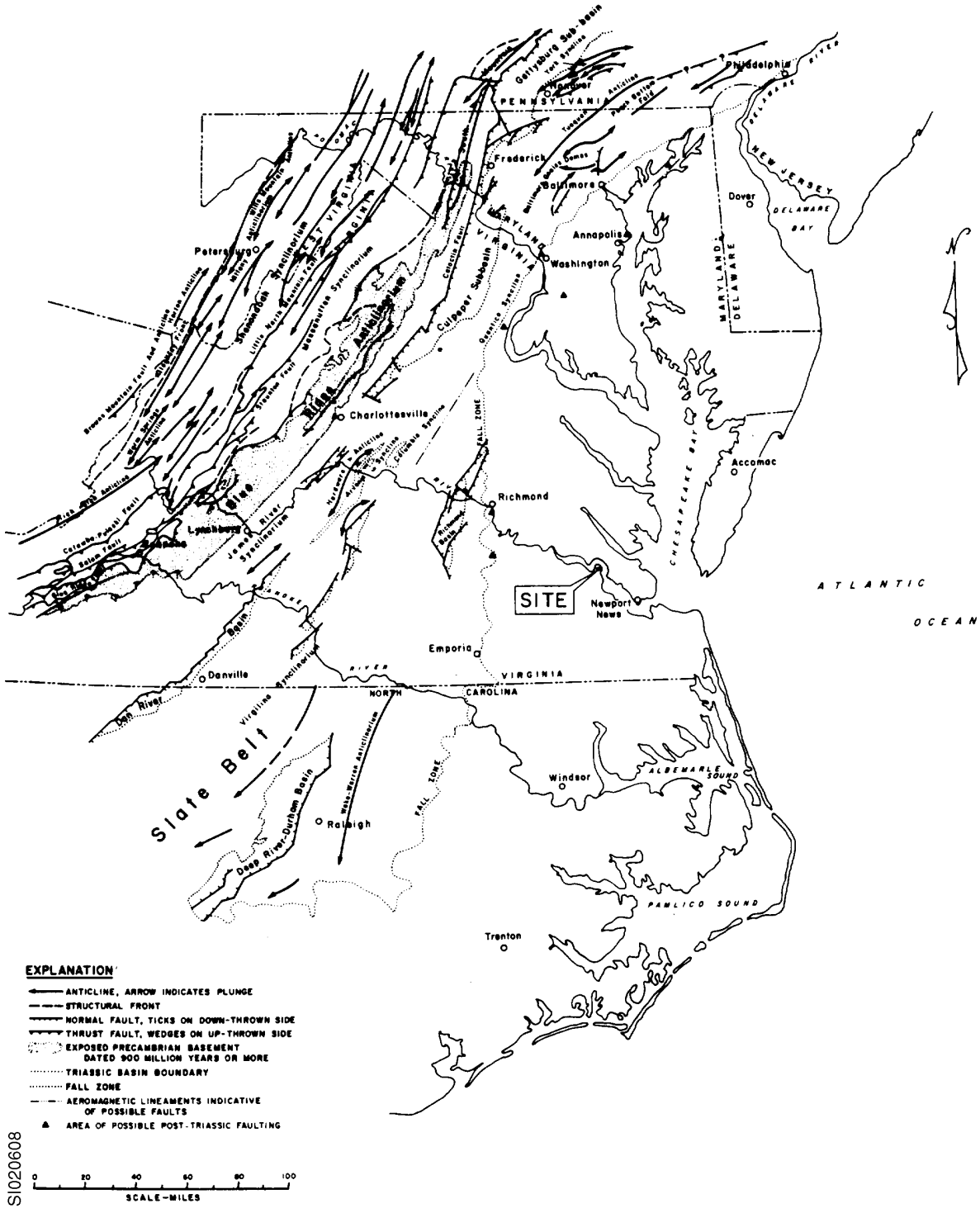


Figure 2.6-9
STRUCTURAL CONTOURS BASEMENT ROCKS

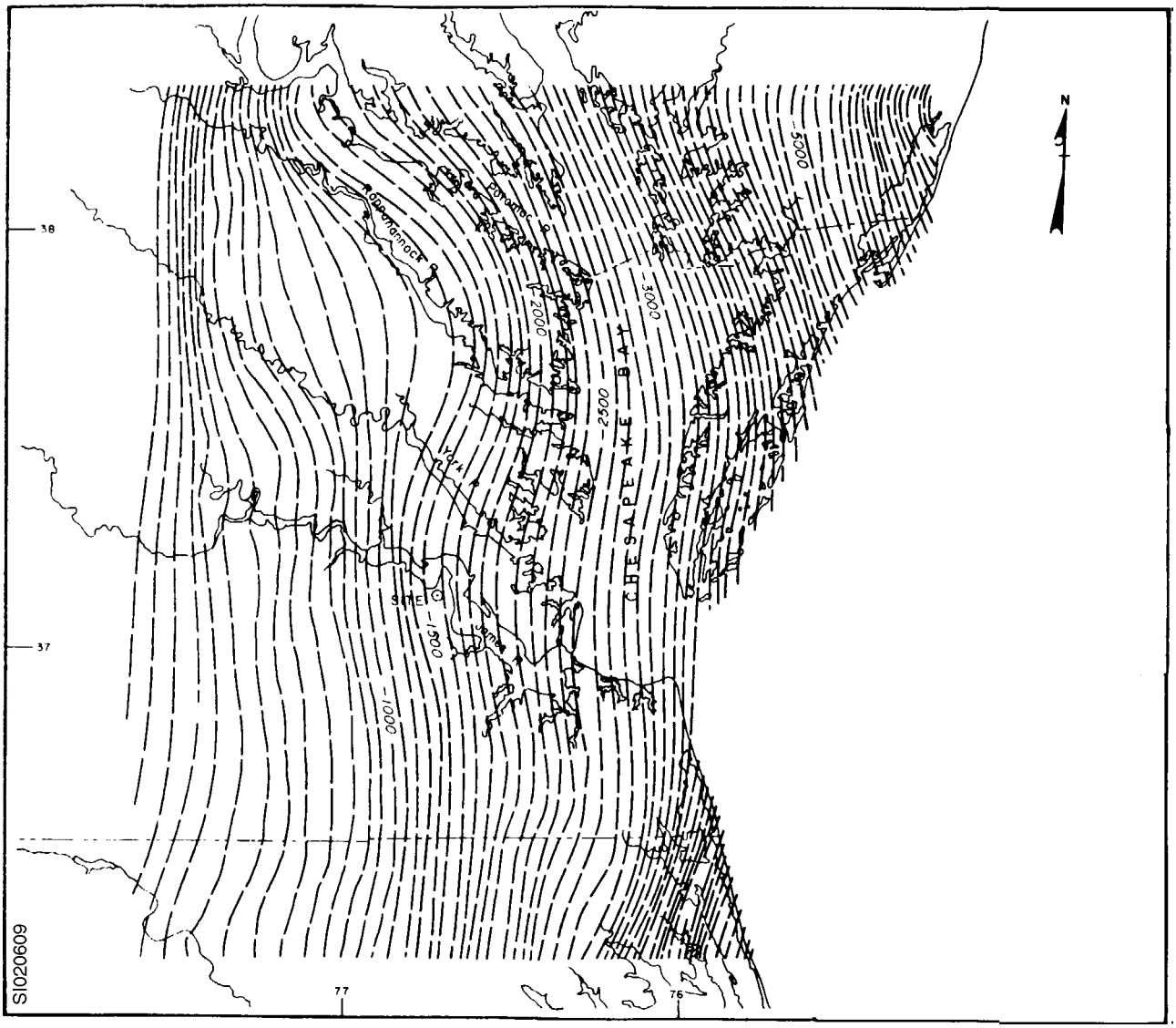


Figure 2.6-10
ISOPACH - CRETACEOUS AND LATE JURASSIC (UNIT H)

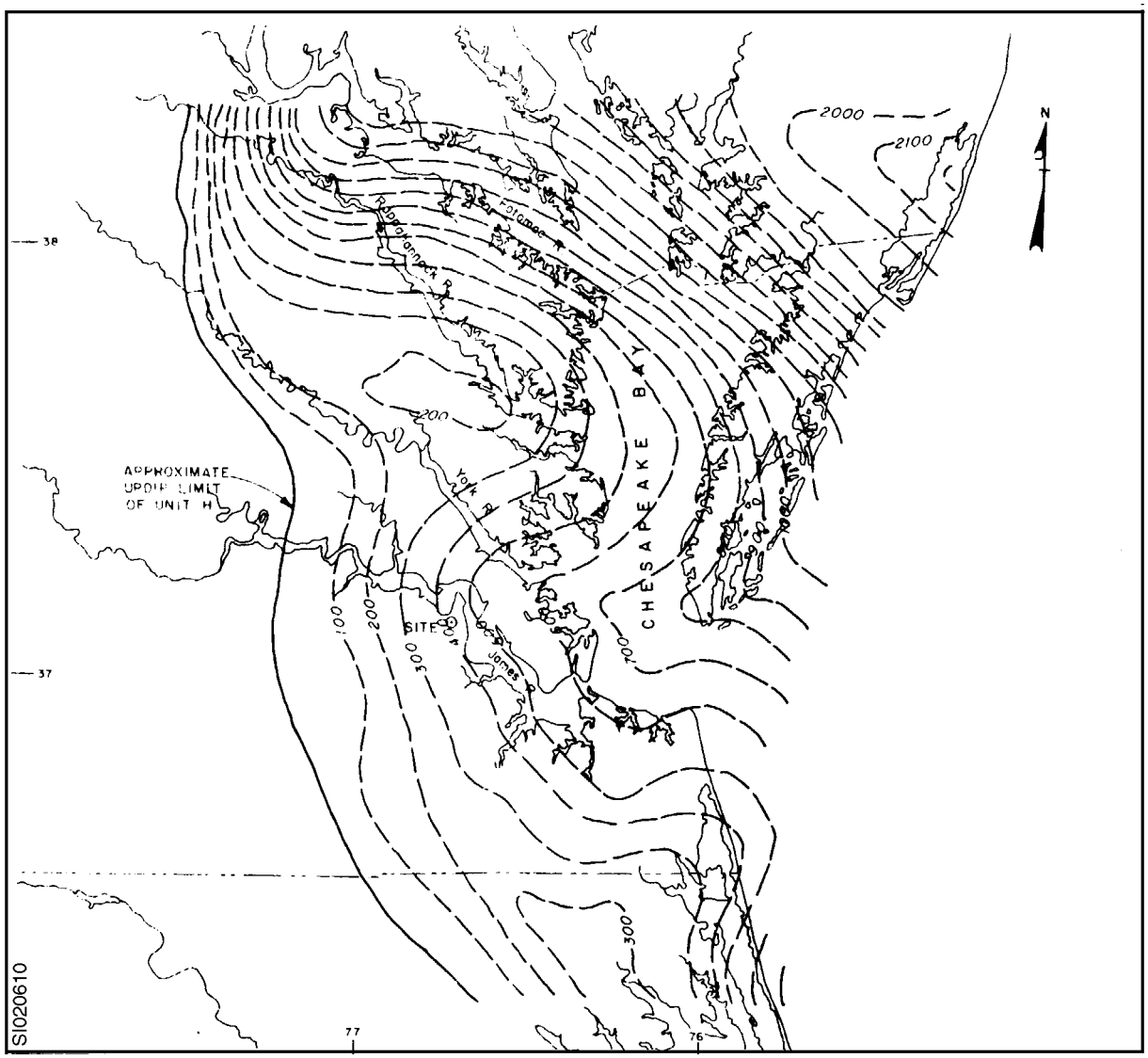


Figure 2.6-11
ISOPACHS - CRETACEOUS (UNIT G)

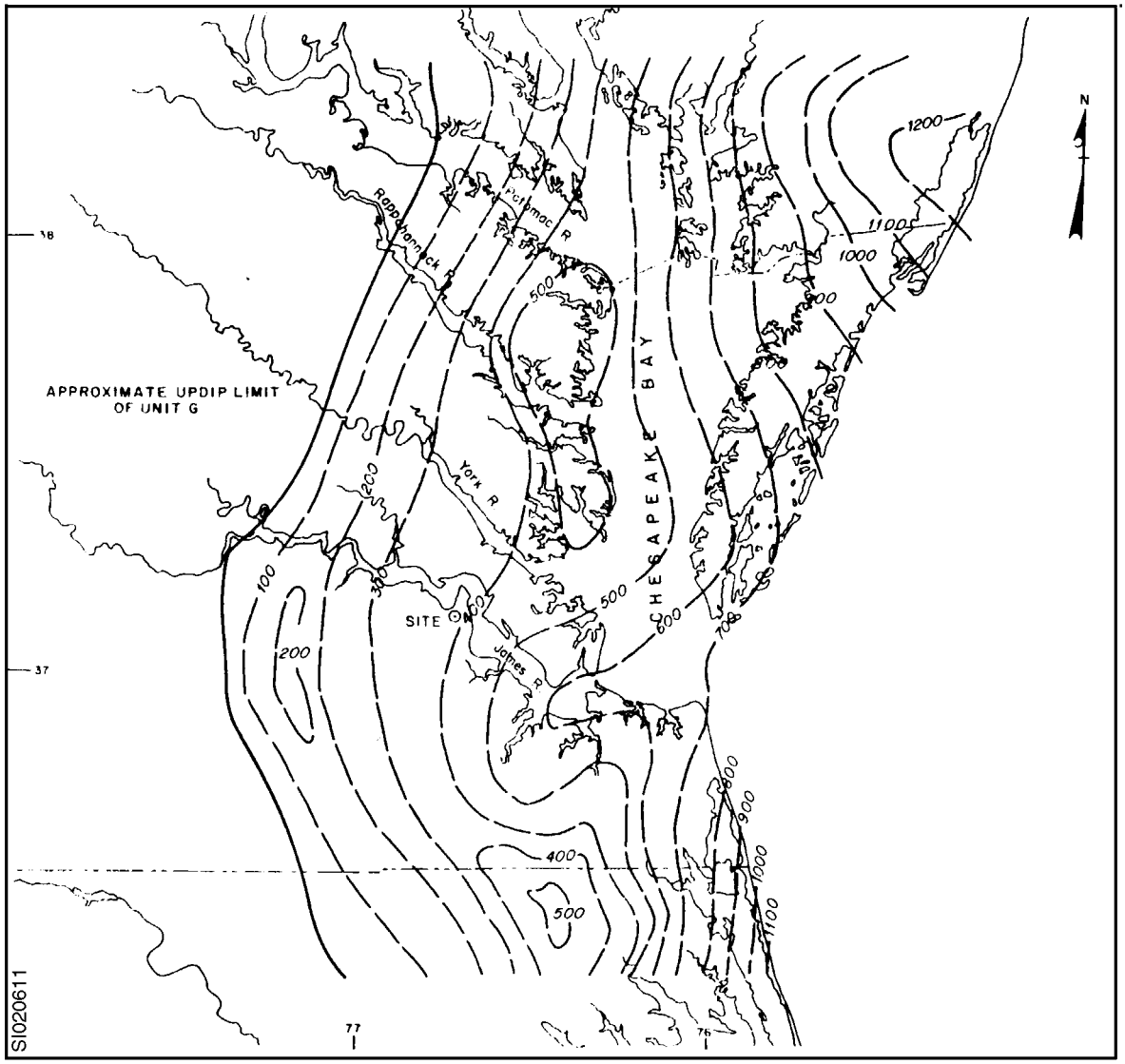


Figure 2.6-12
ISOPACHS - CRETACEOUS (UNIT F)

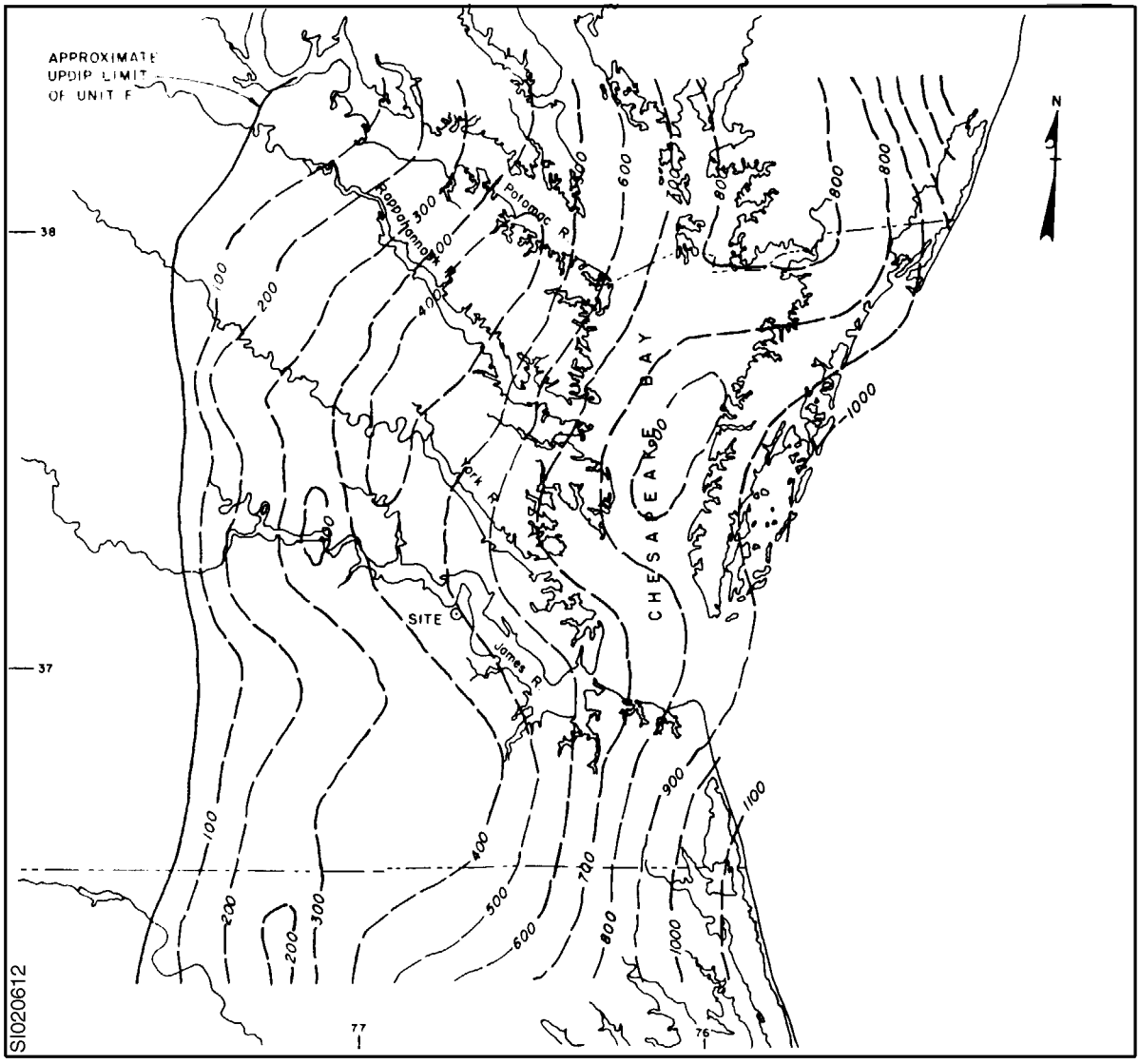


Figure 2.6-13
ISOPACHS - CRETACEOUS (UNIT C)

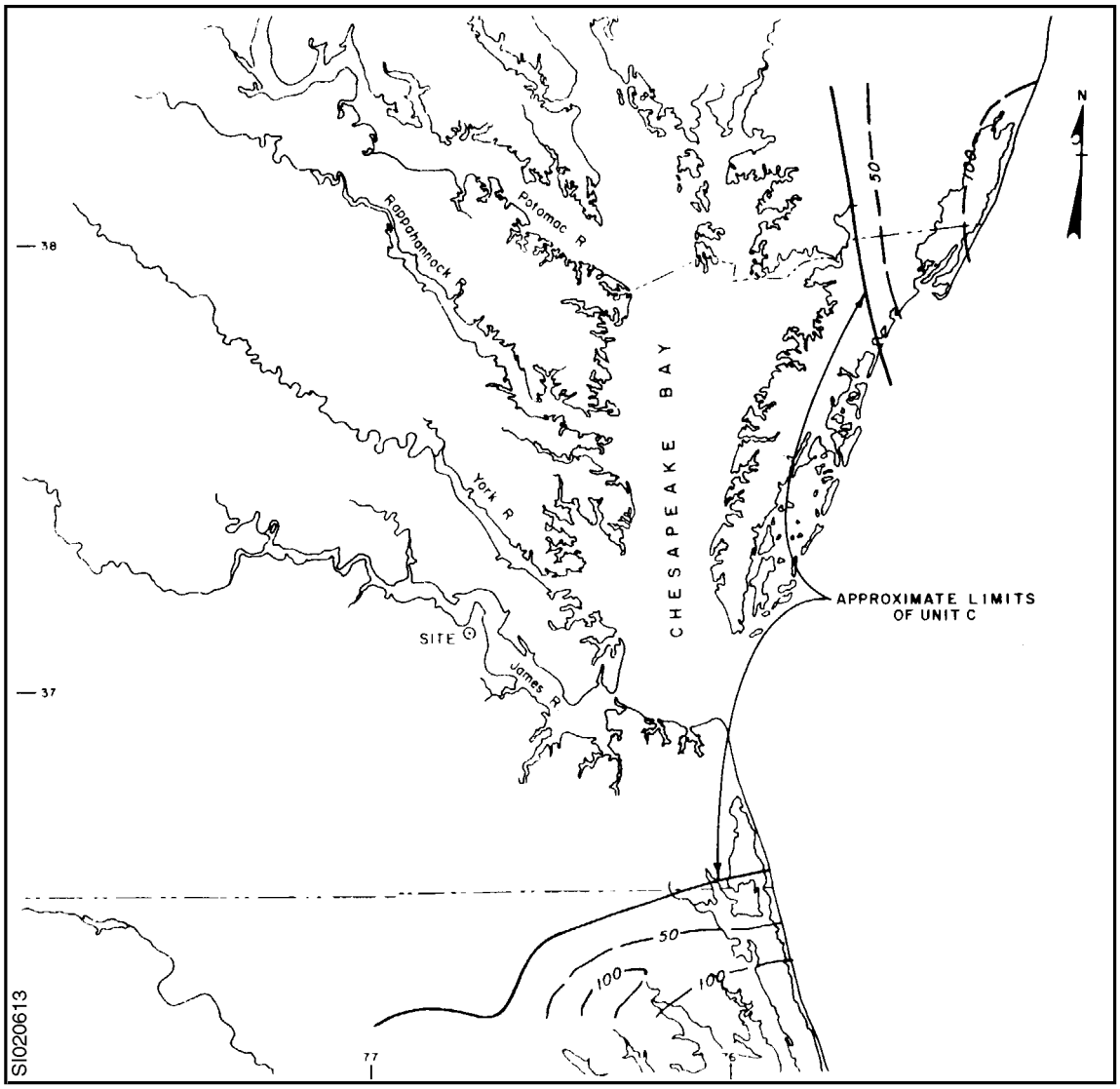


Figure 2.6-14
ISOPACHS - CRETACEOUS (UNIT B)

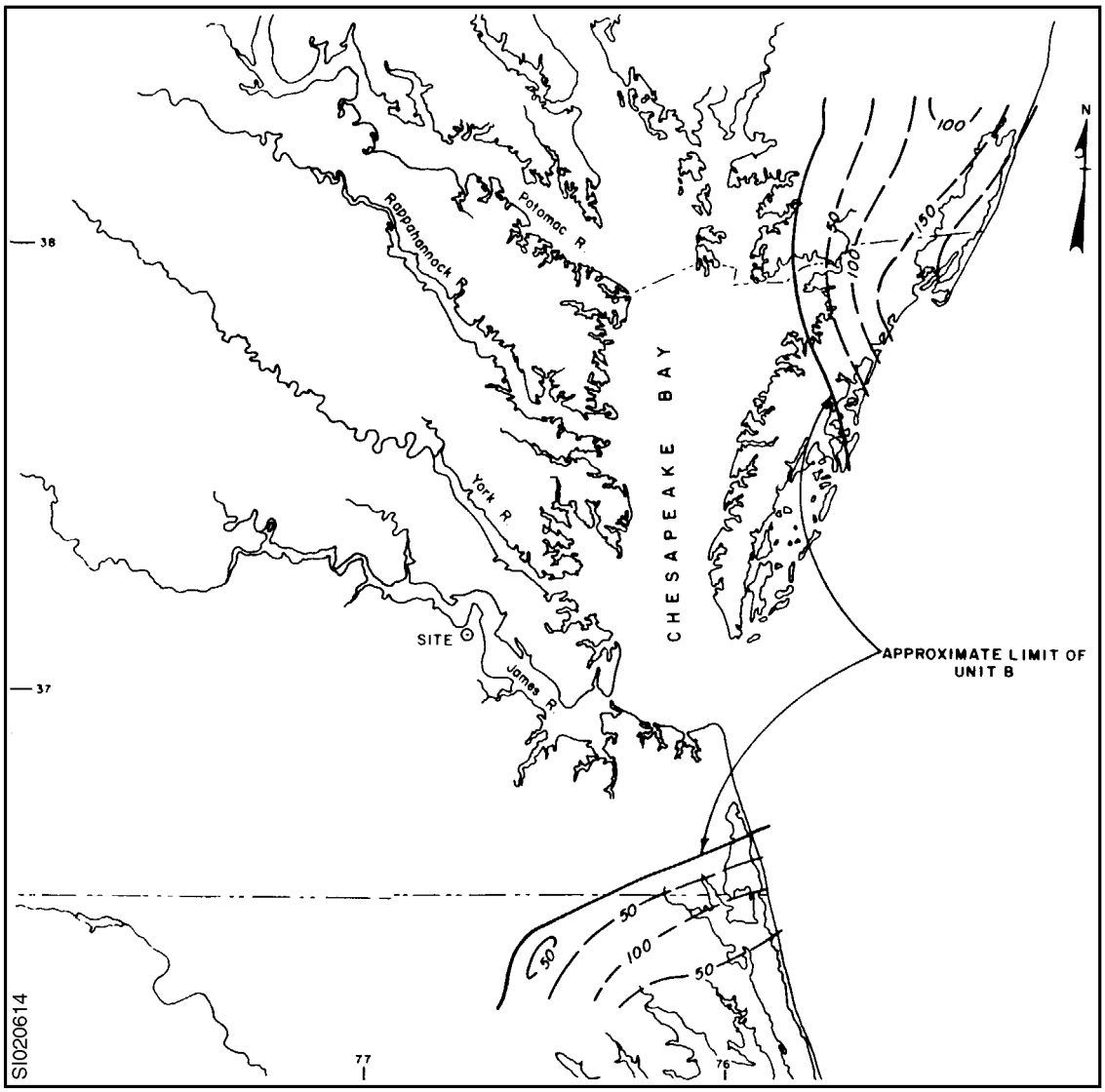


Figure 2.6-15
ISOPACHS - MIDWAY AGE ROCK

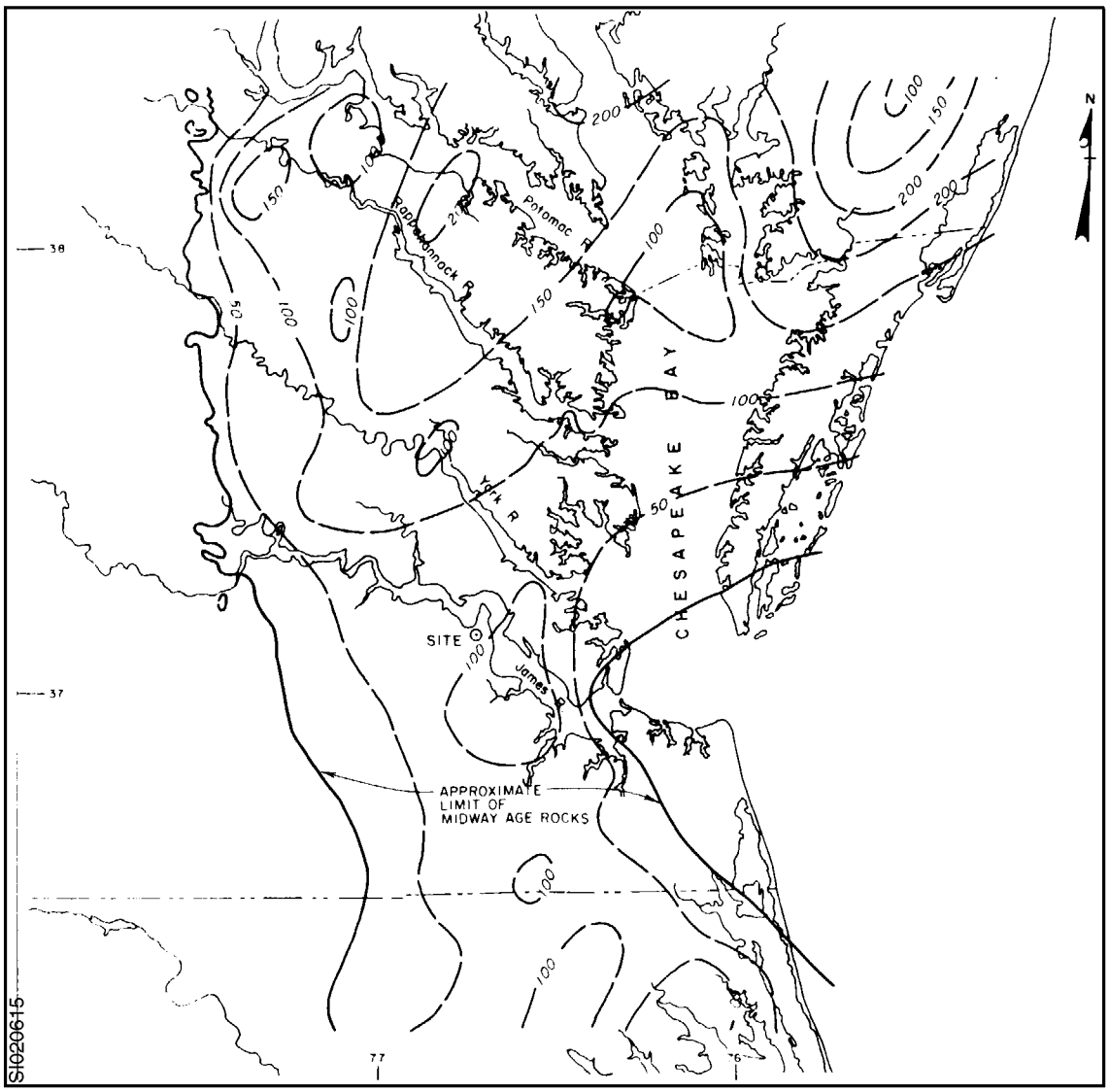


Figure 2.6-16
ISOPACHS - CLAIBORNE AGE ROCKS

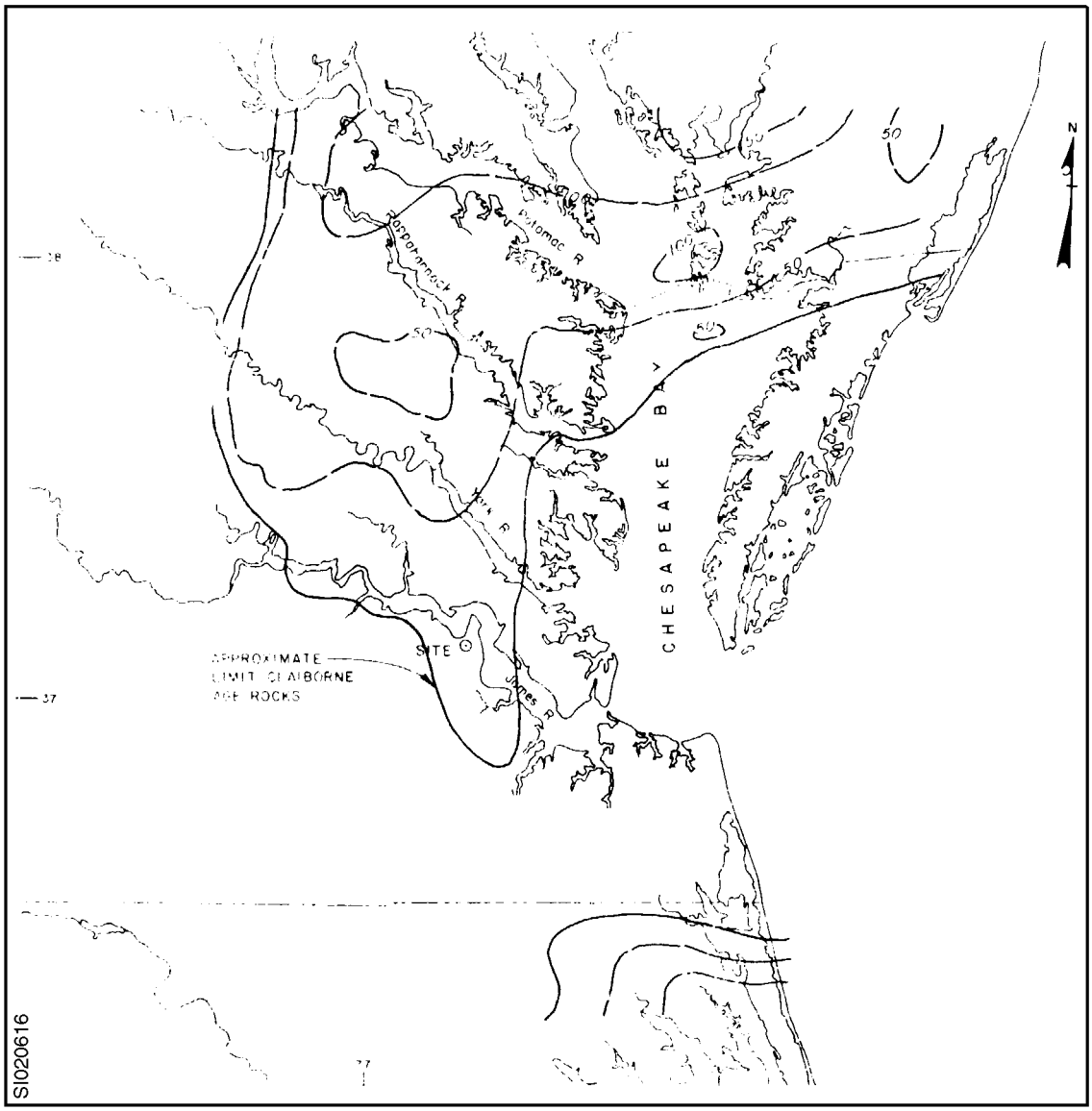


Figure 2.6-17
ISOPACHS - JACKSON AGE ROCKS

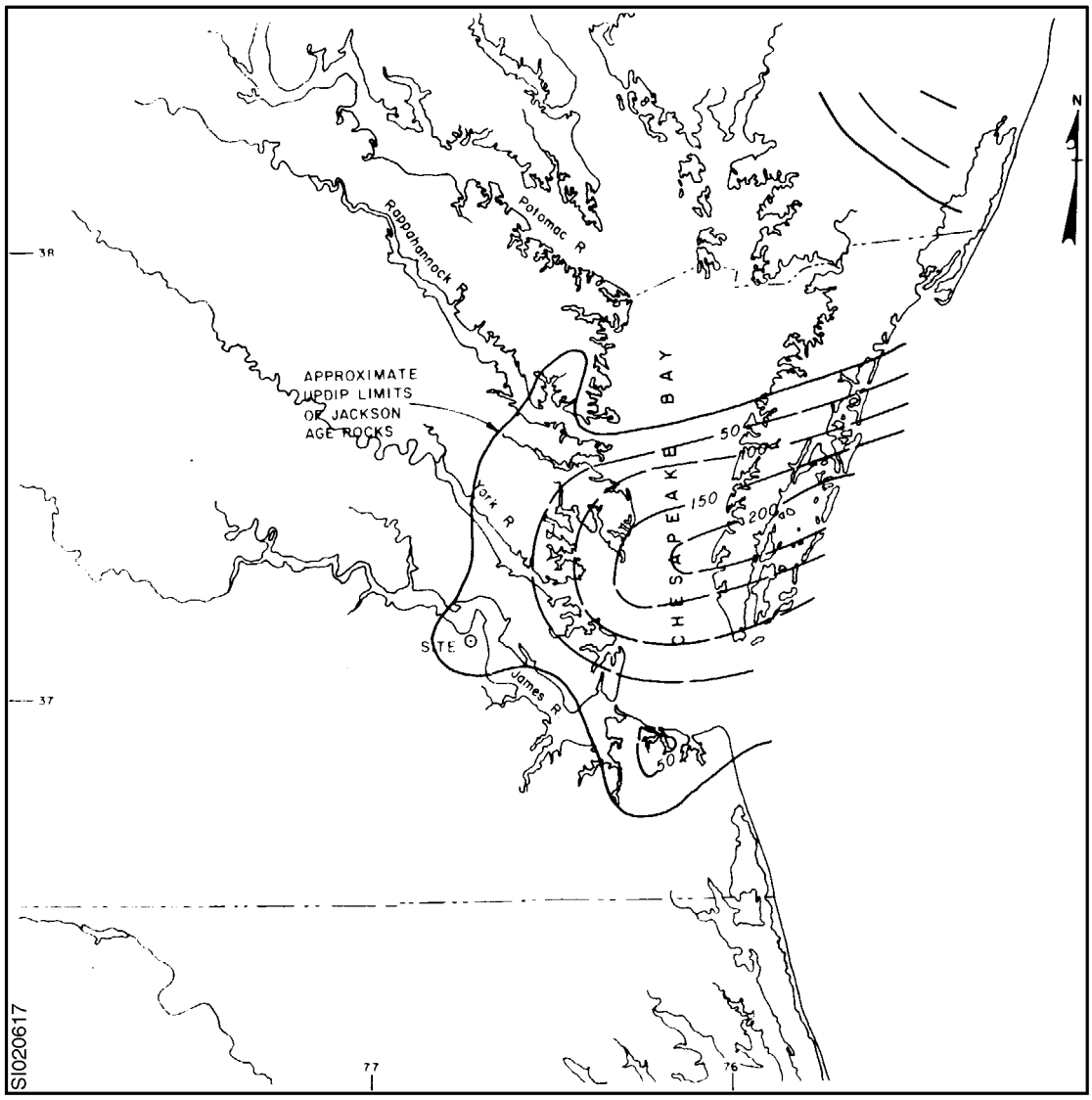


Figure 2.6-18
ISOPACHS - MIDDLE MIOCENE

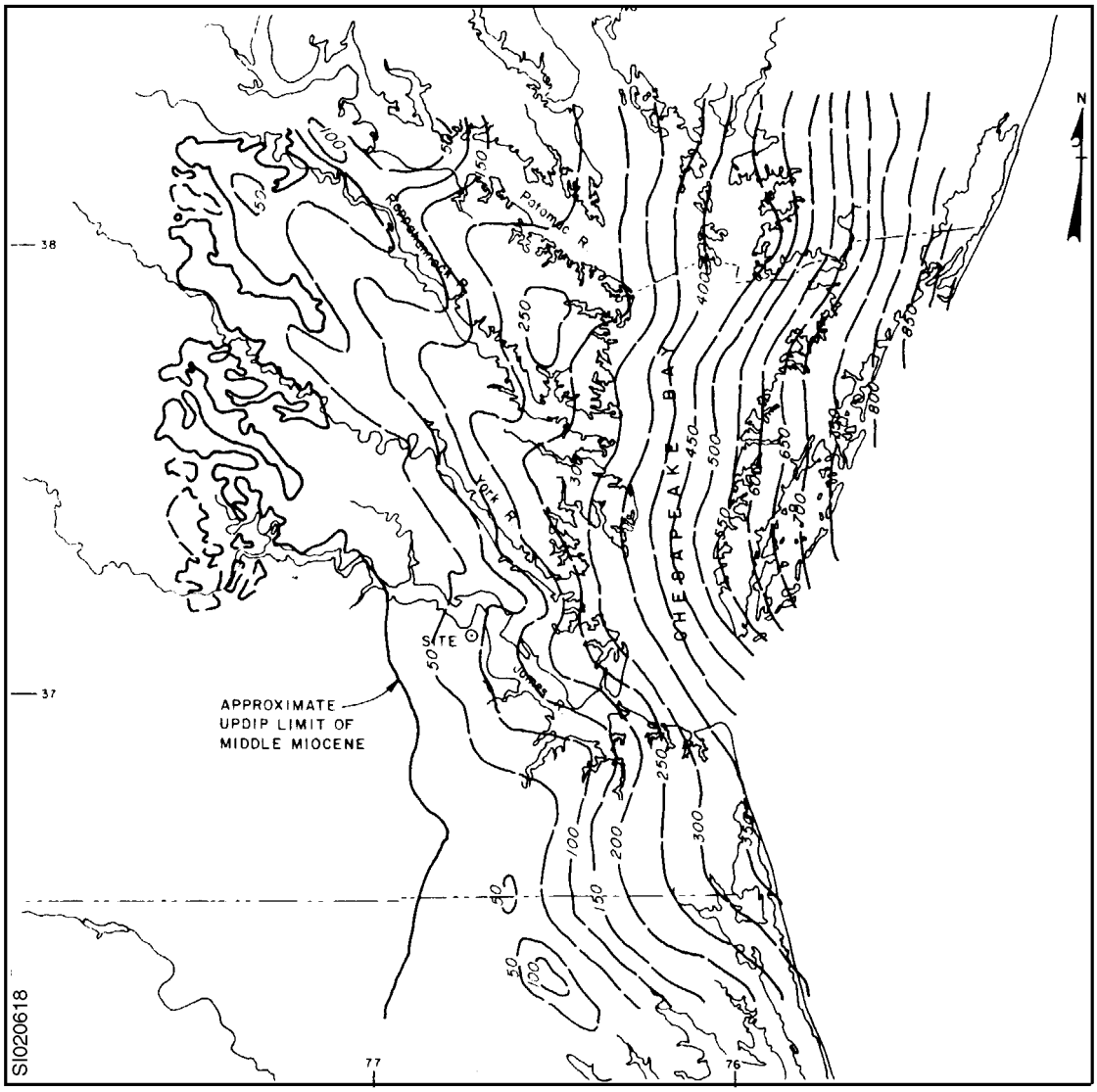


Figure 2.6-19
ISOPACHS LATE MIOCENE

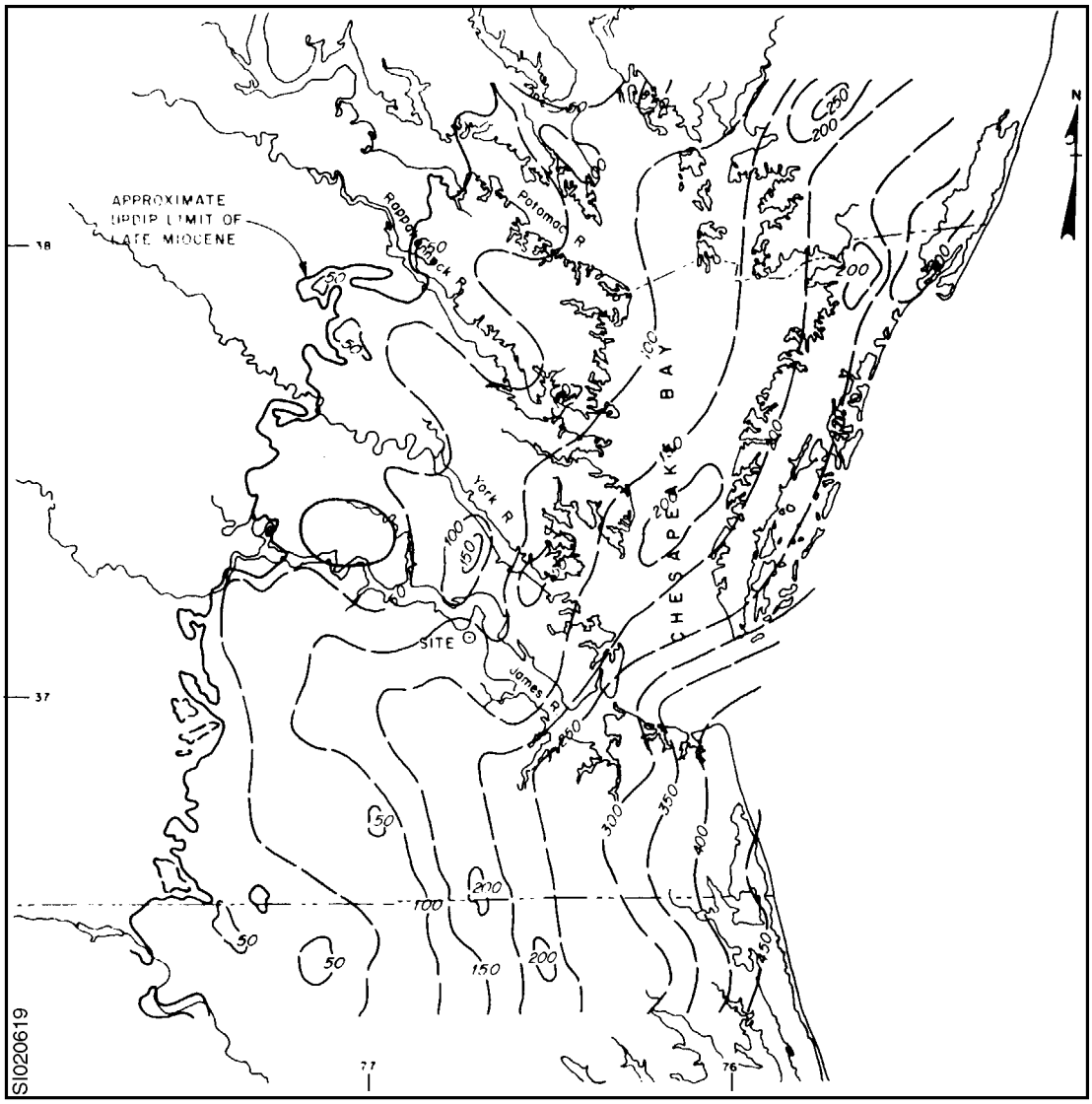


Figure 2.6-20
ISOPACHS - POST MIOCENE

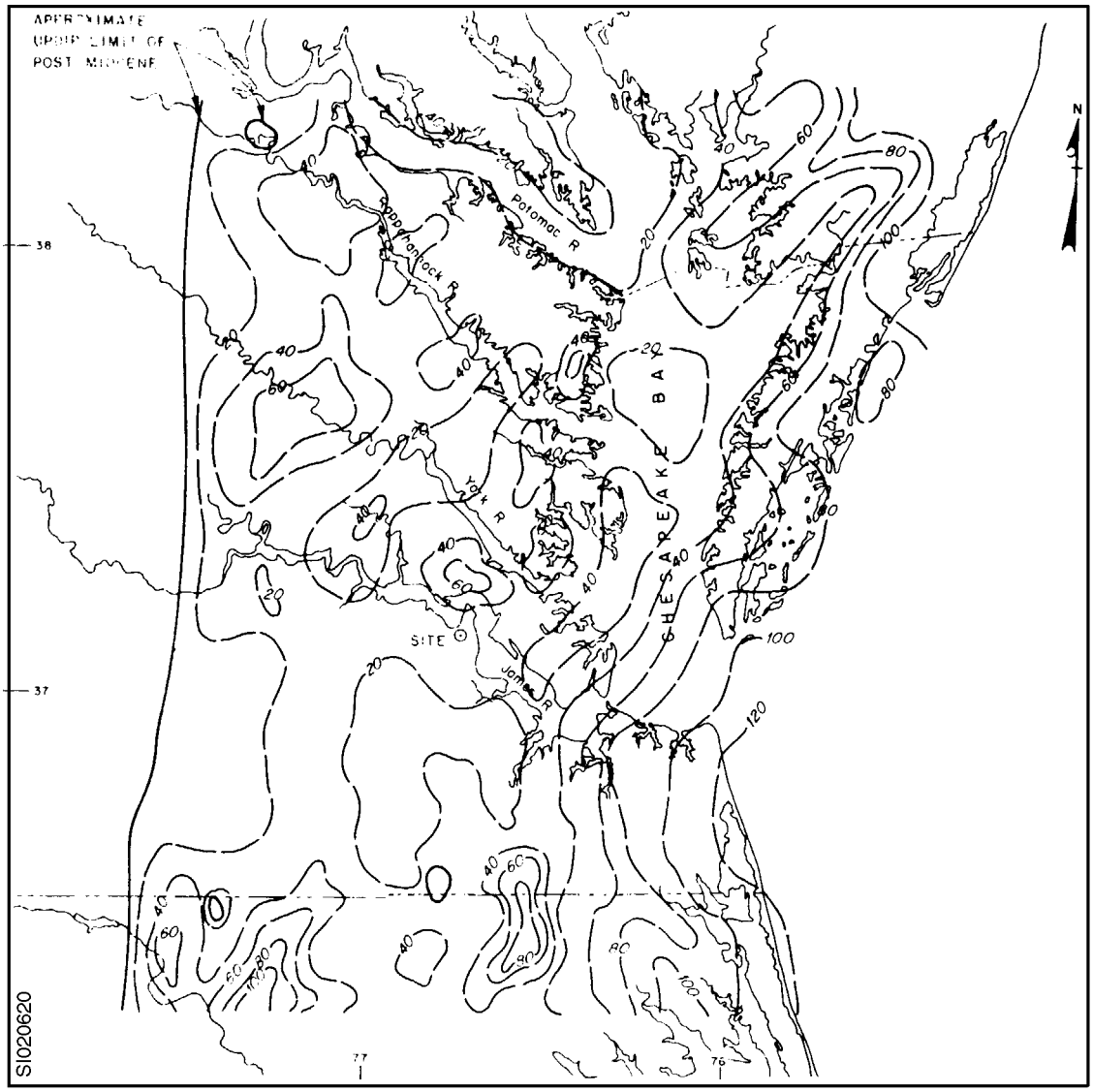
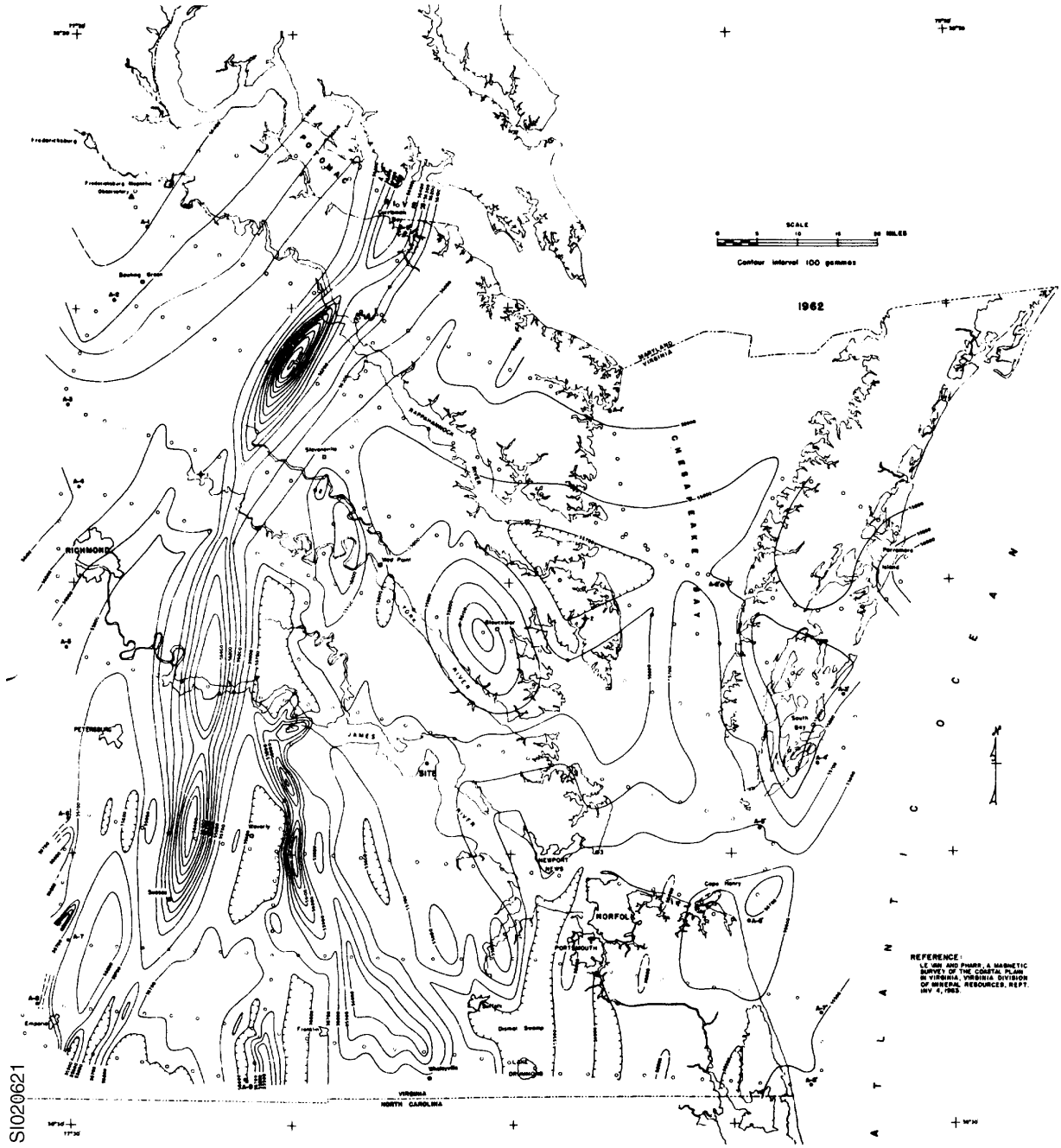
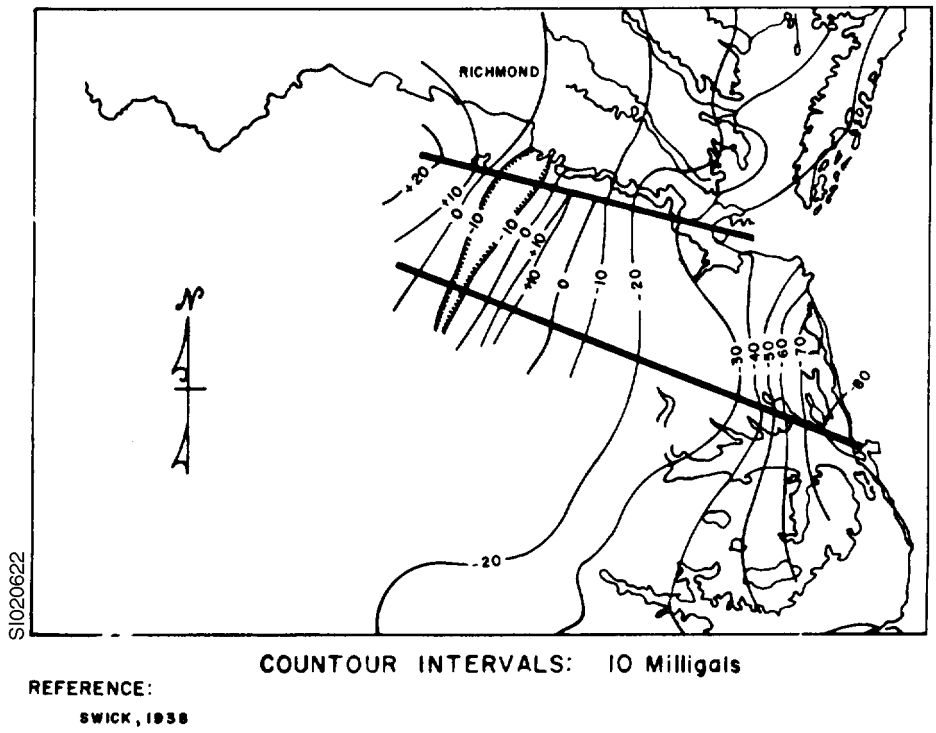


Figure 2.6-21
TOTAL INTENSITY AEROMAGNETIC MAP OF THE VIRGINIA COASTAL PLAIN



SI020621

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

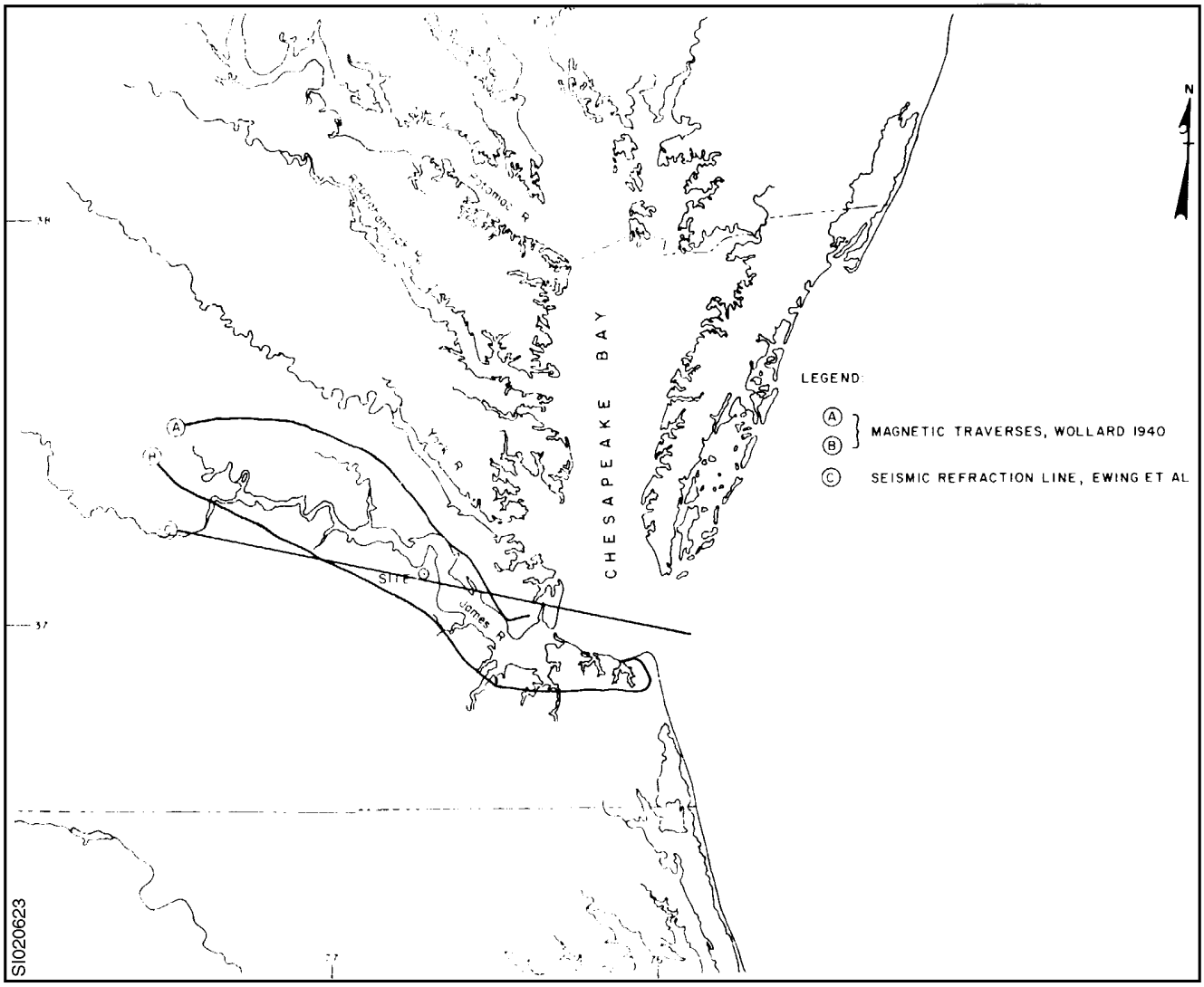


Figure 2.6-24
DEEP WELL LOCATIONS ON COASTAL PLAIN

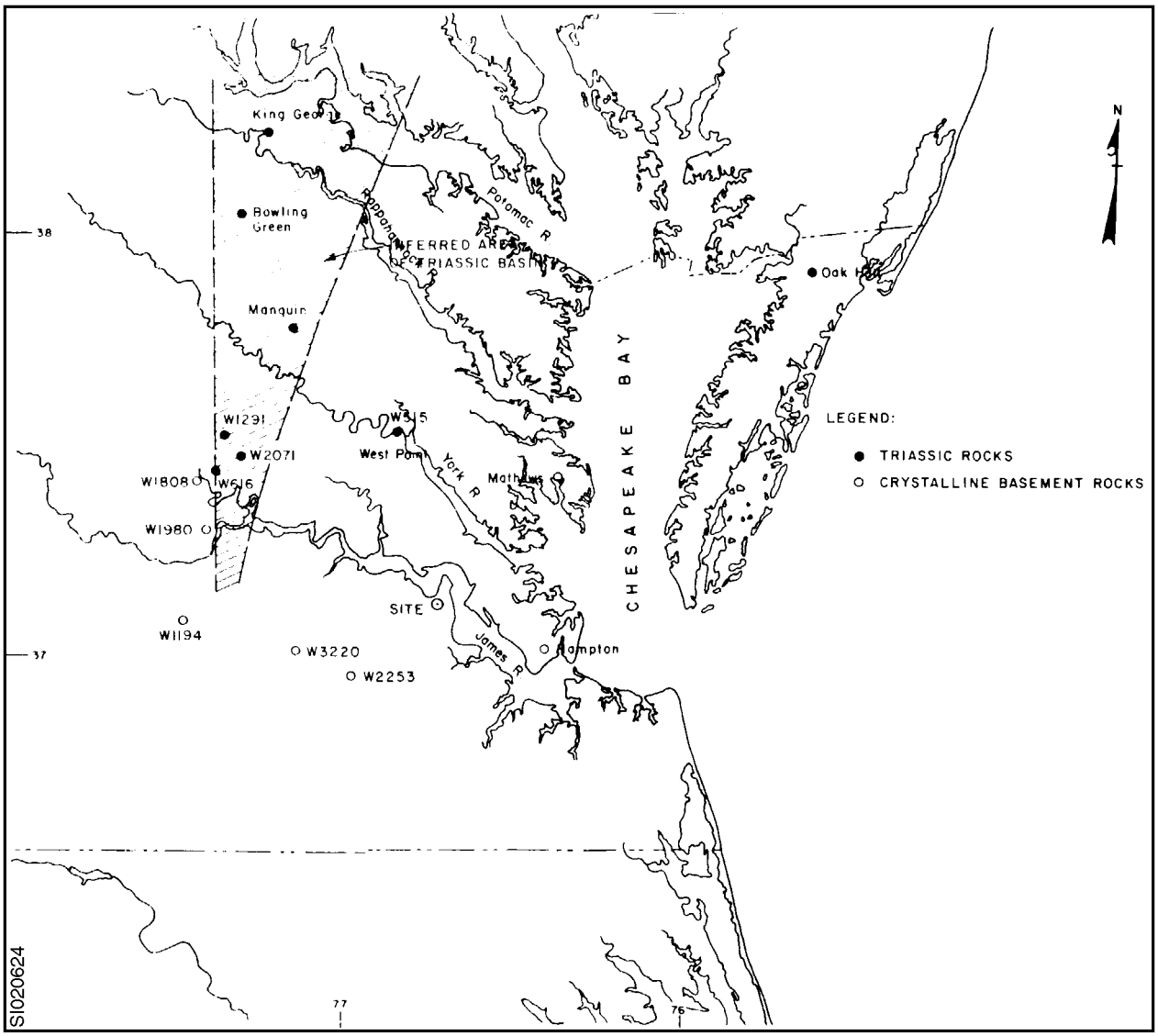


Figure 2.6-25
REGIONAL EPICENTER MAP

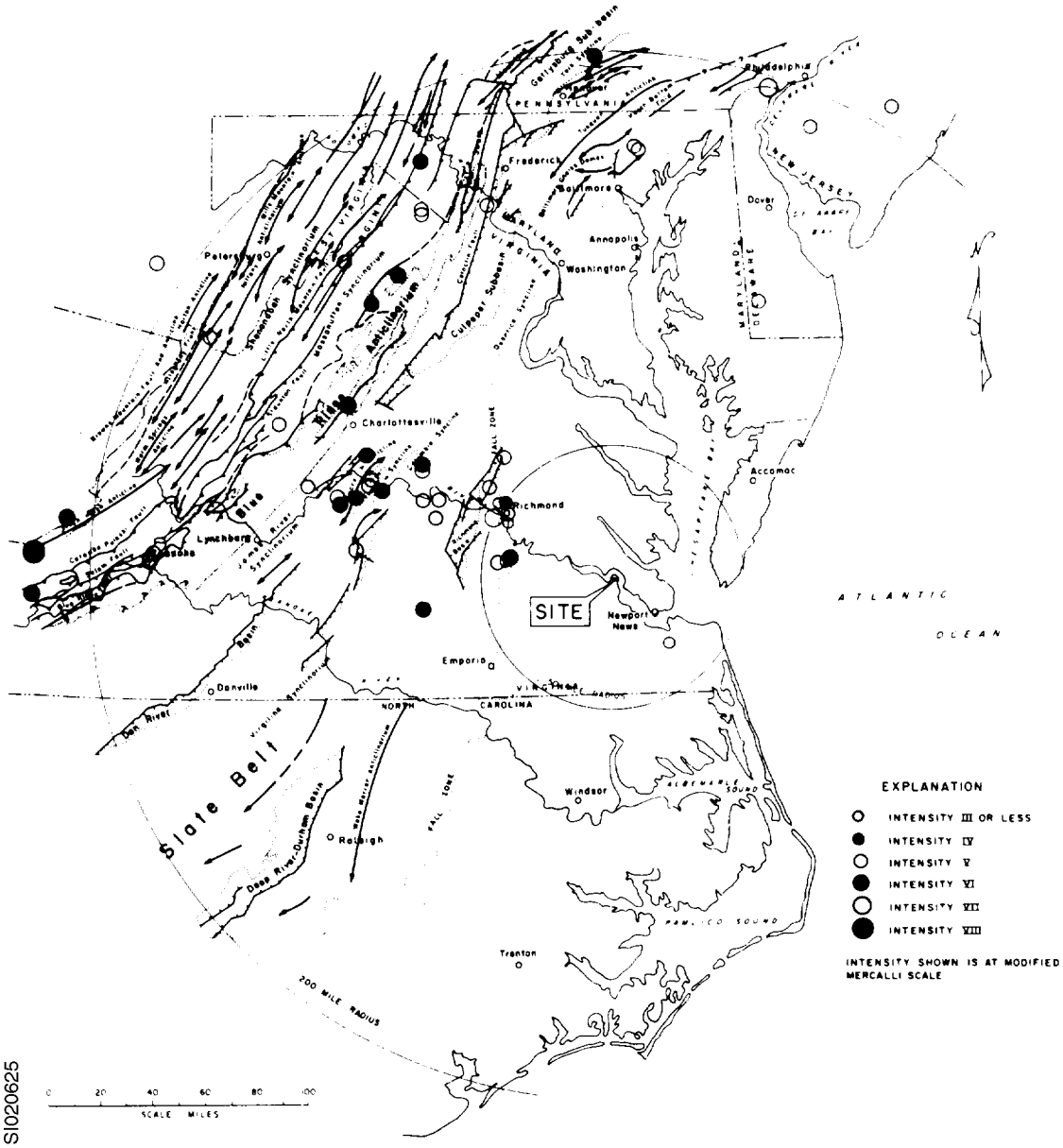


Figure 2.6-26
EARTHQUAKE ACTIVITY OF THE CENTRAL VIRGINIA SEISMIC ZONE

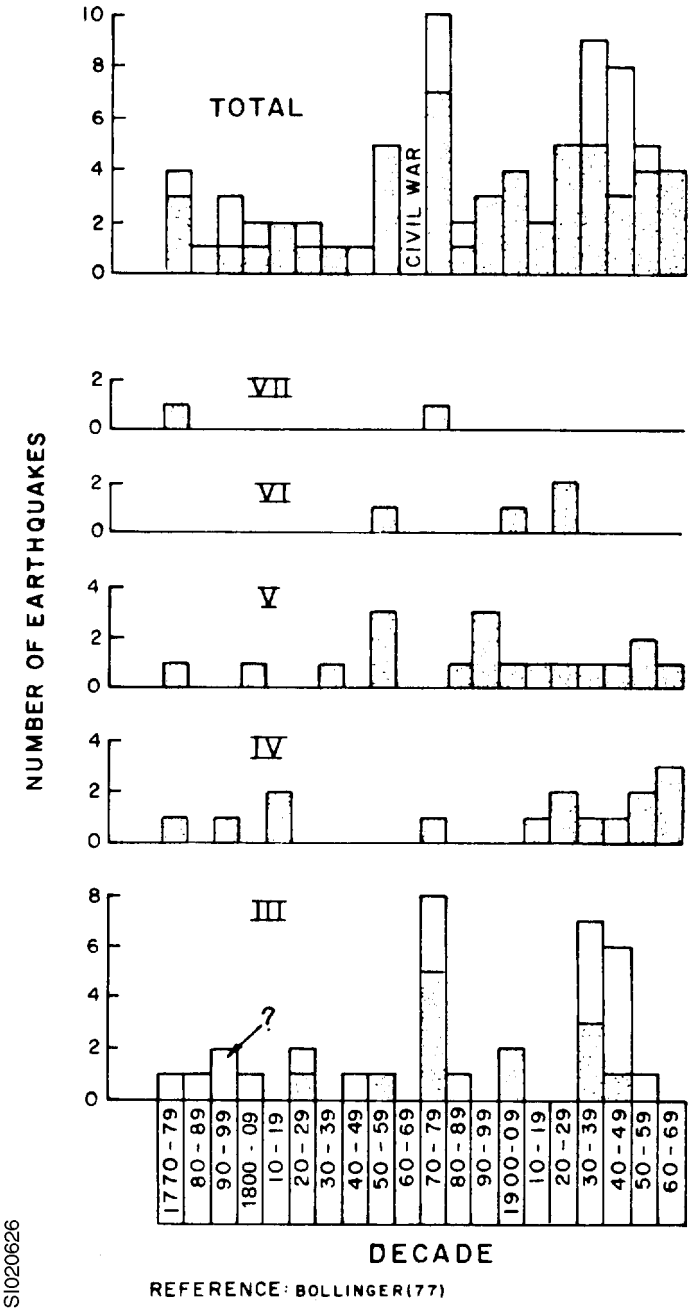


Figure 2.6-27
ISOSEISMAL PATTERNS SOUTH EASTERN UNITED STATES

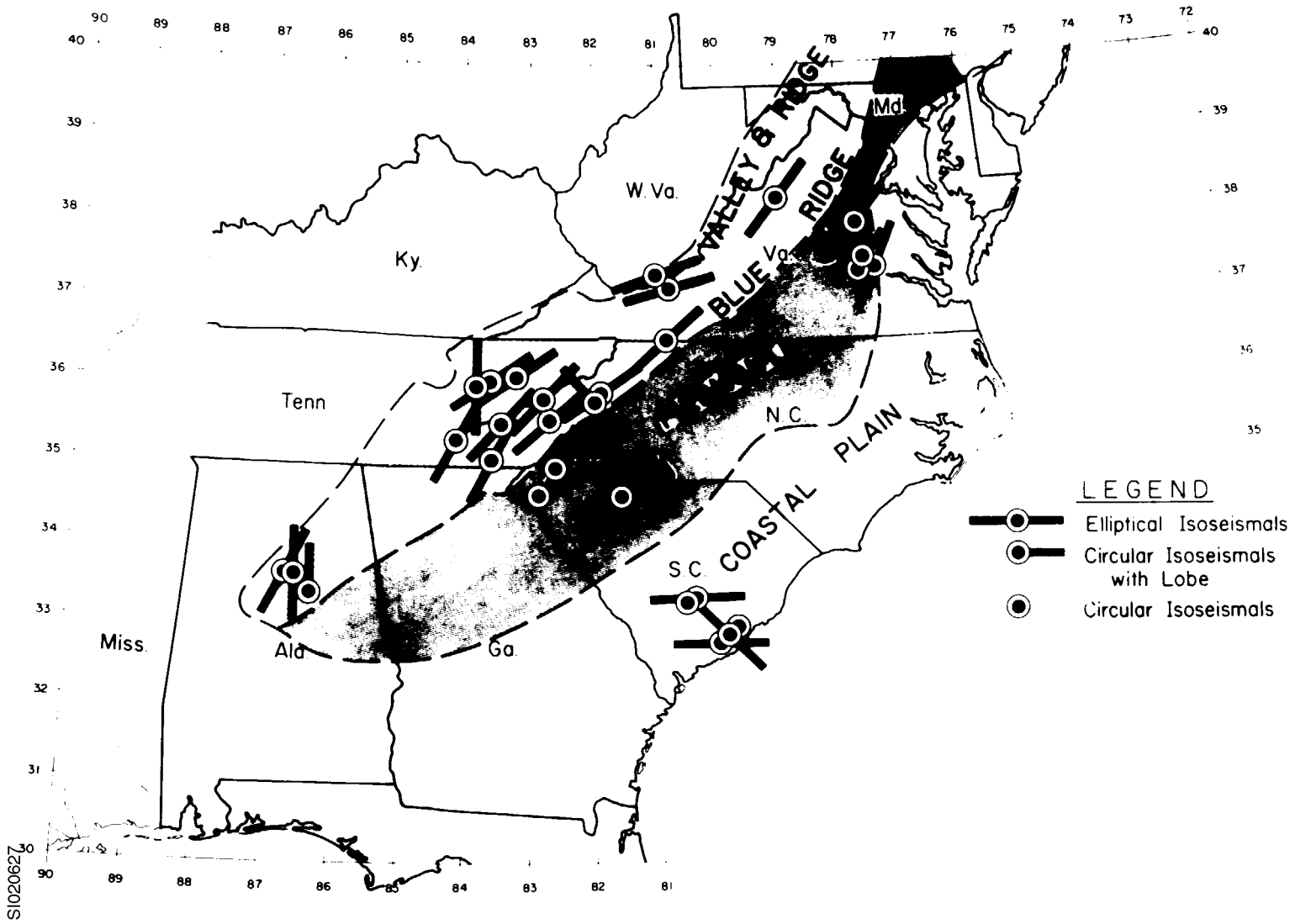


Figure 2.6-28
ISOSEISMAL MAPS; CENTRAL VIRGINIA - SEISMIC ZONES

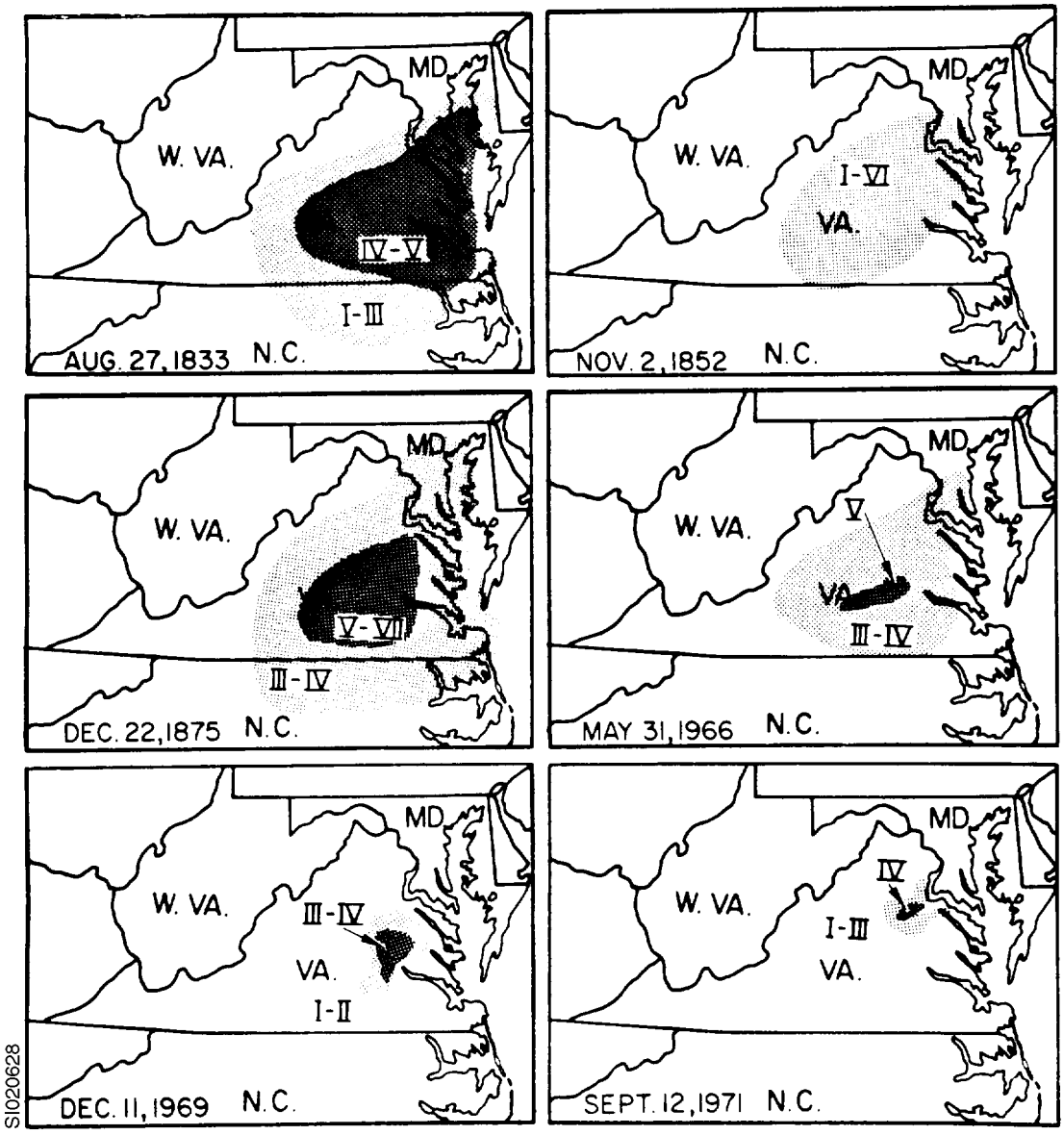


Figure 2.6-29
AEROMAGNETIC MAP OF THE CENTRAL EAST COAST OF THE UNITED STATES

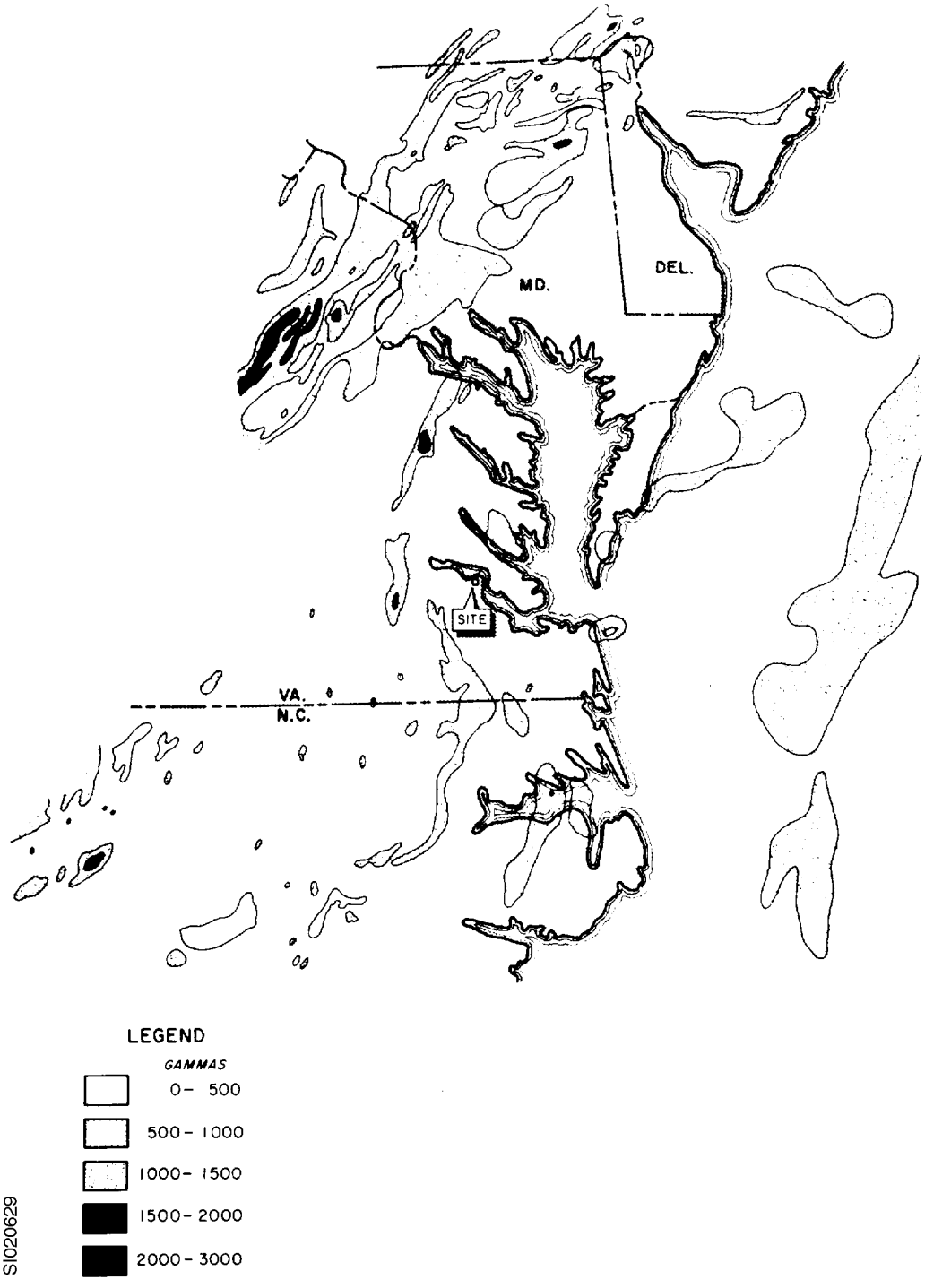


Figure 2.6-30
CRUSTAL MOVEMENT MAP SHOWING PROBABLE VERTICAL MOVEMENTS OF THE EARTH'S SURFACE

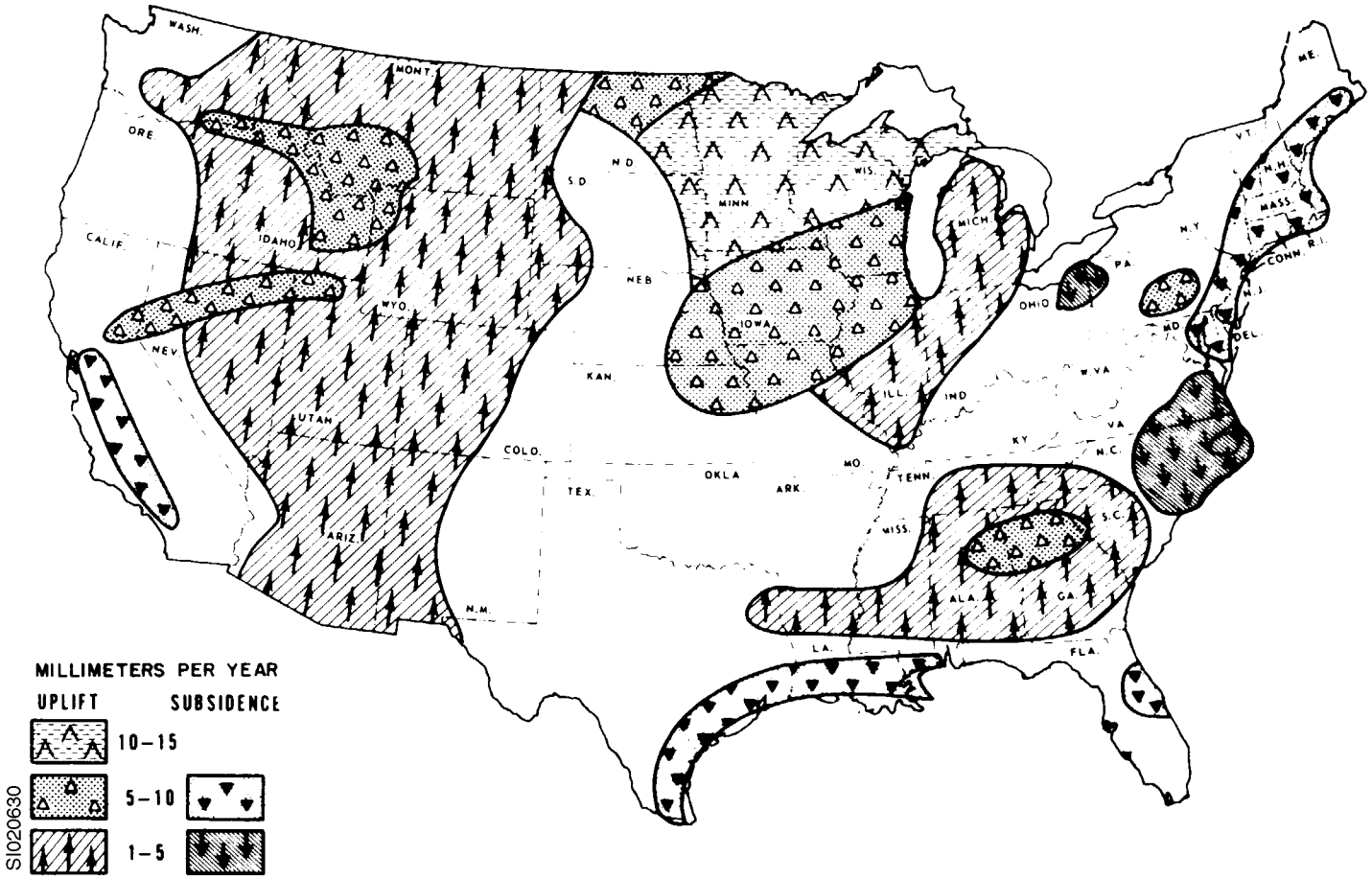


Figure 2.6-31
CRUSTAL MOVEMENT MAP OF EASTERN UNITED STATES

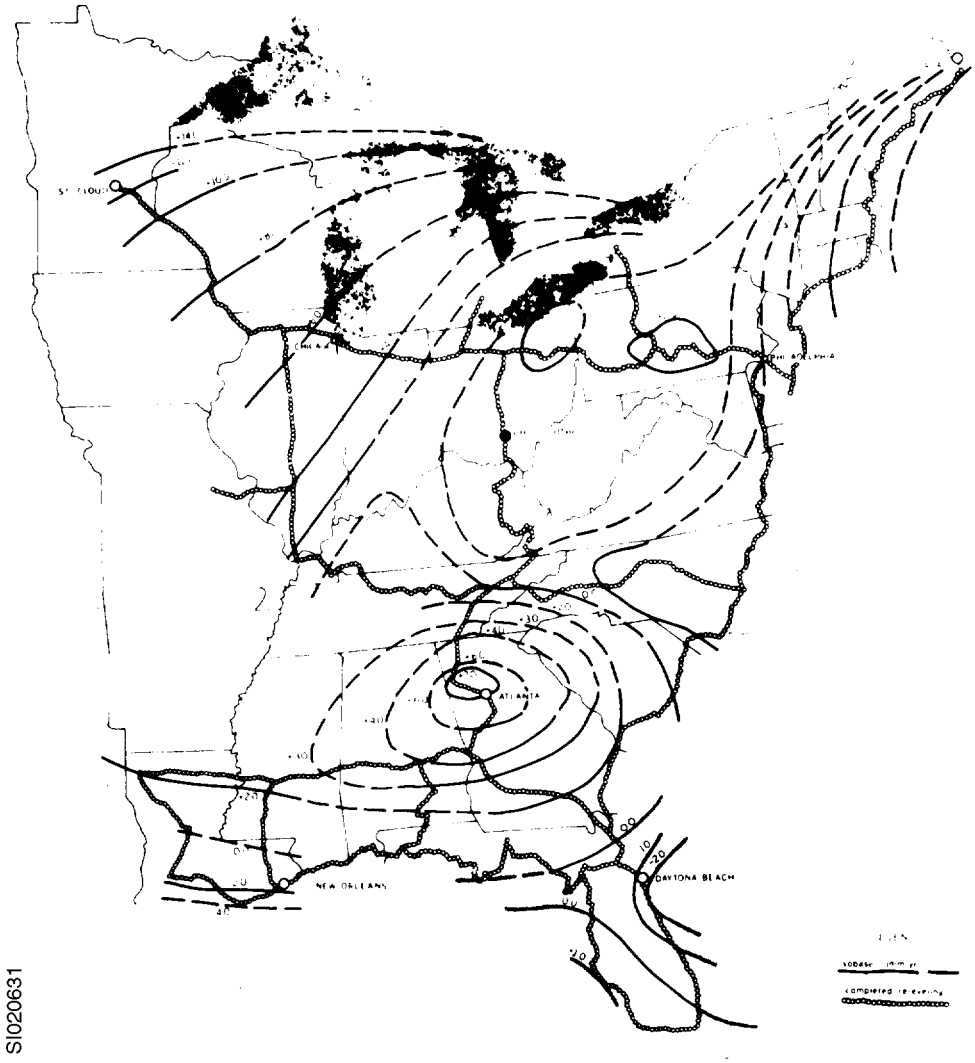


Figure 2.6-32 (SHEET 1 OF 2)
BORING LOG—HOLE NO. B-1

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 CORE RUN (FT.)	CORE 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]
							0					
SS	18"		12	3	5	7		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

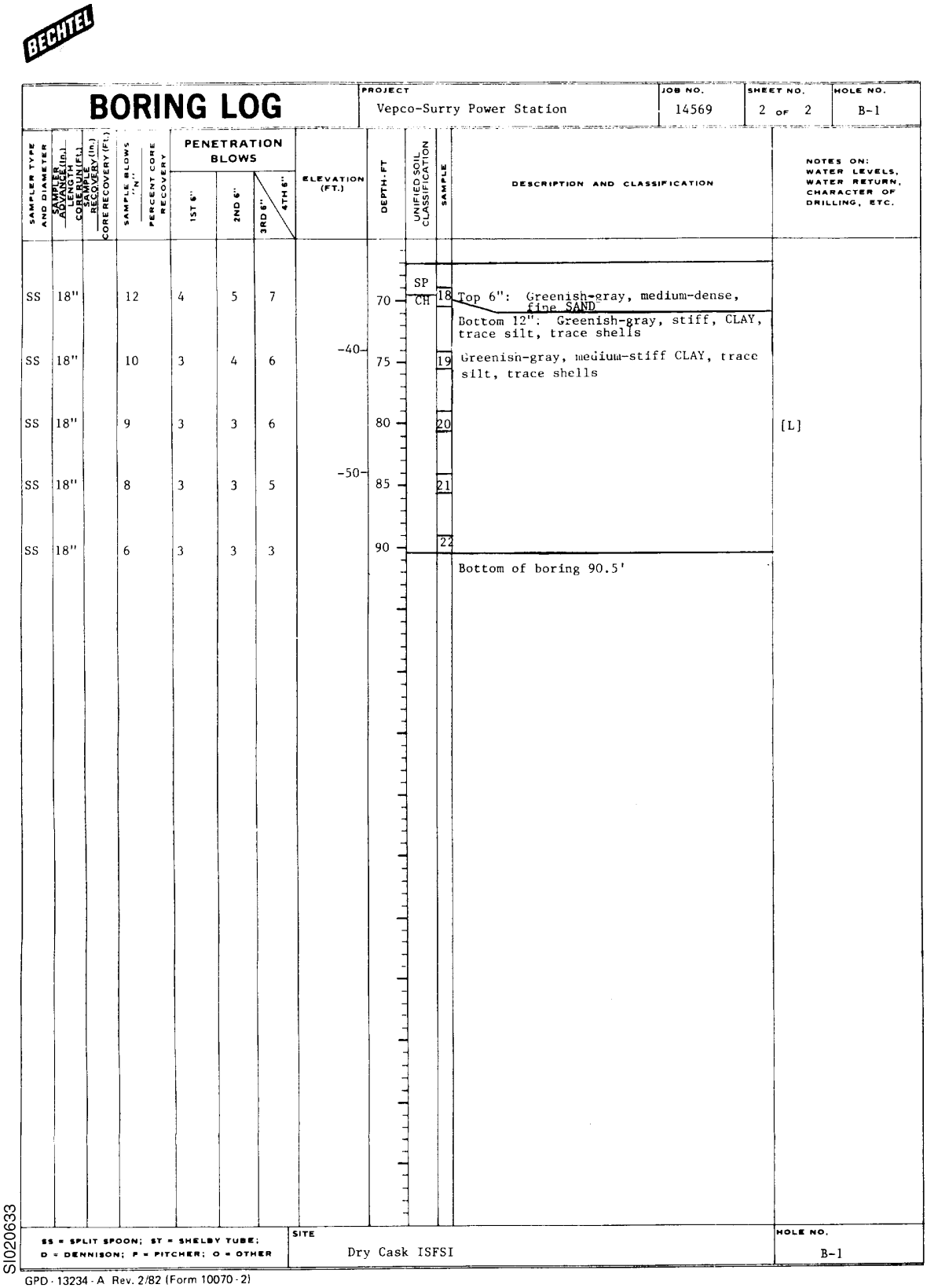
SITE: Dry Cask ISFSI

HOLE NO. 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



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 OF 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'	

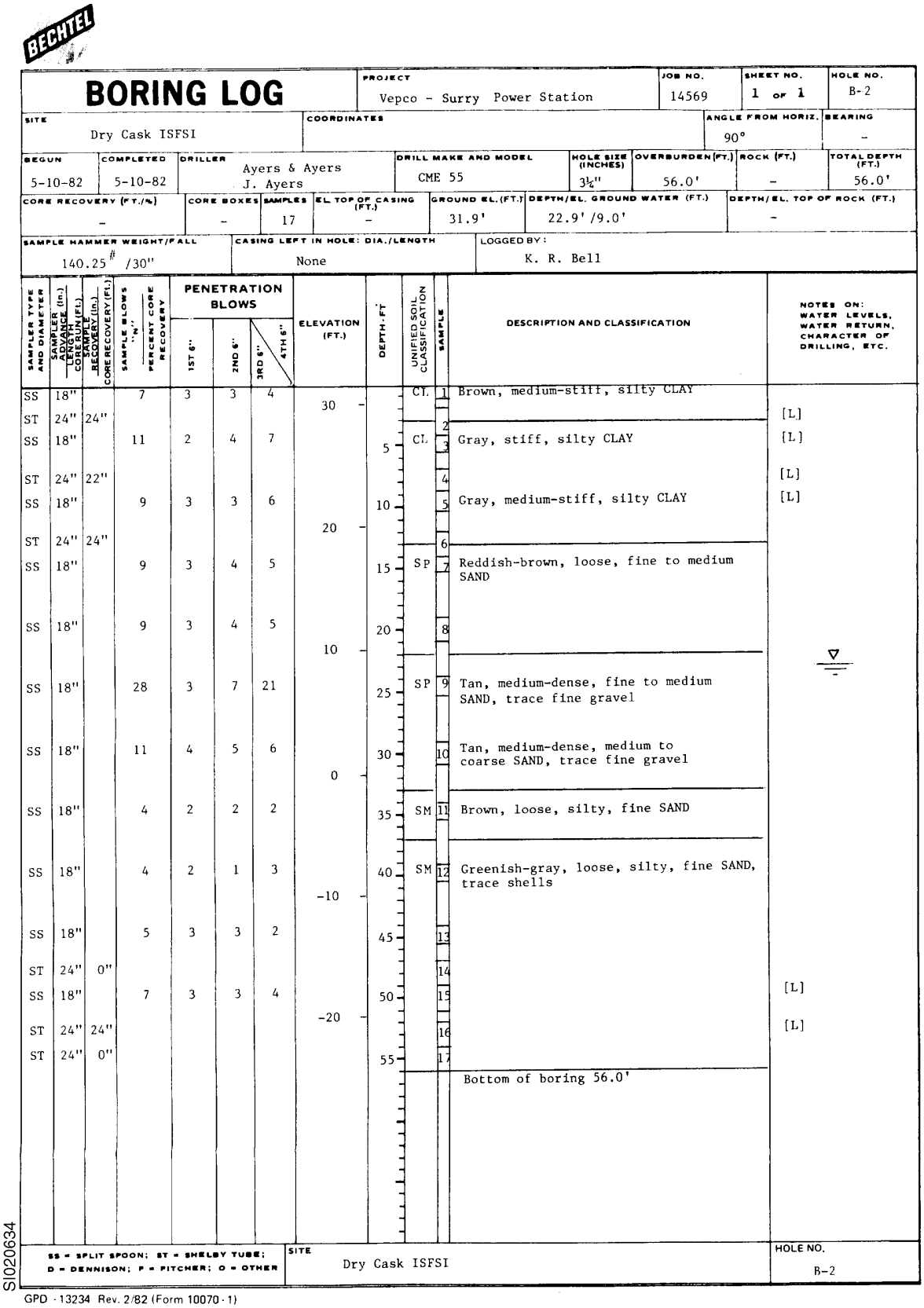
SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

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

SI020633

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

Figure 2.6-33
BORING LOG—HOLE NO. B-2



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 (in.) / LENGTH OF SAMPLE (Ft.)	CORE BARREL ADVANCE (Ft.) / 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	3	3	4	30		CL	1	Brown, medium-stiff, silty CLAY	
ST	24"	24"											[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"						20			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	10	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	0	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	-10	45		13		
ST	24"	0"									14		
SS	18"			7	3	3	4		50		15		[L]
ST	24"	24"						-20			16		[L]
ST	24"	0"							55		17		
												Bottom of boring 56.0'	

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

SITE: Dry Cask ISFSI

HOLE NO. B-2

SI020634

GPD · 13234 Rev. 2/82 (Form 10070-1)

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 (in.) / LENGTH CORE RUN (Ft.)	CORE 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]
ST	24"	23"						5	CL	2	Gray silty CLAY	[L]
ST	24"	23"					20	10	SP	3	Reddish-brown fine to medium SAND	[L]
								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

SI020635

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

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 (In.) / CORE BARREL (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					
SS	18"		12	2	5	7			CH	2	Gray, stiff, silty CLAY	
								5		3		[L]
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	
SS	18"		22	4	10	12		15		7		[L]
SS	18"		12	6	7	5		20	SP	8	Bottom 6": Gray, medium-dense, fine to medium SAND	▽
							10					
SS	18"		7	1	3	4		25	CH	9	Gray, soft, CLAY, some wood	[L]
SS	18"		43	12	20	23		30	SP	10	Bottom 15": Tan, dense, medium to coarse SAND, some fine gravel	
							0					
SS	18"		7	1	3	4		35	SM	11	Gray, loose, silty fine SAND	[L]
SS	18"		4	1	2	2		40		12		
							-10					
SS	18"		6	1	3	3		45	SM	13	Greenish-gray, loose, silty fine SAND, trace shells	[L]
SS	18"		10	3	5	5		50		14		
							-20					
SS	18"		12	3	5	7		55		15	Greenish-gray, medium-dense, silty fine SAND, trace shells	
SS	18"		7	1	3	4		60		16	Greenish-gray, loose, silty fine SAND, trace shells	
							-30					
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

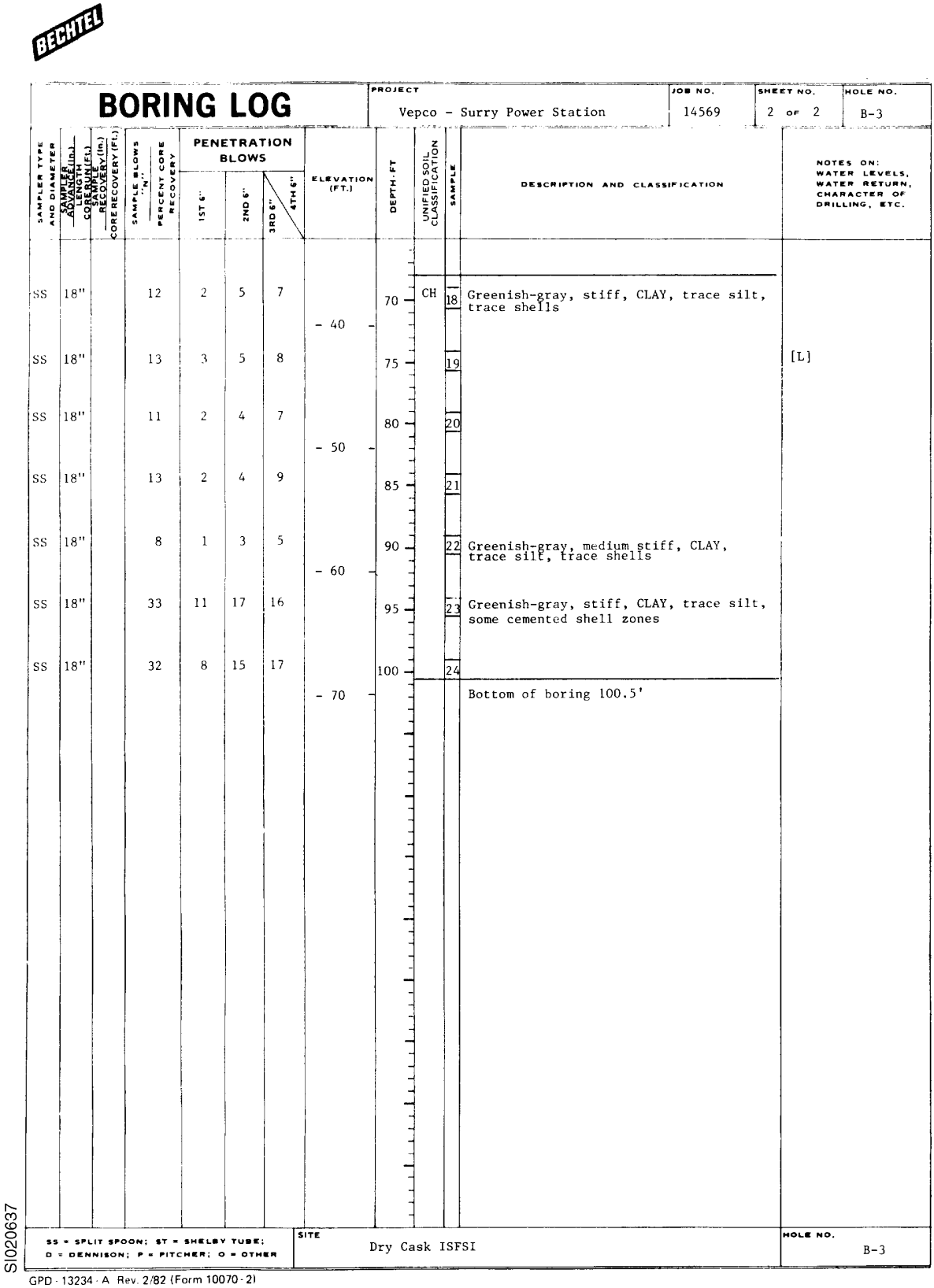
SITE: Dry Cask ISFSI

HOLE NO. B-3

S1020636

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

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 OR CASING LENGTH (In.) / CORE BARREL LENGTH (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

SI020637

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

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 LENGTH / CORE RUN (FT.)	CORE 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	6	Top 6": Gray, medium-stiff, sandy CLAY	
SS	18"			20		7	9	11		20	15	SM	7	Bottom 12": Reddish-brown, medium-dense, silty SAND	[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

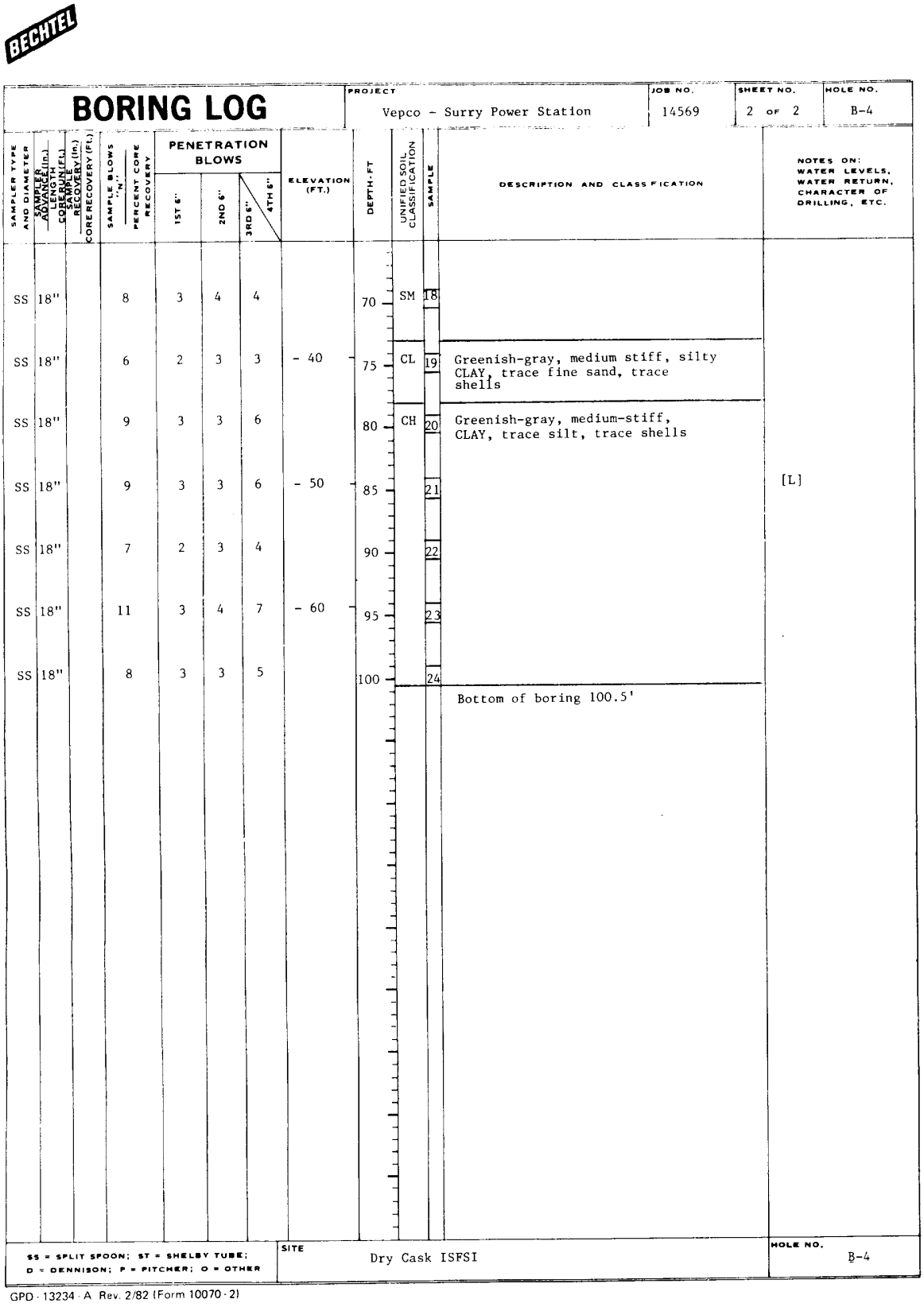
SITE: Dry Cask ISFSI

HOLE NO. B-4

SI020638

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

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



BORING LOG

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

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE (in.) LENGTH OF CORE (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'	

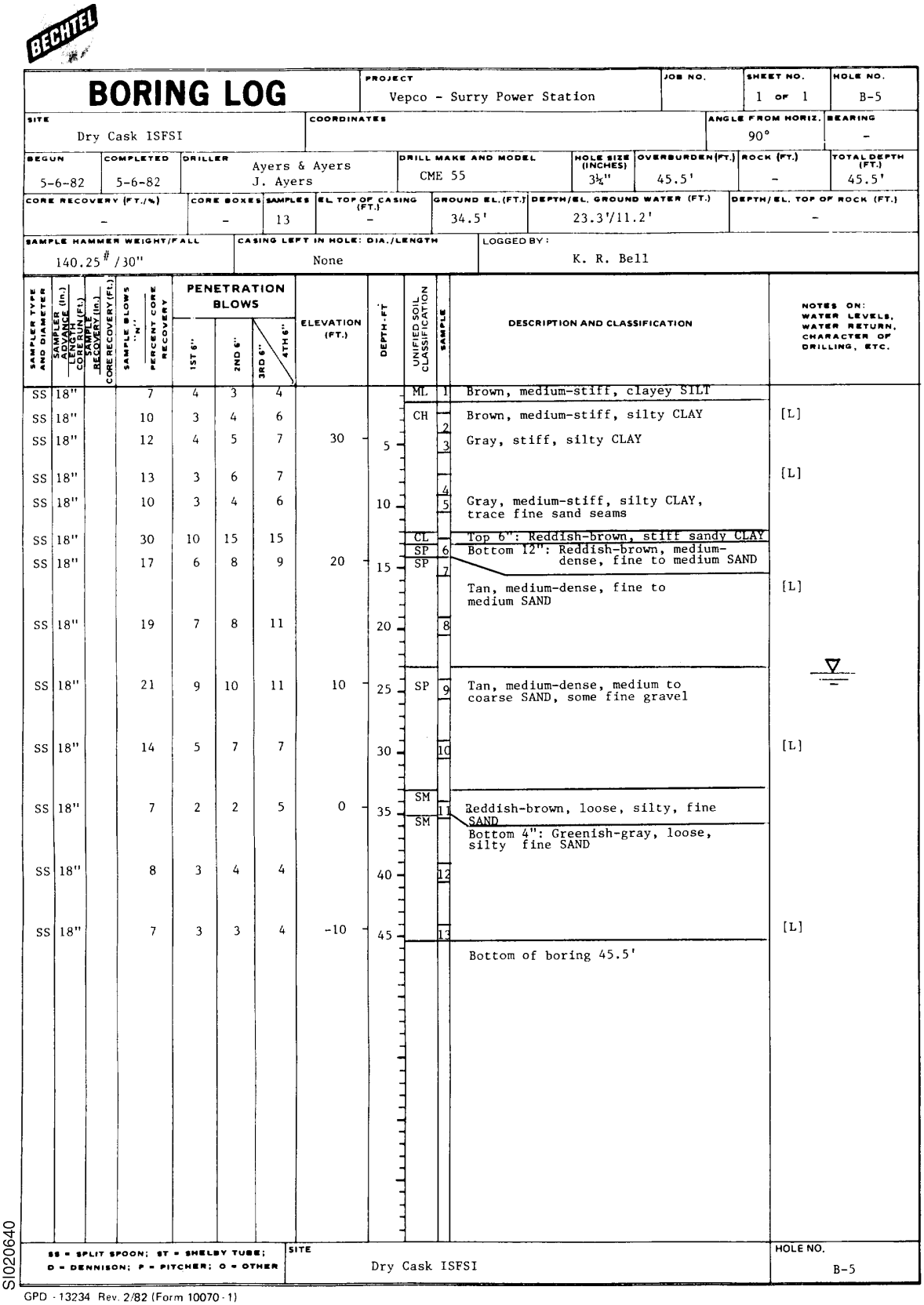
SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE: Dry Cask ISFSI | HOLE NO.: B-4

SI020639

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

Figure 2.6-37
BORING LOG—HOLE NO. B-5



BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station		1 OF 1	B-5

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"	45.5'	-	45.5'

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.)
-	-	13	-	34.5'	23.3'/11.2'	-

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 CORE RUN (FT.)	CORE RECOVERY (IN.) / 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		4	3	4			ML	1	Brown, medium-stiff, clayey SILT	
SS	18"		10		3	4	6			CH	2	Brown, medium-stiff, silty CLAY	[L]
SS	18"		12		4	5	7	30	5		3	Gray, stiff, silty CLAY	
SS	18"		13		3	6	7				4		[L]
SS	18"		10		3	4	6		10		5	Gray, medium-stiff, silty CLAY, trace fine sand seams	
SS	18"		30		10	15	15			CL		Top 6": Reddish-brown, stiff sandy CLAY	
SS	18"		17		6	8	9	20	15	SP	6	Bottom 12": Reddish-brown, medium-dense, fine to medium SAND	
										SP	7	Tan, medium-dense, fine to medium SAND	[L]
SS	18"		19		7	8	11		20		8		
SS	18"		21		9	10	11	10	25	SP	9	Tan, medium-dense, medium to coarse SAND, some fine gravel	▽
SS	18"		14		5	7	7		30		10		[L]
										SM			
SS	18"		7		2	2	5	0	35	SM	11	Reddish-brown, loose, silty, fine SAND	
												Bottom 4": Greenish-gray, loose, silty fine SAND	
SS	18"		8		3	4	4		40		12		
SS	18"		7		3	3	4	-10	45		13		[L]
												Bottom of boring 45.5'	

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

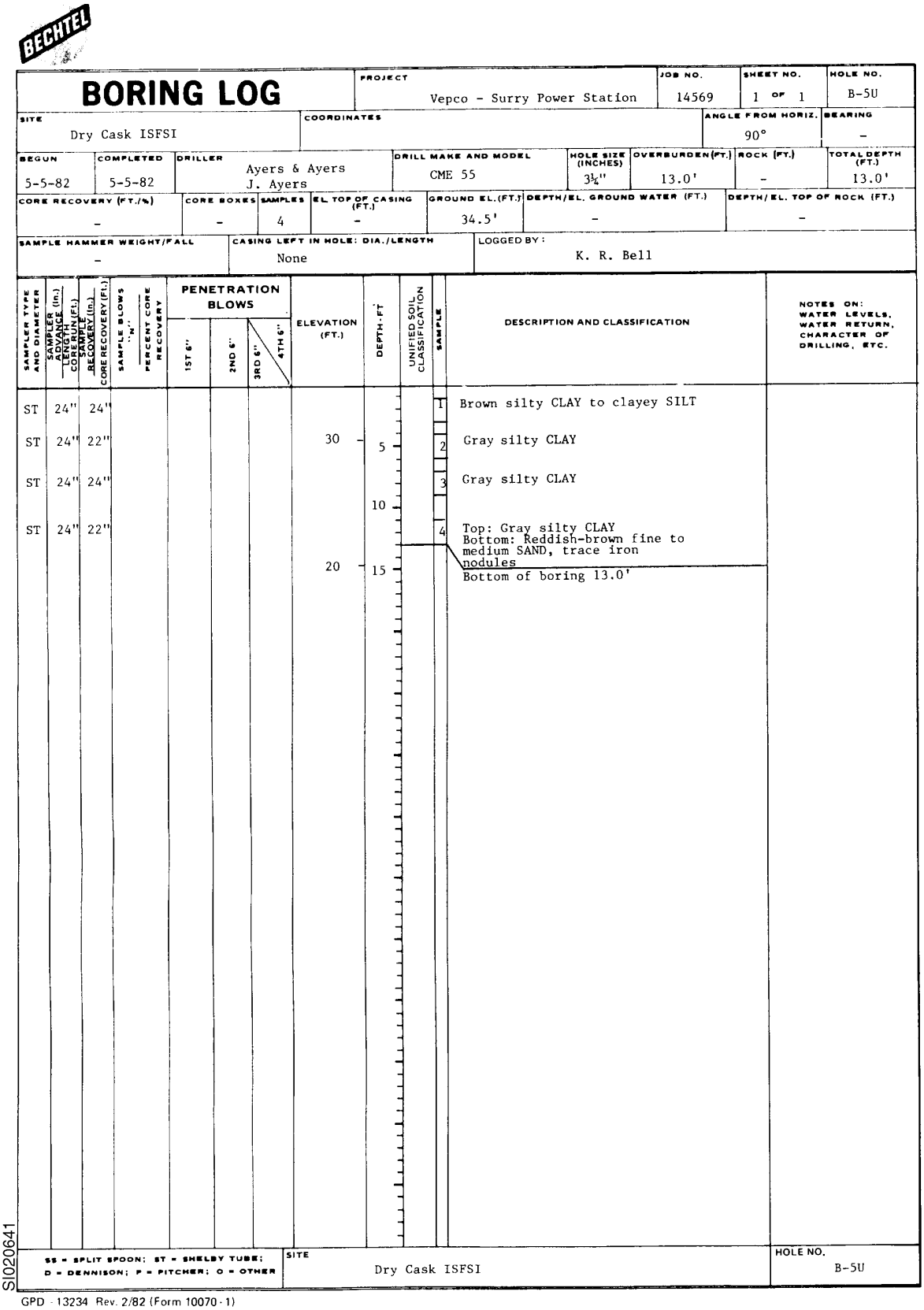
SITE: Dry Cask ISFSI

HOLE NO.: B-5

SI020640

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

Figure 2.6-38
BORING LOG—HOLE NO. B-5U



BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 OF 1	B-5U

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.)
5-5-82	5-5-82	Ayers & Ayers J. Ayers	CME 55	3¼"	13.0'	-	13.0'

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.)
-	-	4	-	34.5'	-	-

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

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE (In.) / LENGTH OF 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"	24"									1	Brown silty CLAY to clayey SILT	
ST	24"	22"						30	5		2	Gray silty CLAY	
ST	24"	24"									3	Gray silty CLAY	
									10				
ST	24"	22"									4	Top: Gray silty CLAY Bottom: Reddish-brown fine to medium SAND, trace iron nodules	
								20	15			Bottom of boring 13.0'	

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

SITE: Dry Cask ISFSI

HOLE NO.: B-5U

SI020641

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

Figure 2.6-39 (SHEET 1 OF 2)
BORING LOG—HOLE NO. B-6

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 OF 2	B-6

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.)
4-29-82	4-29-82	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		34.8'	23.0'/11.8'	-

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.) / 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	2	3	6			CL	1	Brown, medium-stiff, silty CLAY	
SS	18"		11	2	4	7			CH		Brown and gray, stiff, silty CLAY	[L]
SS	18"		12	3	4	8	30	5		2 3		
SS	18"		10	3	4	6				4		
SS	18"		5	2	2	3		10		5	Brown, soft, silty CLAY, trace reddish-brown sand seams	
SS	18"		12	2	4	8			CL	6	Reddish-brown, stiff, silty CLAY	
SS	18"		32	13	13	19	20	15	SP	7	Reddish-brown, dense, medium to coarse SAND, trace fine gravel	
SS	18"		18	4	9	9		20		8	Top 9": Reddish-brown, medium-dense, medium to coarse SAND Bottom 9": Tan, medium-dense, fine to medium SAND	
SS	18"		10	4	4	6	10	25	SP	9	Tan, loose, medium to coarse SAND, some fine gravel	
SS	18"		17	6	8	9		30		10	Tan, medium-dense, medium to coarse SAND, some fine gravel	
SS	18"		40	8	32	8	0	35	SC	11	Reddish-brown, dense clayey SAND, trace fine gravel	
SS	18"	0"	14	5	8	6		40		12		
SS	18"		8	2	4	4			SM	12	Greenish-gray, loose, silty fine SAND, trace shells	
SS	18"		7	2	3	4	-10	45		13		[L]
SS	18"		8	2	4	4		50		14		
SS	18"		8	2	3	5	-20	55		15		
SS	18"		7	2	2	5		60		16		
SS	18"		10	2	4	6	-30	65		17		

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

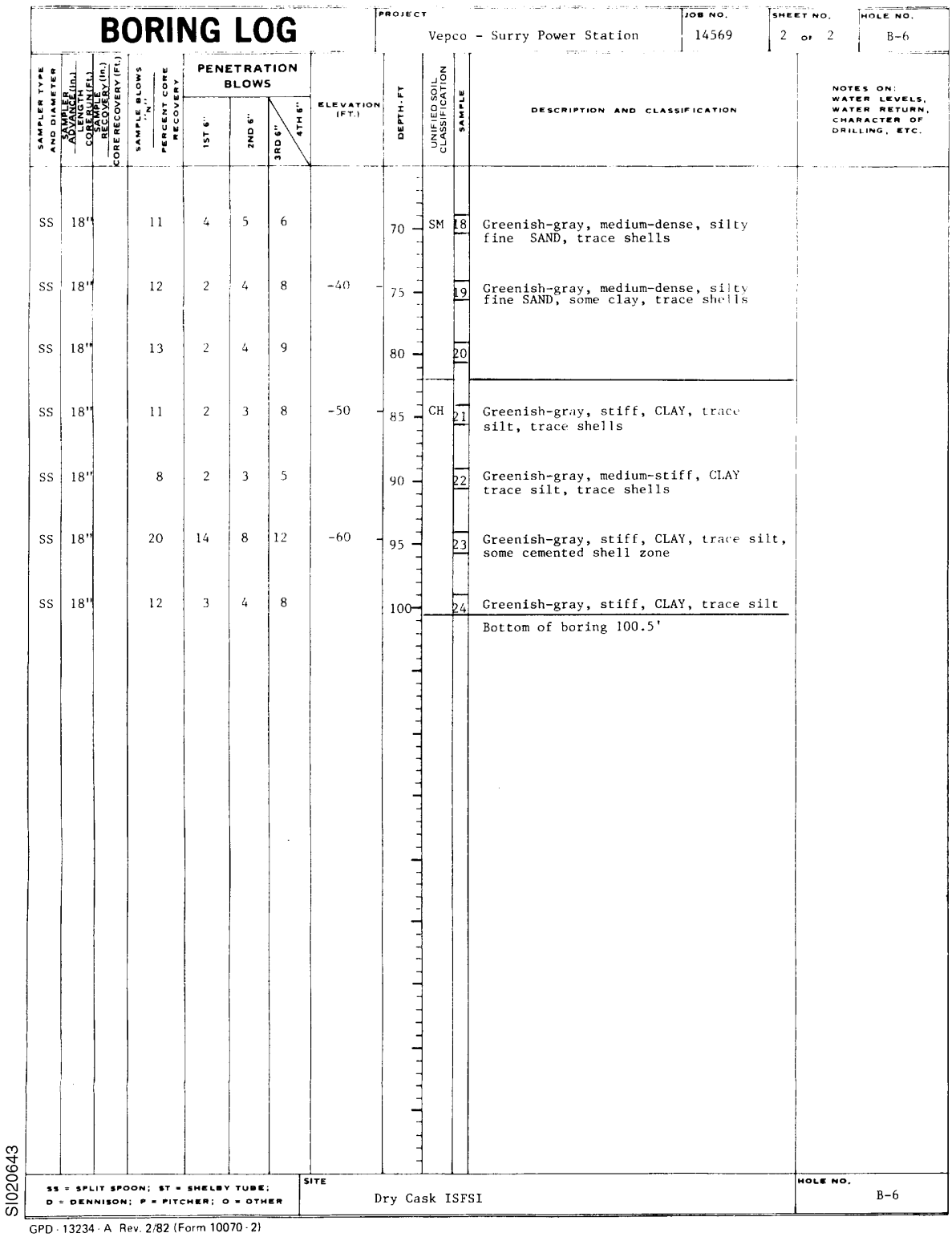
SITE: Dry Cask ISFSI

HOLE NO. B-6

SI020642

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

Figure 2.6-39 (SHEET 2 OF 2)
BORING LOG—HOLE NO. B-6



BECHTEL

BORING LOG

PROJECT: Vepco - Surry Power Station | JOB NO.: 14569 | SHEET NO.: 2 of 2 | HOLE NO.: B-6

SAMPLER TYPE AND DIAMETER	ADVANCE LENGTH / CORE BARREL LENGTH / 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"	11	4	5	6		70	SM	18	Greenish-gray, medium-dense, silty fine SAND, trace shells	
SS	18"	12	2	4	8	-40	75		19	Greenish-gray, medium-dense, silty fine SAND, some clay, trace shells	
SS	18"	13	2	4	9		80		20		
SS	18"	11	2	3	8	-50	85	CH	21	Greenish-gray, stiff, CLAY, trace silt, trace shells	
SS	18"	8	2	3	5		90		22	Greenish-gray, medium-stiff, CLAY trace silt, trace shells	
SS	18"	20	14	8	12	-60	95		23	Greenish-gray, stiff, CLAY, trace silt, some cemented shell zone	
SS	18"	12	3	4	8		100		24	Greenish-gray, stiff, CLAY, trace silt	
										Bottom of boring 100.5'	

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

SITE: Dry Cask ISFSI | HOLE NO.: B-6

SI020643

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

Figure 2.6-40 (SHEET 1 OF 2)
BORING LOG—HOLE NO. B-7

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 OF 2	B-7

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.)
5-3-82	5-3-82	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	-	34.1'	23.3'/10.8'	-

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

SAMPLER TYPE AND DIAMETER	SAMPLER (In.) / CASING (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"		6	2	4	4				CL	1	Brown and gray, medium-stiff, silty CLAY	
SS	18"		11	3	4	7				CL-CH	2	Brown and gray, stiff, silty CLAY, some reddish-brown sand seams	
SS	18"		9	3	4	5		30	5	CL-CH	3	Gray, medium stiff, silty CLAY, some reddish-brown sand seams	
SS	18"		6	2	3	3					4		
SS	18"		6	2	3	3			10		5		[L]
SS	18"		9	4	5	5				SC	6	Reddish brown, loose, clayey fine SAND	
SS	18"		17	5	8	9		20	15	SP	7	Tan, medium-dense, fine SAND	
SS	18"		31	9	14	17			20		8	Reddish-brown, dense, fine to medium SAND	
SS	18"		11	3	5	6		10	25	SP	9	Tan, medium-dense, medium to coarse SAND, some fine gravel	▽
SS	18"		11	3	4	7			30		10		[L]
SS	18"		4	1	2	2		0	35	SM	11	Middle 6": Reddish-brown, loose, silty fine SAND	
										SM		Bottom 6": Greenish-gray, loose, silty fine SAND	
SS	18"		11	4	5	6			40	SM	12	Greenish-gray, medium-dense, silty fine SAND, trace shells	
SS	18"		6	3	3	3		-10	45	SM	13	Greenish-gray, loose, silty fine SAND, trace shells	[L]
SS	18"		10	3	5	5			50		14		
SS	18"		12	4	5	7		-20	55	SM	15	Greenish-gray, medium-dense, silty fine SAND, trace shells	
SS	18"		10	3	4	6			60	SM	16	Greenish-gray, loose, silty fine SAND, trace shells	
SS	18"		9	3	3	6		-30	65		17		

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

SITE: Dry Cask ISFSI

HOLE NO. B-7

S1020644

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

Figure 2.6-40 (SHEET 2 OF 2)
BORING LOG—HOLE NO. B-7

BECHTEL

BORING LOG

PROJECT: Vepco - Surry Power Station | JOB NO.: 14569 | SHEET NO.: 2 OF 2 | HOLE NO.: B-7

SAMPLER TYPE AND DIAMETER	SAMPLE OR CORE 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"		11	3	4	7		70	SM	18	Greenish-gray, medium-dense, silty fine SAND, trace shells	
SS	18"		9	3	3	6	- 40	75	SM	19	Greenish gray, loose, silty fine SAND, trace clay, trace shells	
SS	18"		11	3	4	7		80	CH	20	Greenish-gray, stiff, CLAY, some silt, trace shells	
SS	18"		10	4	4	6	- 50	85		21		[L]
SS	18"		7	3	3	4		90	CH	22	Greenish-gray, medium-stiff, CLAY, some silt, some shells	
SS	18"		15	25	7	8	- 60	95	CH	23	Top: Cemented shell zone Bottom: Greenish-gray, stiff, CLAY, some shells, some silt	
SS	18"		11	3	4	7		100		24		[L]
											Bottom of boring 100.5'	

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

SITE: Dry Cask ISFSI | HOLE NO.: B-7

SI020645

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

Figure 2.6-41 (SHEET 1 OF 2)
BORING LOG—HOLE NO. B-8

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 OF 2	B-8

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.)
5-4-82	5-4-82	Ayers & Ayers J. Ayers	CME 55	3¼"	85.5'	-	85.5'

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	-	34.2	23.0'/11.2'	-

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 (In.) / LENGTH CORE BARREL (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"		6	2	2	4			CL	1	Brown, medium-stiff, silty CLAY	
ST	24"	16"							CH-CL	2	Gray, silty CLAY	[L]
SS	18"		13	3	6	7	30	5		3	Gray, stiff, silty CLAY	[L]
ST	24"	22"								4	Gray, silty CLAY	[L]
SS	18"		7	3	3	4		10		5	Gray, medium-stiff, silty CLAY, some reddish-brown fine sand seams	
ST	24"	24"									Top: Gray, silty CLAY	[L]
SS	18"		9	3	4	5	20	15	SC	6 7	Bottom: Reddish-brown, clayey SAND Reddish-brown, loose, clayey SAND	[L]
SS	18"		10	3	4	6		20	SP	8	Tan, loose, fine to medium SAND	
SS	18"		10	3	5	5	10	25	SP	9	Tan, loose, medium to coarse SAND, trace fine gravel	
SS	18"		11	3	4	7		30		10	Tan, medium-dense, medium to coarse SAND, some fine gravel	[L]
SS	18"		12	7	3	9	0	35	SM	11	Greenish-gray, medium-dense, silty fine SAND, trace shells	
SS	18"		8	3	3	5		40		12	Greenish-gray, loose, silty fine SAND, trace shells	
ST	24"	23"								13		[L]
SS	18"		8	3	4	4	-10	45		14		
SS	18"		8	3	3	5		50		15		
SS	18"		8	3	3	5	-20	55		16		
SS	18"		8	2	3	5		60		17		
ST	24"	24"								18		[L]
SS	18"		8	2	3	5	-30	65		19		

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

SITE: Dry Cask ISFSI

HOLE NO: B-8

SI020646

GPD · 13234 Rev. 2/82 (Form 10070-1)

Figure 2.6-41 (SHEET 2 OF 2)
BORING LOG—HOLE NO. B-8

BECHTEL

BORING LOG

PROJECT: Vepco - Surry Power Station | JOB NO.: 14569 | SHEET NO.: 2 OF 2 | HOLE NO.: B-8

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE (in.) / LENGTH CORE BARREL (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"	10	3	4	6		70	SM	20	Greenish-gray, loose, silty fine SAND, trace shells	
SS	18"	10	3	4	6	-40	75	CH	21	Greenish-gray, medium-stiff CLAY, some silt, trace shells, trace fine sand	
SS	18"	10	3	4	6		80		22	Greenish-gray, medium stiff CLAY trace silt, trace shells	
ST	24"	24"							23		[L]
SS	18"	9	2	3	6	-50	85		24		[L]
										Bottom of boring 85.5'	

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

SITE: Dry Cask ISFSI

HOLE NO.: B-8

SI020647

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

Figure 2.6-42 (SHEET 1 OF 2)
BORING LOG—HOLE NO. B-9

BECHTEL

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
Vepco - Surry Power Station	14569	1 OF 2	B-9

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.)
4-29-82	4-29-82	Ayers & Ayers R. Ayers	CME 55	3¼"	101.5'	-	101.5'

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	-	36.1	25.0'/11.1'	-

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 / CORE RUN (FT.) / 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			CH	1	Brown and gray, medium-stiff, silty CLAY	[L]
SS	18"	7		2	3	3				2		
SS	18"	11		2	5	6	30	5		3	Gray, stiff, silty CLAY	
SS	18"	9		2	3	6				4	Gray, medium-stiff, silty CLAY	
SS	18"	8		2	4	4		10		5		[L]
SS	18"	5		2	2	3				6	Gray, soft, silty CLAY	
SS	18"	8		1	2	6		15		7	Gray, medium-stiff, silty CLAY, some reddish-brown fine sand seams	
SS	18"	25		3	11	14	20	20	SC	8	Gray, medium-dense, clayey SAND	
SS	18"	24		4	6	18		25	SP	9	Reddish-brown, medium dense, medium SAND, some fine gravel	▽
SS	18"	24		7	12	12	10	30	SP	10	Tan, medium-dense, medium to coarse SAND, some fine gravel	
SS	18"	21		5	7	14		35		11		
SS	18"	7		2	4	3	0	40	SM	12	Gray, loose, silty fine SAND, some shells	
SS	18"	4		2	2	2		45	SM	13	Greenish-gray, loose, silty fine SAND, trace shells	[L]
SS	18"	8		2	4	4	-10	50		14		
SS	18"	11		3	5	6		55		15		
SS	18"	10		3	5	5	-20	60		16		
SS	18"	8		2	4	4		65		17		
							-30					

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

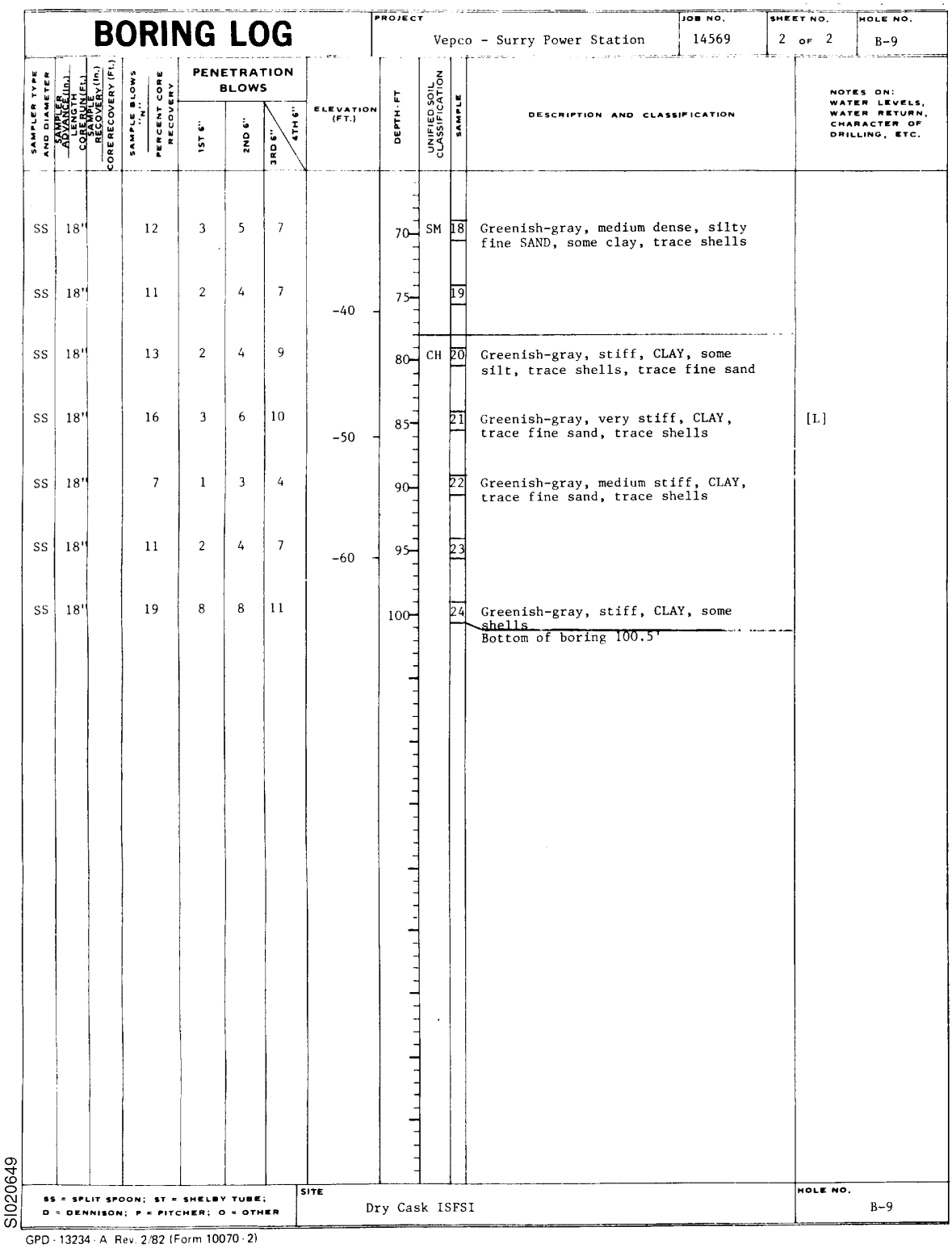
SITE: Dry Cask ISFSI

HOLE NO. B-9

SI020648

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

Figure 2.6-42 (SHEET 2 OF 2)
BORING LOG—HOLE NO. B-9



BECHTEL

BORING LOG

PROJECT: Vepco - Surry Power Station | JOB NO.: 14569 | SHEET NO.: 2 OF 2 | HOLE NO.: B-9

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE (in.) / LENGTH CORE BARREL (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	3	5	7		70	SM	18	Greenish-gray, medium dense, silty fine SAND, some clay, trace shells	
SS	18"	11	2	4	7	-40	75		19		
SS	18"	13	2	4	9		80	CH	20	Greenish-gray, stiff, CLAY, some silt, trace shells, trace fine sand	
SS	18"	16	3	6	10	-50	85		21	Greenish-gray, very stiff, CLAY, trace fine sand, trace shells	[L]
SS	18"	7	1	3	4		90		22	Greenish-gray, medium stiff, CLAY, trace fine sand, trace shells	
SS	18"	11	2	4	7	-60	95		23		
SS	18"	19	8	8	11		100		24	Greenish-gray, stiff, CLAY, some shells Bottom of boring 100.5'	

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

SITE: Dry Cask ISFSI | HOLE NO.: B-9

SI020649

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

Figure 2.6-43
BORING LOCATION PLAN

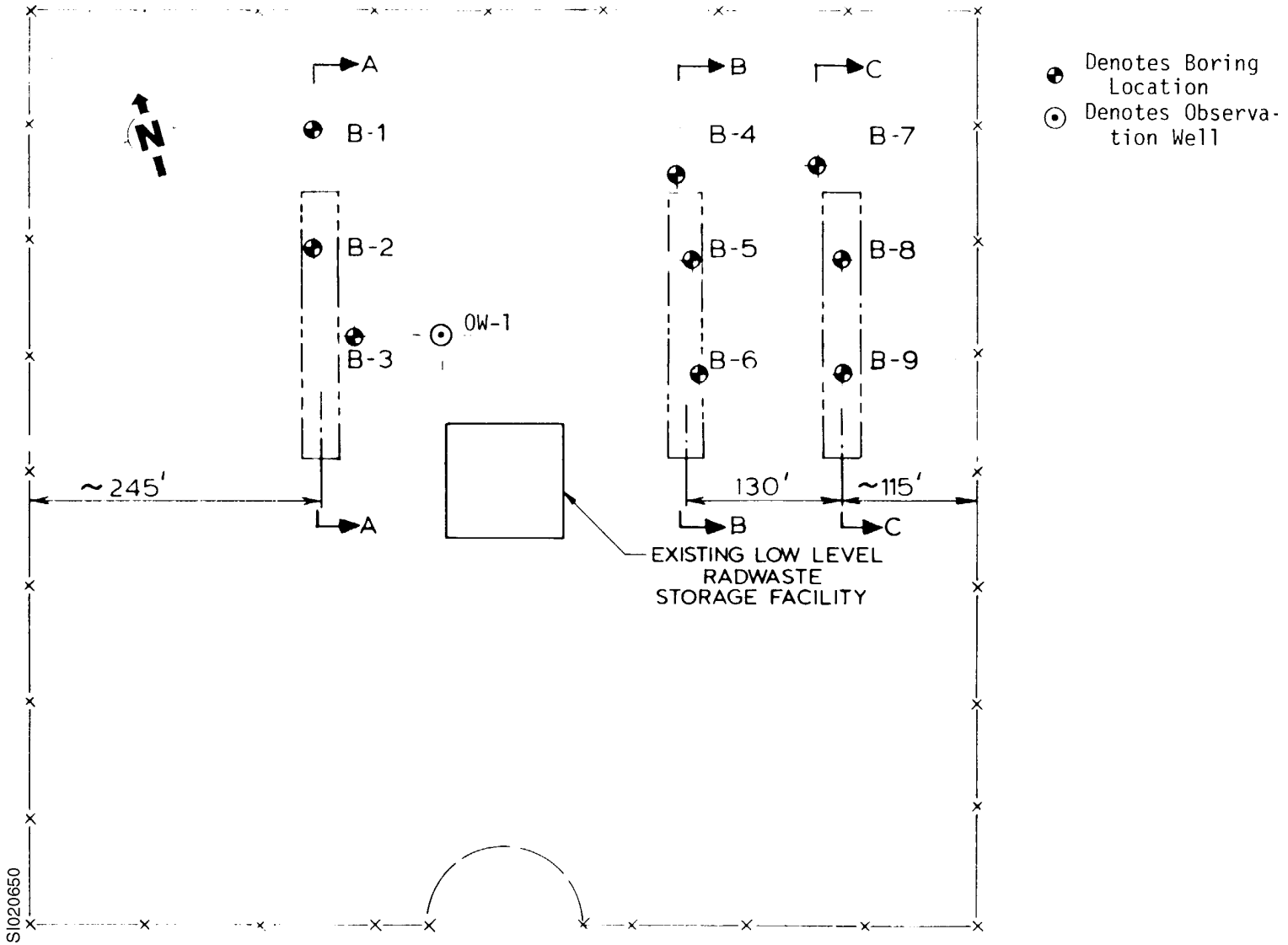
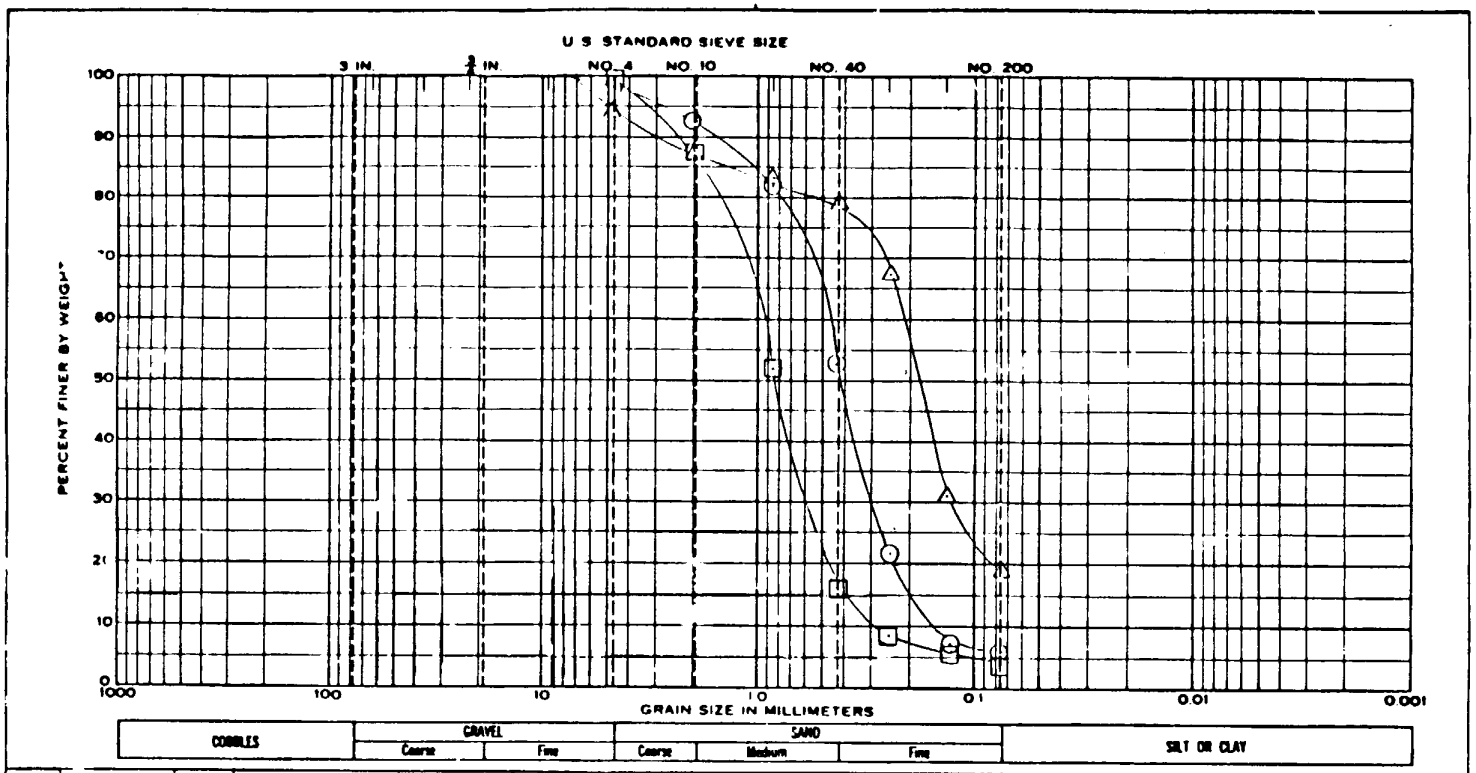


Figure 2.6-44 (SHEET 1 OF 8)
GRADATION CURVES



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASSIF.	M.C.	LL	PI
⊙	B-1	19'-20.5'	FINE TO COARSE SAND, TRACE SILT, WITH GRAVEL - TAN	SP-SM	–	–	–
⊡	B-1	27'-30.5'	FINE TO COARSE SAND, TRACE SILT AND FINE GRAVEL - TAN	SP-SM	–	–	–
△	B-1	34'-35.5'	FINE TO MEDIUM SAND, SOME SILT, WITH SHELL FRAGMENTS - BROWN	SM	24.4	NP	NP

SCHNABEL ENGINEERING ASSOCIATES

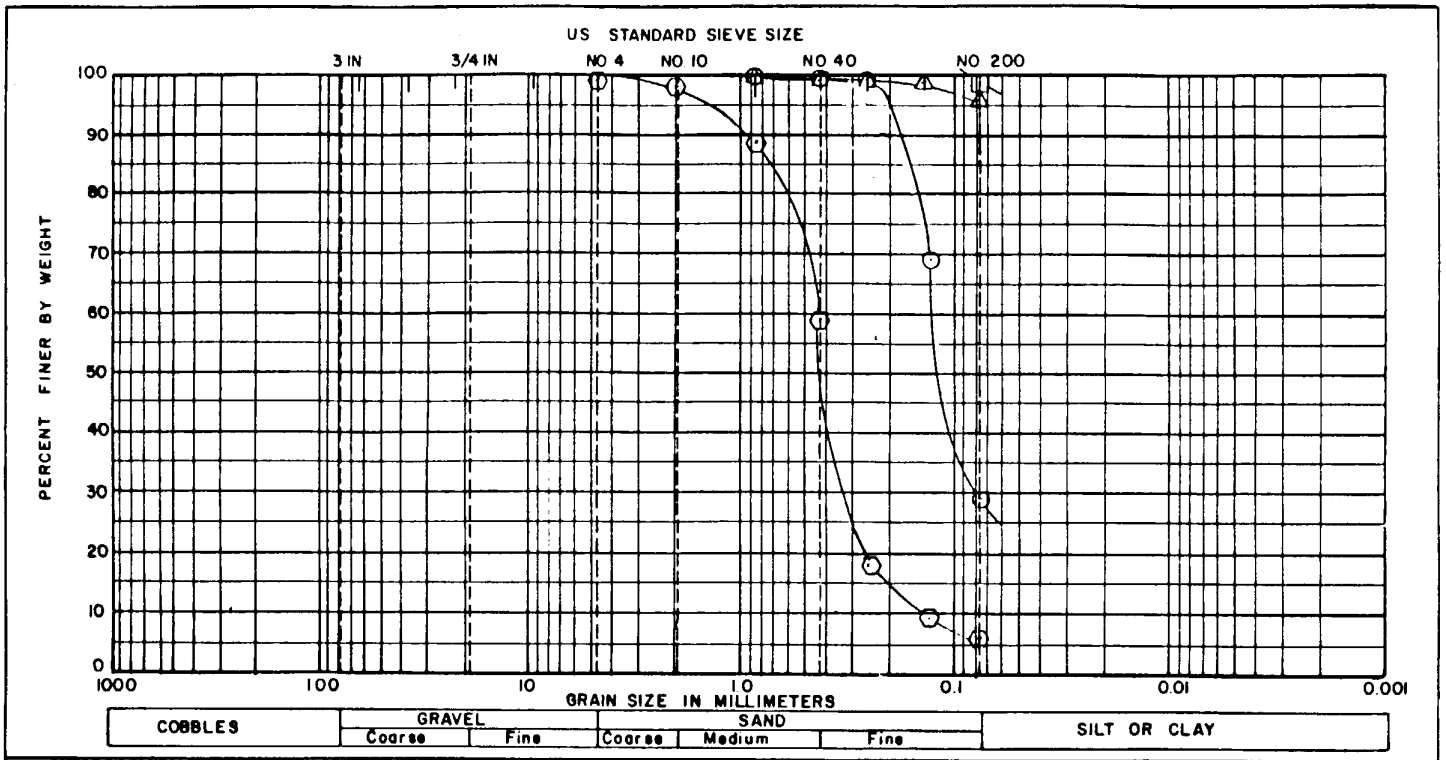
GRADATION CURVES

PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO., VA.

DATE: 6/11/82 CONTR. NO.: VS[illegible]

SI020651

Figure 2.6-44 (SHEET 2 OF 8)
GRADATION CURVES



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASS	MC	LL	PI
⊙	B-1	49'-50.5'	FINE SAND, SOME SILT, WITH SHELL FRAGMENTS - GRAY	SM	30.5	NP	NP
⊡	B-3	0'-1.5'	SILTY CLAY, TRACE FINE SAND - BROWN	CL	21.7	24	11
△	B-3	4'-5.5'	CLAY, TRACE FINE SAND - GRAY	CH	24.3	58	38
⊙	B-3	14-15.5'	FINE TO COARSE SAND, TRACE SILT - TAN AND BROWN	SP-SM	-	-	-

SCHNABEL ENGINEERING ASSOCIATES

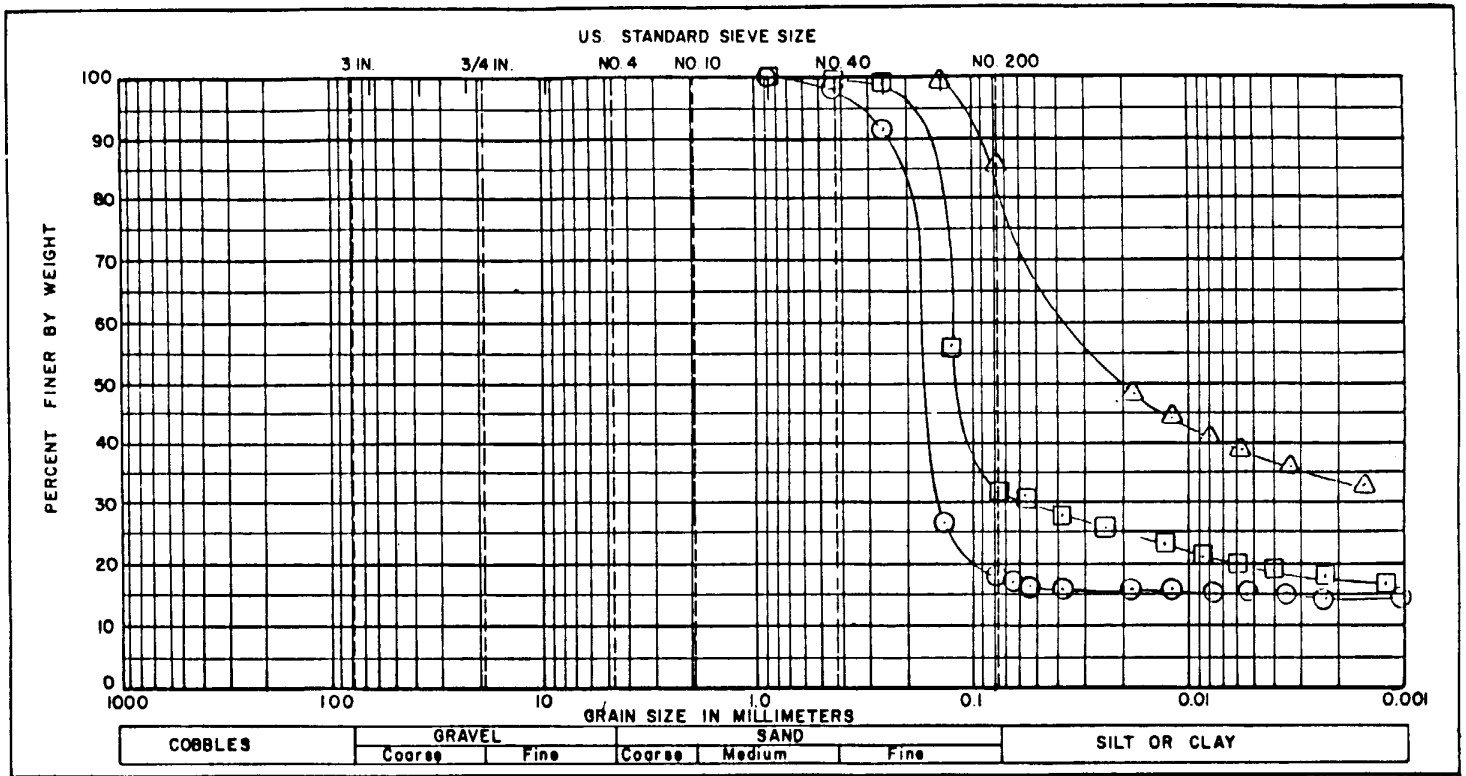
GRADATION CURVES

PROJET: DRY CASK SPENT FUEL FACILITY, SURRY CO., VA.

DATE: 6/11/82 CONTRACT NO. VP2[illegible]

SI020652

Figure 2.6-44 (SHEET 3 OF 8)
GRADATION CURVES



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASS	MC	LL	PI
⊙	B-3	31'-35'	FINE SAND, SOME SILT - BROWN	SM	-	NP	NP
⊡	B-3	44'-45'	FINE SAND, SOME SILT WITH SHELL FRAGMENTS - GREENISH GRAY	SM	31.6	NP	NP
△	B-3	14'-15'	CLAY, SOME FINE SAND, WITH SHELL FRAGMENTS - GREENISH GRAY	CH	44.9	57	30

SCHNABEL ENGINEERING ASSOCIATES

GRADATION CURVES

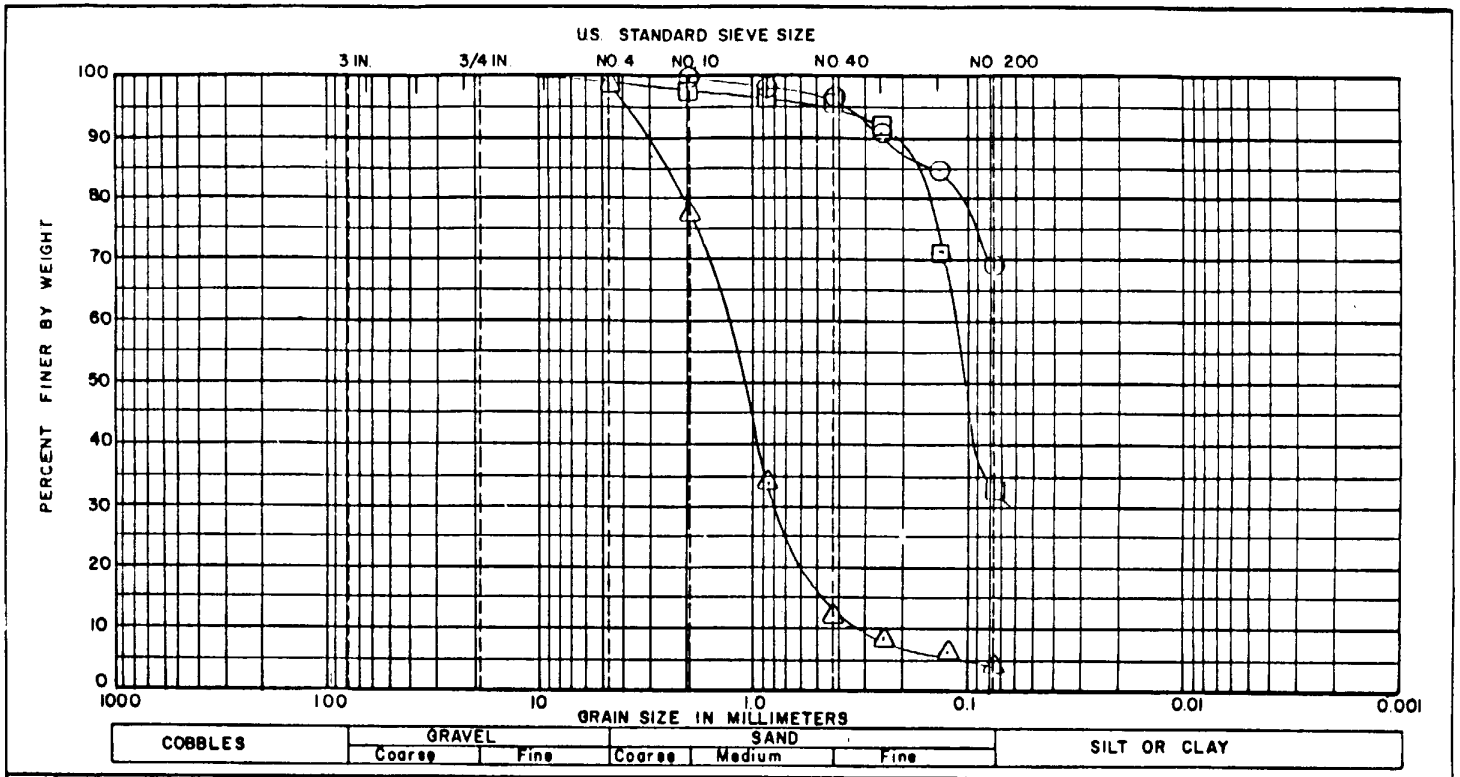
PROJET: DRY CASK SPENT FUEL

FACILITY, SURRY CO. VA.

DATE: 6/11/82 CONTRACT NO. [illegible]

S1020653

Figure 2.6-44 (SHEET 4 OF 8)
GRADATION CURVES



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASS	MC	LL	PI
○	B-4	4'-0"	FINE SILT, SOME SAND, WITH ORGANIC MATTER AND SHELL FRAGMENTS GRAY AND BROWN	ML	-	-	-
□	B-4	14'-15'	FINE SAND, SOME SILT - BROWN	SM	-	-	-
△	B-4	24'-30'	FINE TO COARSE SAND, TRACE SILT AND FINE GRAVEL - TAN	SP-SM	-	-	-

SCHNABEL ENGINEERING ASSOCIATES

GRADATION CURVES

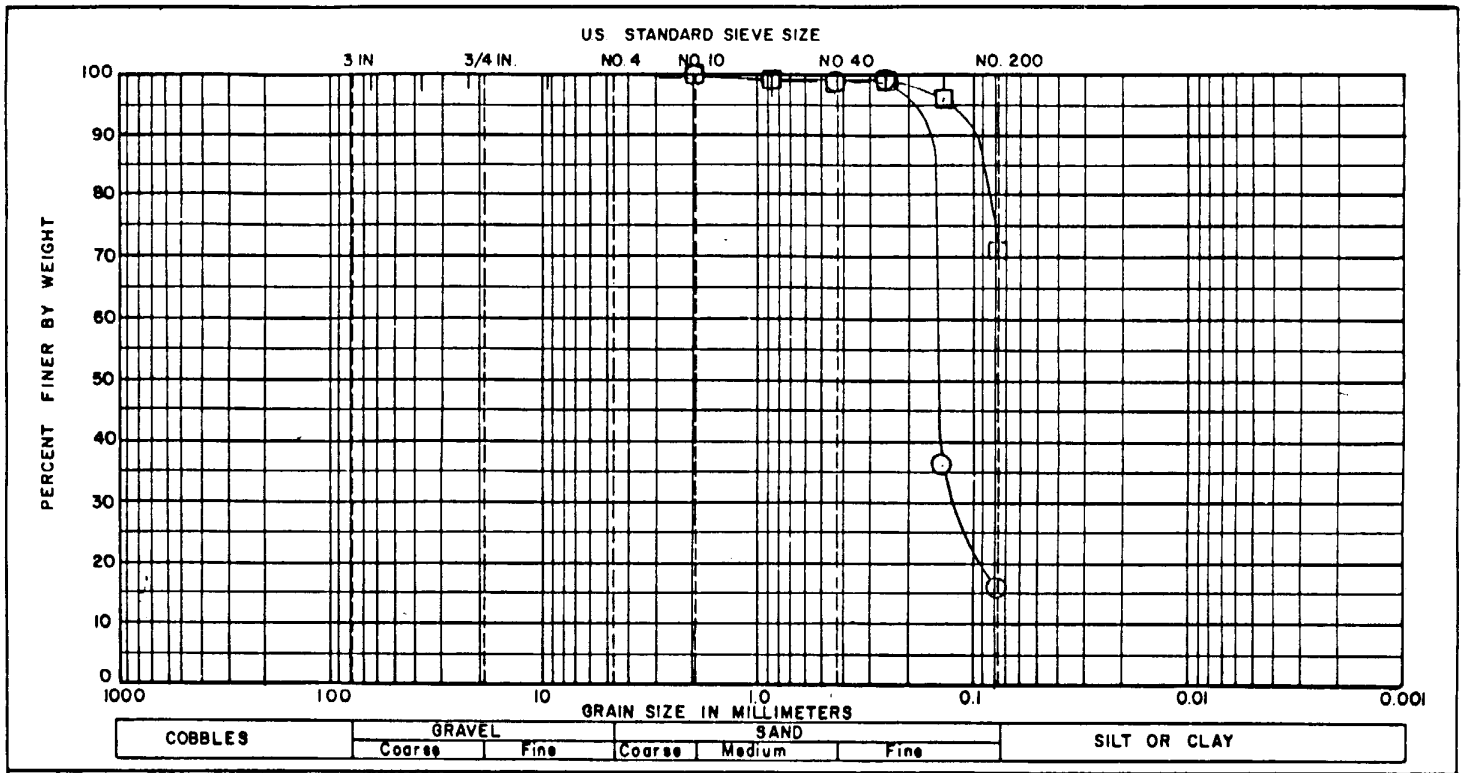
PROJET: DRY CASK SPENT FUEL

FACILITY: SURRY CO., VA.

DATE: 6/11/82 CONTRACT NO. VP2762

S1020654

Figure 2.6-44 (SHEET 5 OF 8)
GRADATION CURVES



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASS	MC	LL	PI
○	B-4	44'-45'	FINE SAND, SOME SILT, WITH SHELL FRAGMENTS - DARK GREENISH GRAY	SM	29.3	NP	NP
□	B-4	49'-50'	CLAYEY SILT, SOME FINE SAND, WITH SHELL FRAGMENTS - DARK GRAY	ML-MH	34.4	50	17

SCHNABEL ENGINEERING ASSOCIATES

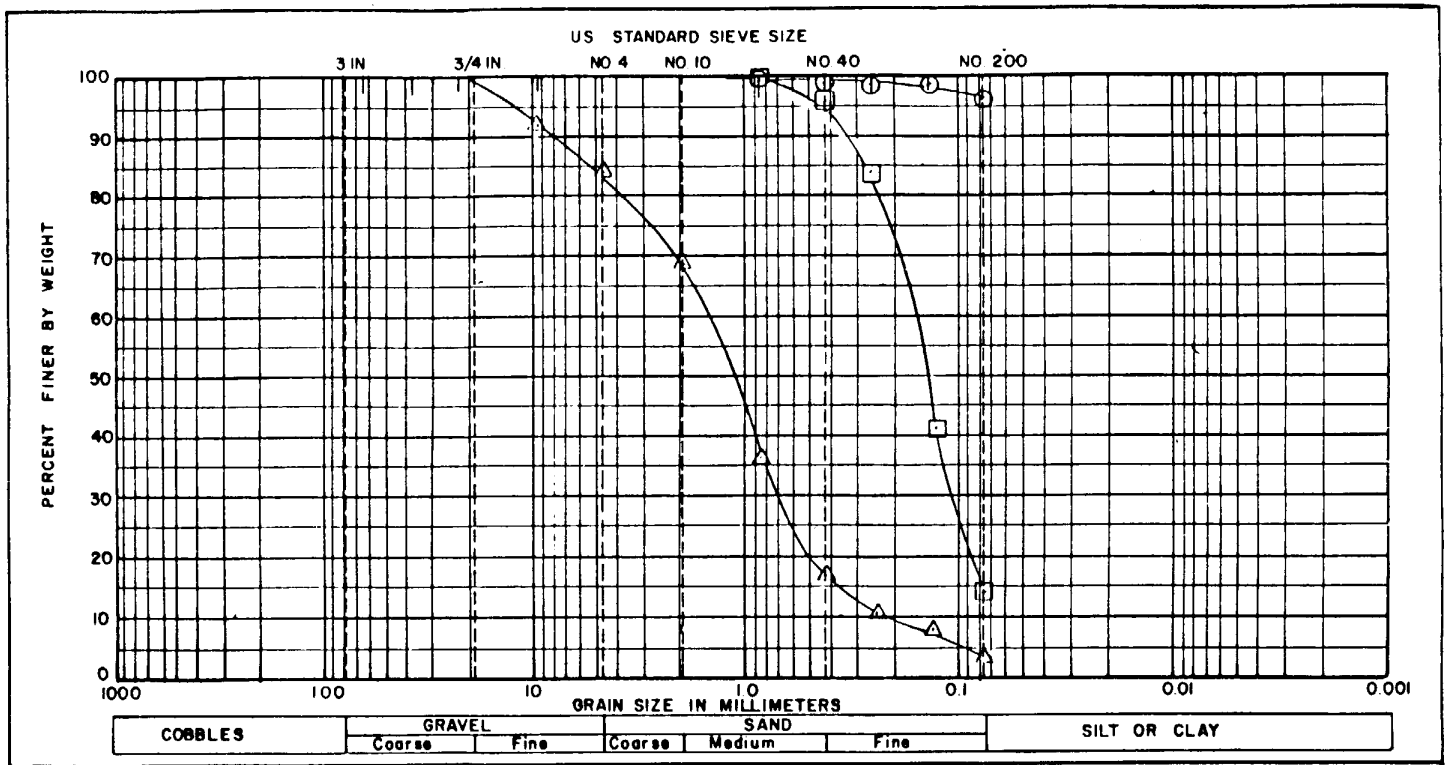
GRADATION CURVES

PROJET: DRY CASK SPENT FUEL FACILITY, SURRY CO, VA.

DATE: 6/11/82 CONTRACT NO. 86-182

S1020655

Figure 2.6-44 (SHEET 6 OF 8)
GRADATION CURVES



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASS	MC	LL	PI
○	B-5	7.5'-9'	CLAYEY SILT, TRACE FINE SAND - GRAY AND BROWN	MH	36A	65	27
□	B-5	14'-15.5'	FINE SAND, SOME SILT - BROWN	SM	-	-	-
△	B-5	29'-30.5'	FINE TO COARSE SAND, SOME FINE GRAVEL, TRACE SILT - BROWN	SW-SM	-	-	—

SCHNABEL ENGINEERING ASSOCIATES

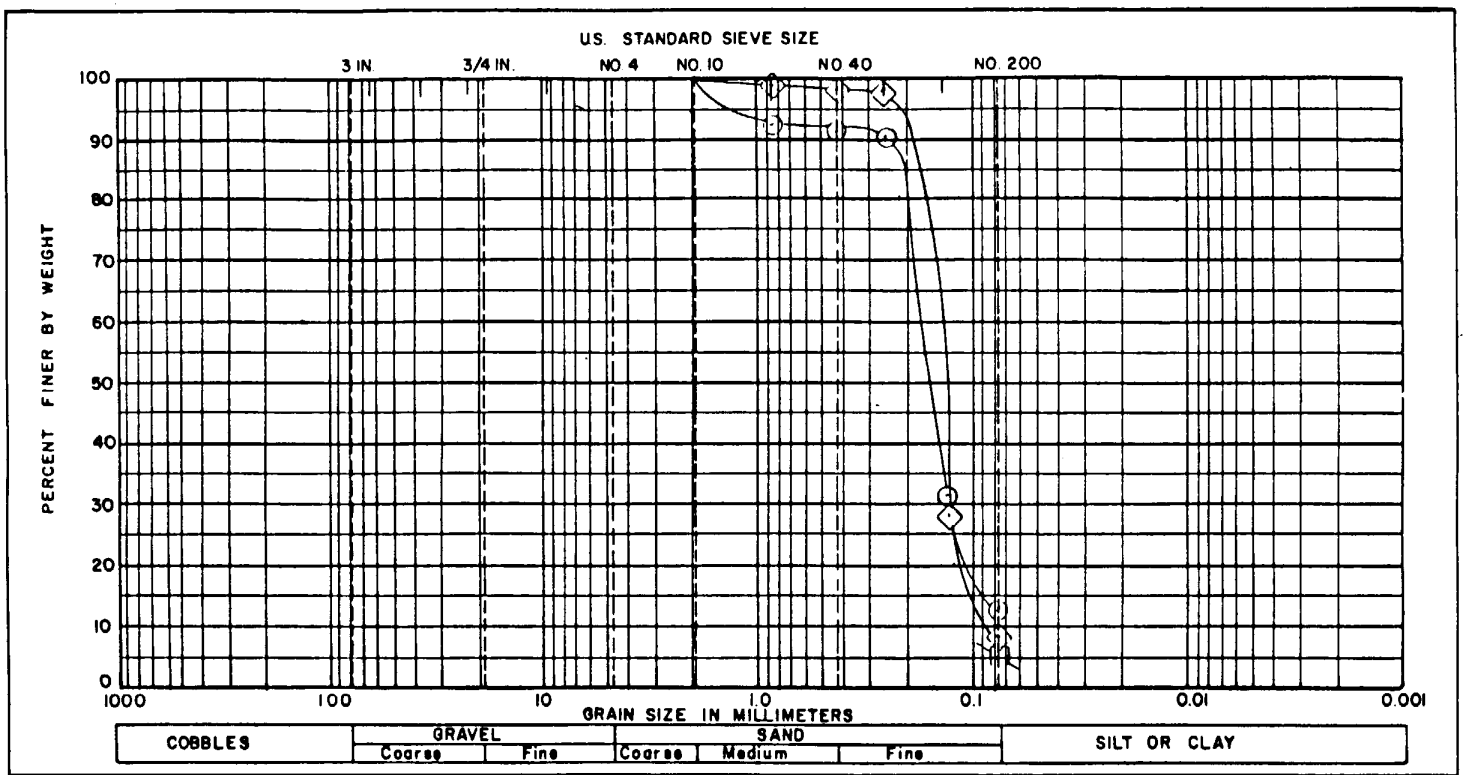
GRADATION CURVES

PROJET: DRY CASK SPENT FUEL FACILITY, SURRY CO, VA.

DATE 6/11/97 CONTRACT NO. [illegible]

SI020656

Figure 2.6-44 (SHEET 7 OF 8)
GRADATION CURVES



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASS	MC	LL	PI
⊙	B-5	44'-45'	FINE SAND, SOME SILT, WITH SHELL FRAGMENTS - GRAY	SM	29.2	NP	NP
⊡	B-6	24'-25'	FINE TO COARSE SAND, TRACE SILT AND FINE GRAVEL - TAN	SP-SM	–	–	–
◈	B-6	44'-45'	FINE SAND, TRACE SILT, WITH SHELL FRAGMENTS	SP-SM	20.2	NP	NP

SCHNABEL ENGINEERING ASSOCIATES

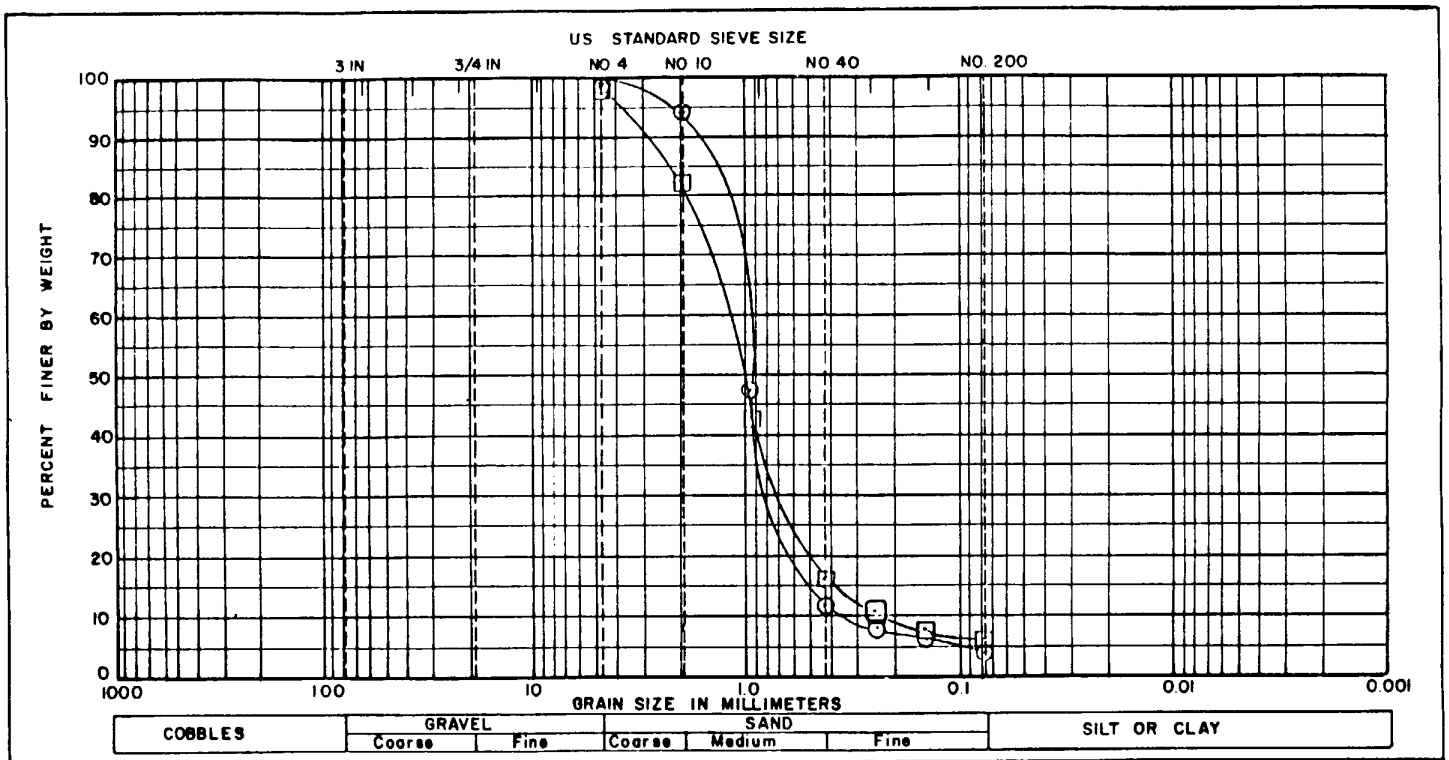
GRADATION CURVES

PROJET: DRY CASK STORAGE FACILITY, SURRY CO[illegible]

DATE: 6/11/82 CONTRACT NO.[illegible]

SI020657

Figure 2.6-44 (SHEET 8 OF 8)
GRADATION CURVES



KEY	BORING	DEPTH	DESCRIPTION OF SOIL SAMPLE TESTED	CLASS	MC	LL	PI
⊙	B-7	29'3"	FINE TO COARSE SAND, TRACE SILT AND FINE GRAVEL - TAN	SP-SM	-	-	-
□	B-8	29'3"	FINE TO COARSE SAND, TRACE SILT AND FINE GRAVEL - TAN	SW-SM	-	-	-

SCHNABEL ENGINEERING ASSOCIATES

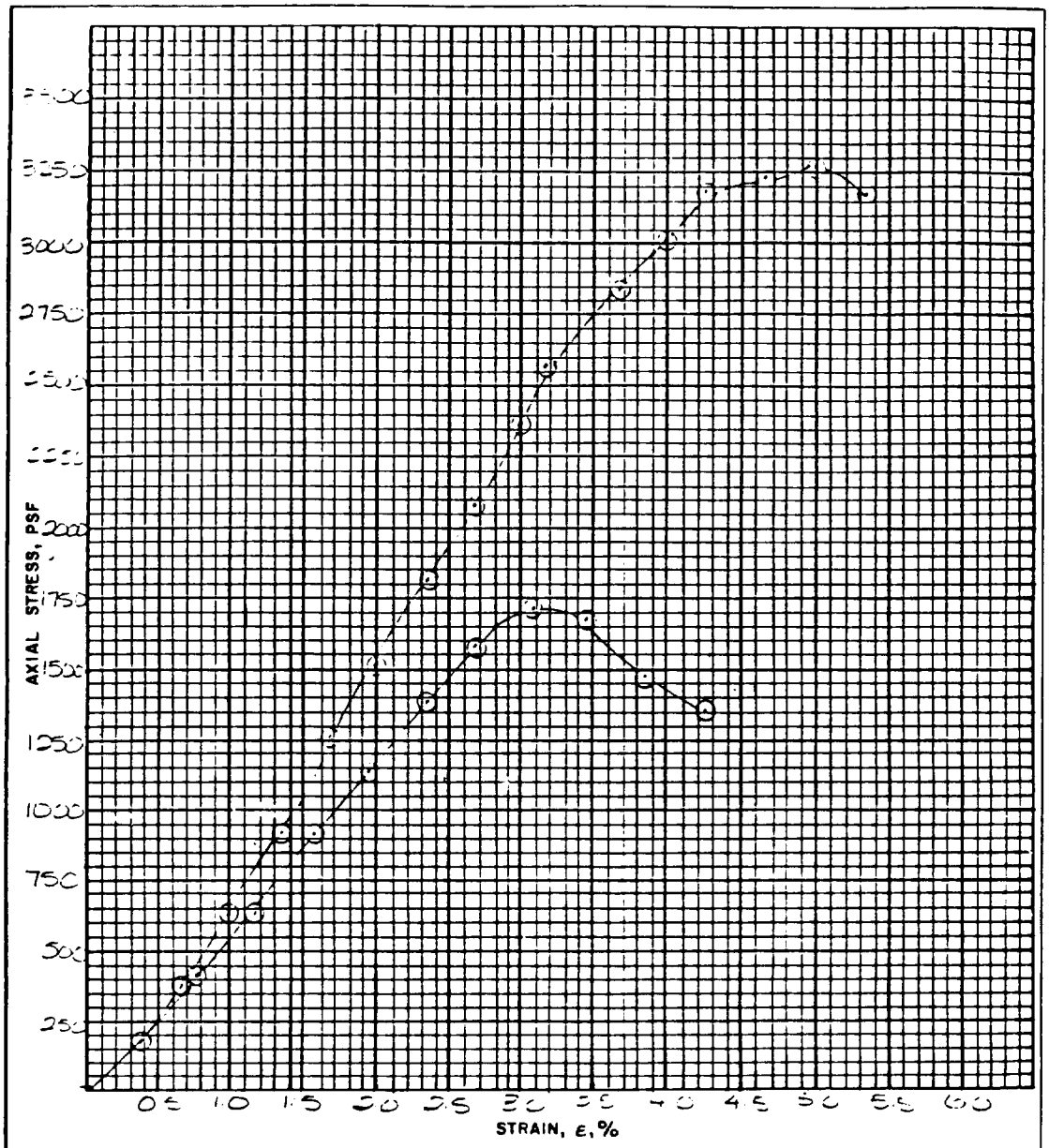
GRADATION CURVES

PROJET: DRY CASK SPENT FUEL

FACILITY, SURRY CO. VA.

SI020658

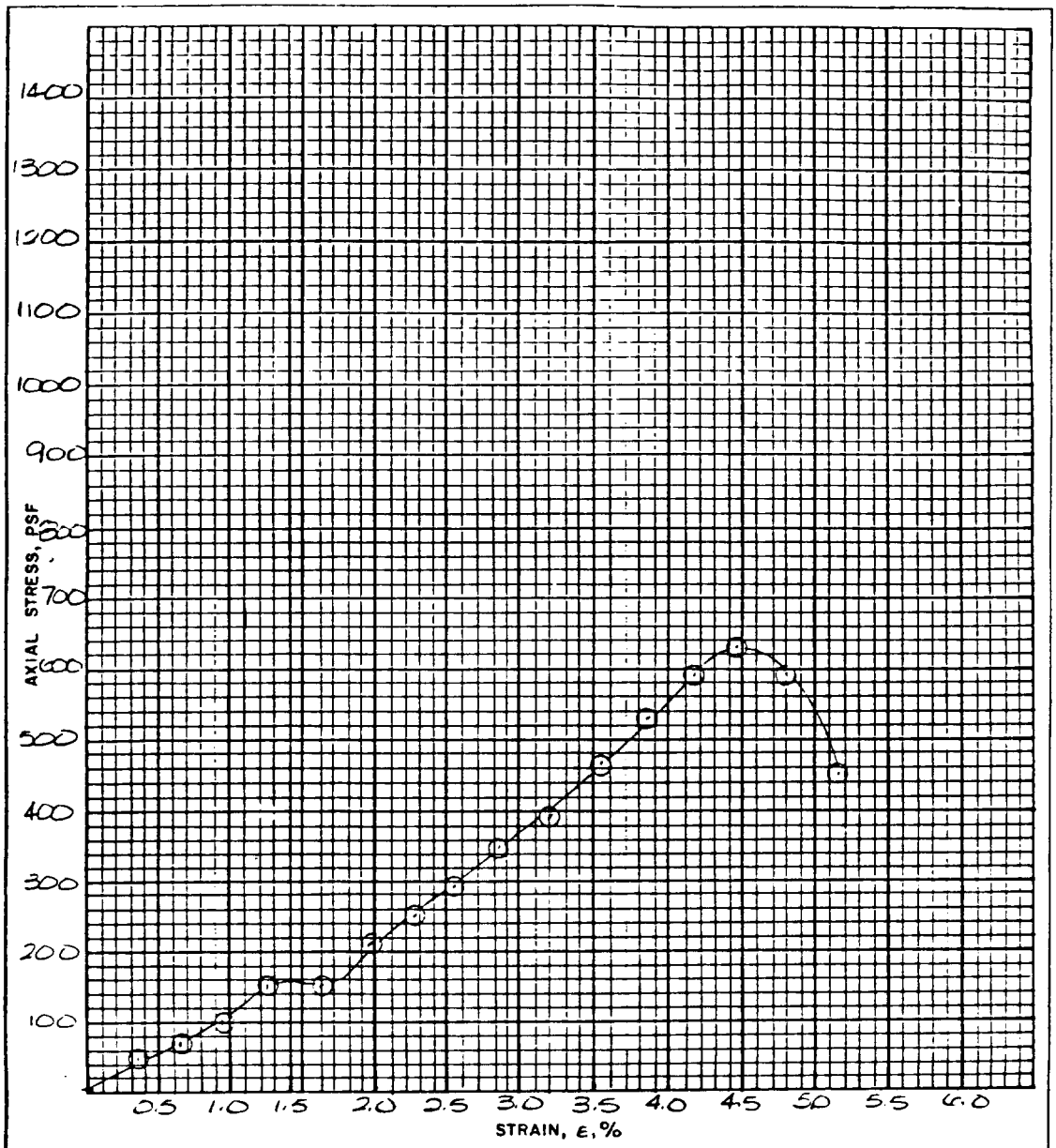
Figure 2.6-45 (SHEET 1 OF 4)
UNCONFINED COMPRESSION TEST



DESCRITION OF SOIL SAMPLE TESTED			SCHNABEL ENGINEERING ASSOCIATES
CLAYEY SILT, TRACE FINE SAND - GRAY AND BROWN (CH)			UNCONFINED COMPRESSION TEST
BORING NO.: B-5U	DEPTH, FT.: 4'-6'		PROJECT: DRY CASK SPENT FUEL
MOIST. CONTENT, %	WET DENSITY, PCF	DRY DENSITY, PCF	FACILITY, SURRY CO, VA.
22.5	120.4	98.0	DATE: 6/11/82 CONTRACT NO. VS-15

SI020659

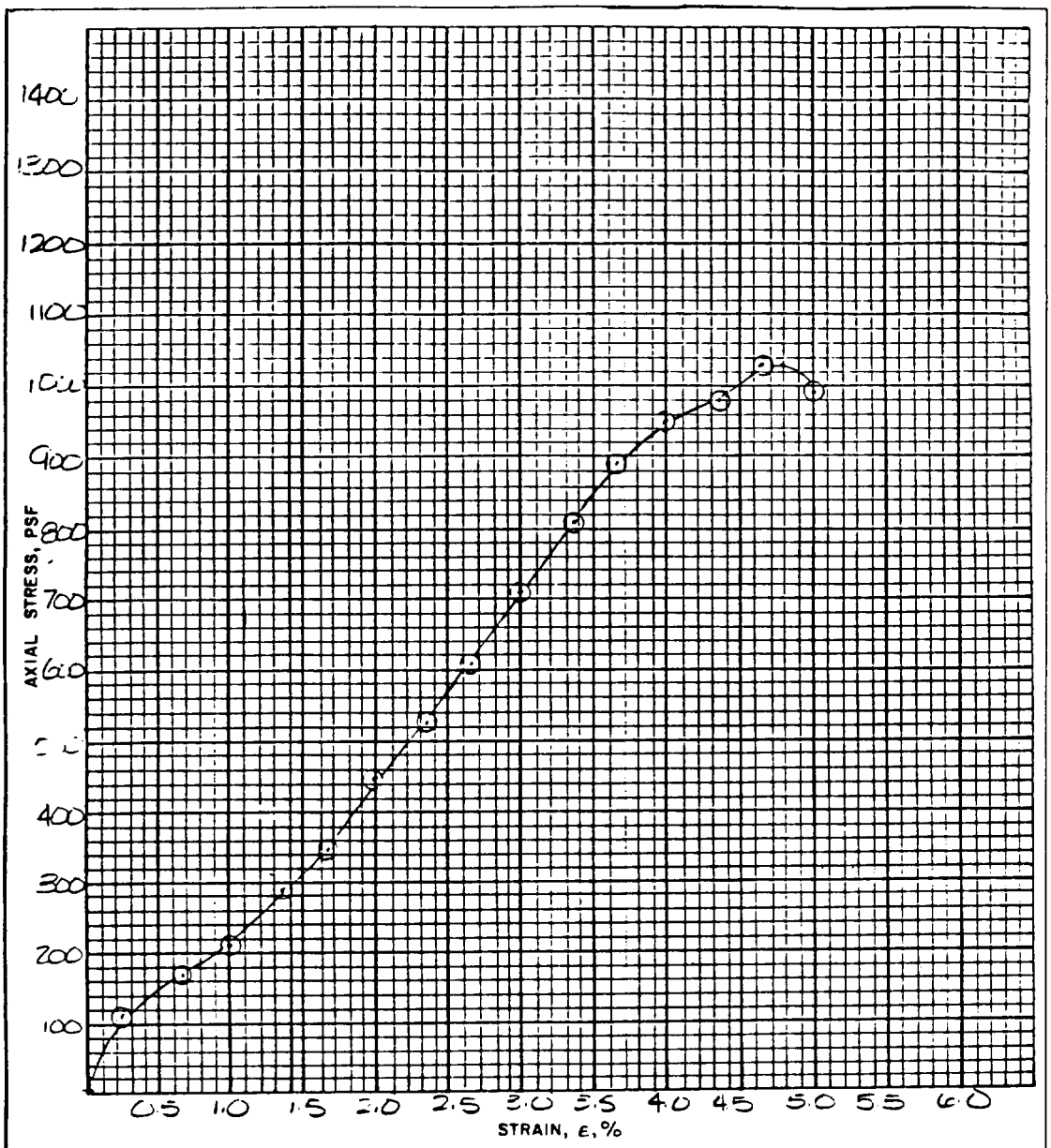
Figure 2.6-45 (SHEET 2 OF 4)
UNCONFINED COMPRESSION TEST



DESCRITION OF SOIL SAMPLE TESTED			SCHNABEL ENGINEERING ASSOCIATES	
CLAYEY SILT, SOME FINE TO COARSE SAND - BROWN & TAN (ML)			UNCONFINED COMPRESSION TEST	
BORING NO.: B-54	DEPTH, FT.: 11' - 13'		PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO., VA.	
MOIST. CONTENT, %	WET DENSITY, PCF	DRY DENSITY, PCF	DATE: 6/11/82	CONTRACT NO. VEC182
31.4	116.5	88.7		

S1020660

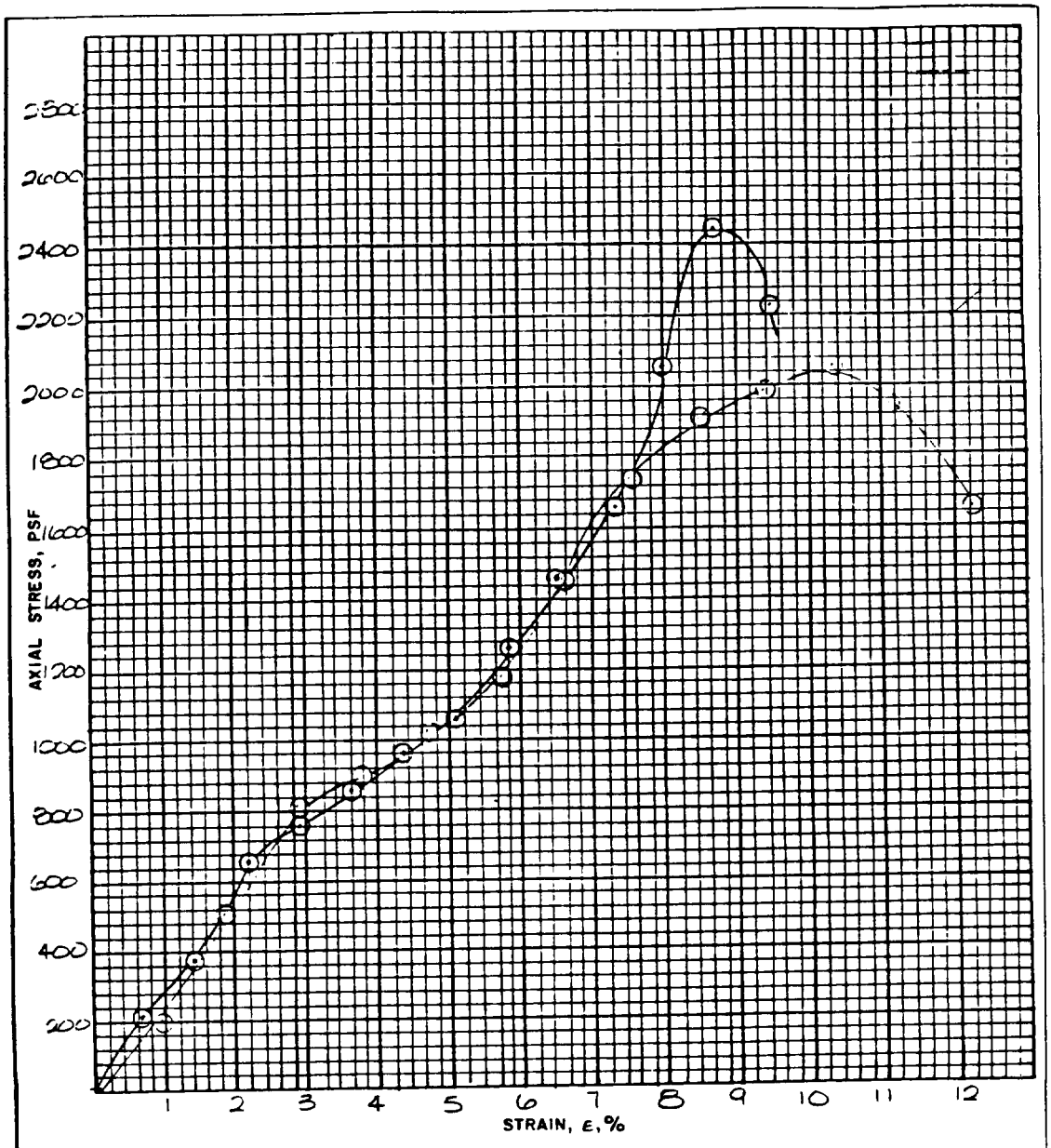
Figure 2.6-45 (SHEET 3 OF 4)
UNCONFINED COMPRESSION TEST



DESCRITION OF SOIL SAMPLE TESTED			SCHNABEL ENGINEERING ASSOCIATES
FINE TO MEDIUM SANDY SILTY CLAY - CLAY AND SILT (CL)			UNCONFINED COMPRESSION TEST
BORING NO.: B-54	DEPTH, FT.: 11'-13'		PROJECT: DRY CASK SPENT FUEL
MOIST. CONTENT, %	WET DENSITY, PCF	DRY DENSITY, PCF	FACILITY, SURRY CO., VA
15.1	116.5	101.2	DATE: 6/11/82 CONTRACT NO. VE2182

S1020661

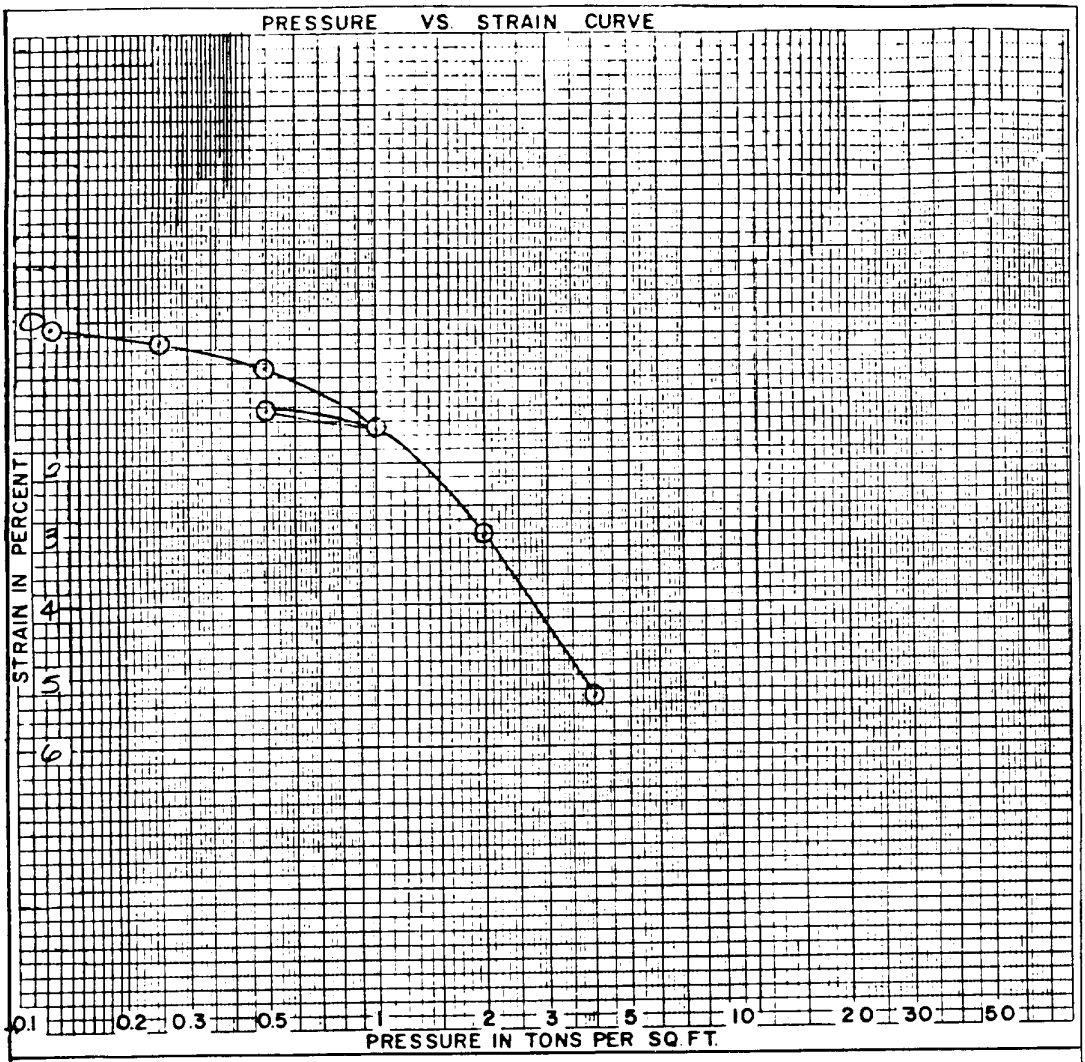
Figure 2.6-45 (SHEET 4 OF 4)
UNCONFINED COMPRESSION TEST



DESCRITION OF SOIL SAMPLE TESTED			SCHNABEL ENGINEERING ASSOCIATES
SILTY CLAY, TRACE FINE SAND - LIGHT GRAY AND BROWN (CL)			UNCONFINED COMPRESSION TEST
BORING NO: B-8	DEPTH, FT.: 7' - 9'		PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO., VA
MOIST CONTENT, %	WET DENSITY, PCF	DRY DENSITY, PCF	DATE: 6/11/82 CONTRACT NO. V82195
36.5	120.9	88.2	

SI020662

Figure 2.6-46 (SHEET 1 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:
SILTY CLAY, TRACE FINE SAND - BROWN & TAN

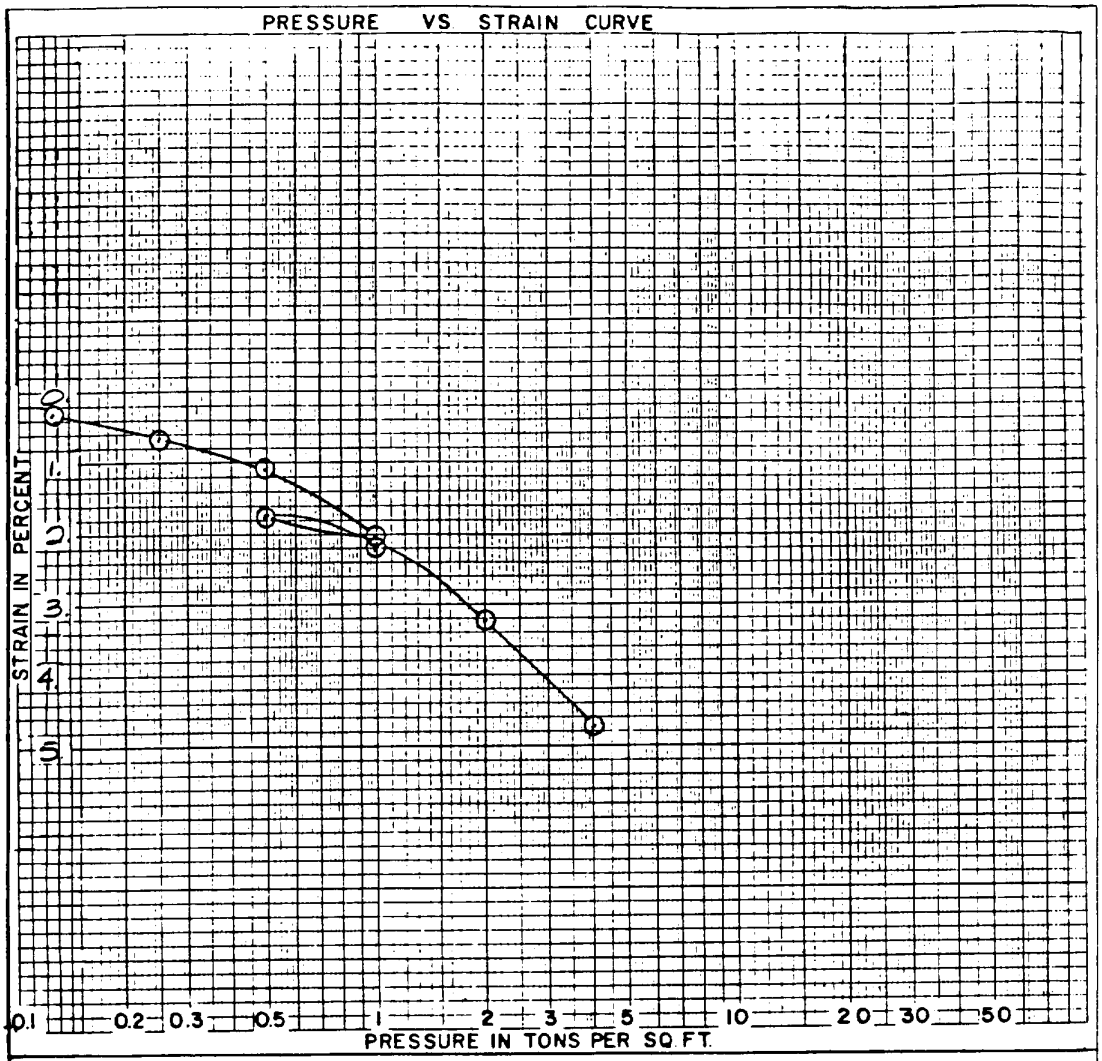
CLASSIFICATION: CL STRATUM DESIGNATION: -

DIAMETER OF SPECIMEN (in.)	2.5
INITIAL THICKNESS OF SPECIMEN (in.)	1.0
INITIAL VOID RATIO, e_o	0.89
PROBABLE PRECONSOLIDATION STRESS (tsf) Pc	-
APPROXIMATE OVERBURDEN STRESS (tsf) Po	-
COMPRESSION RATIO; FROM 2 TO 4 (tsf)	0.076
COMPRESSION INDEX; FROM 2 TO 4 (tsf)	0.144
RECOMPRESSION RATIO; FROM 1/2 TO 1 (tsf)	0.008
RECOMPRESSION INDEX; FROM 1/2 TO 1 (tsf)	0.015

SCHNABEL ENGINEERING ASSOCIATE
CONSOLIDATION TEST
BORING NO: B-2 DEPTH: 2-4'
PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO.
DATE 6/11/82
CONTRACT NO. V82182

SI020663

Figure 2.6-46 (SHEET 2 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:

SILTY CLAY, TRACE FINE SAND - GRAY & BROWN

CLASSIFICATION: CL STRATUM DESIGNATION:-

DIAMETER OF SPECIMEN (in.)	2.5
INITIAL THICKNESS OF SPECIMEN (in.)	1.0
INITIAL VOID RATIO, e_o	0.75
PROBABLE PRECONSOLIDATION STRESS(tsf)Pc	-
APPROXIMATE OVERBURDEN STRESS (tsf) Po	-
COMPRESSION RATIO; FROM 2 TO 4 (tsf)	0.050
COMPRESSION INDEX; FROM 2 TO 4 (tsf)	0.090
RECOMPRESSION RATIO; FROM 1/2 TO 1 (tsf)	0.037
RECOMPRESSION INDEX; FROM 1/2 TO 1 (tsf)	0.065

SCHNABEL ENGINEERING ASSOCIATES

CONSOLIDATION TEST

BORING NO.: B-2 DEPTH: 7-9'

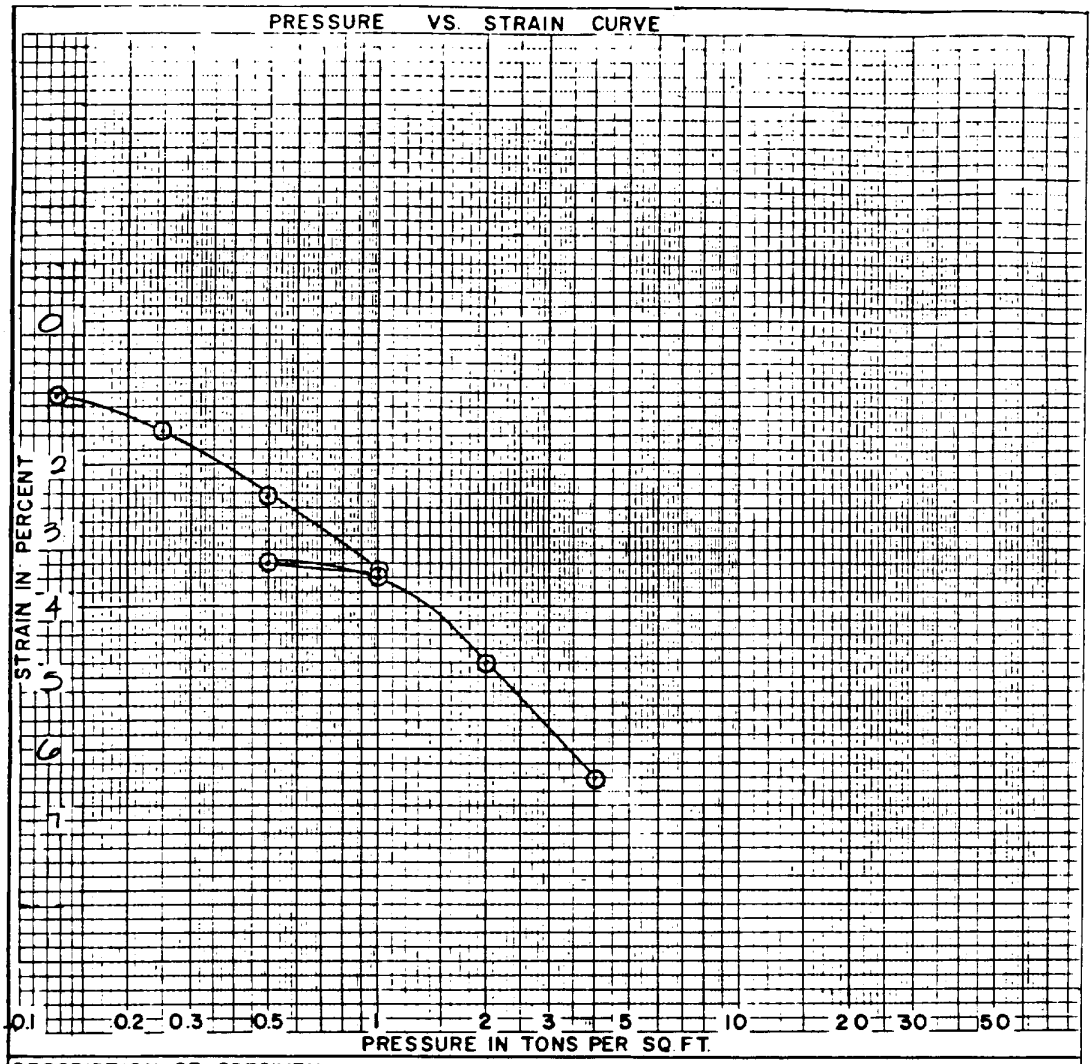
PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO, VA

DATE 6/11/82

CONTRACT NO. V82182

SI020664

Figure 2.6-46 (SHEET 3 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:

FINE SILTY SAND WITH SHELL FRAGMENTS - DARK GRAY

CLASSIFICATION: SM STRATUM DESIGNATION: -

DIAMETER OF SPECIMEN (in.)	2.5
INITIAL THICKNESS OF SPECIMEN (in.)	1.0
INITIAL VOID RATIO, e_o	0.79
PROBABLE PRECONSOLIDATION STRESS (tsf) Pc	-
APPROXIMATE OVERBURDEN STRESS (tsf) Po	-
COMPRESSION RATIO; FROM 2 TO 4 (tsf)	0.050
COMPRESSION INDEX; FROM 2 TO 4 (tsf)	0.090
RECOMPRESSION RATIO; FROM 1/2 TO 1 (tsf)	0.007
RECOMPRESSION INDEX; FROM 1/2 TO 1 (tsf)	0.012

SCHNABEL ENGINEERING ASSOCIATES

CONSOLIDATION TEST

BORING NO.: B-2 DEPTH: 52'-54'

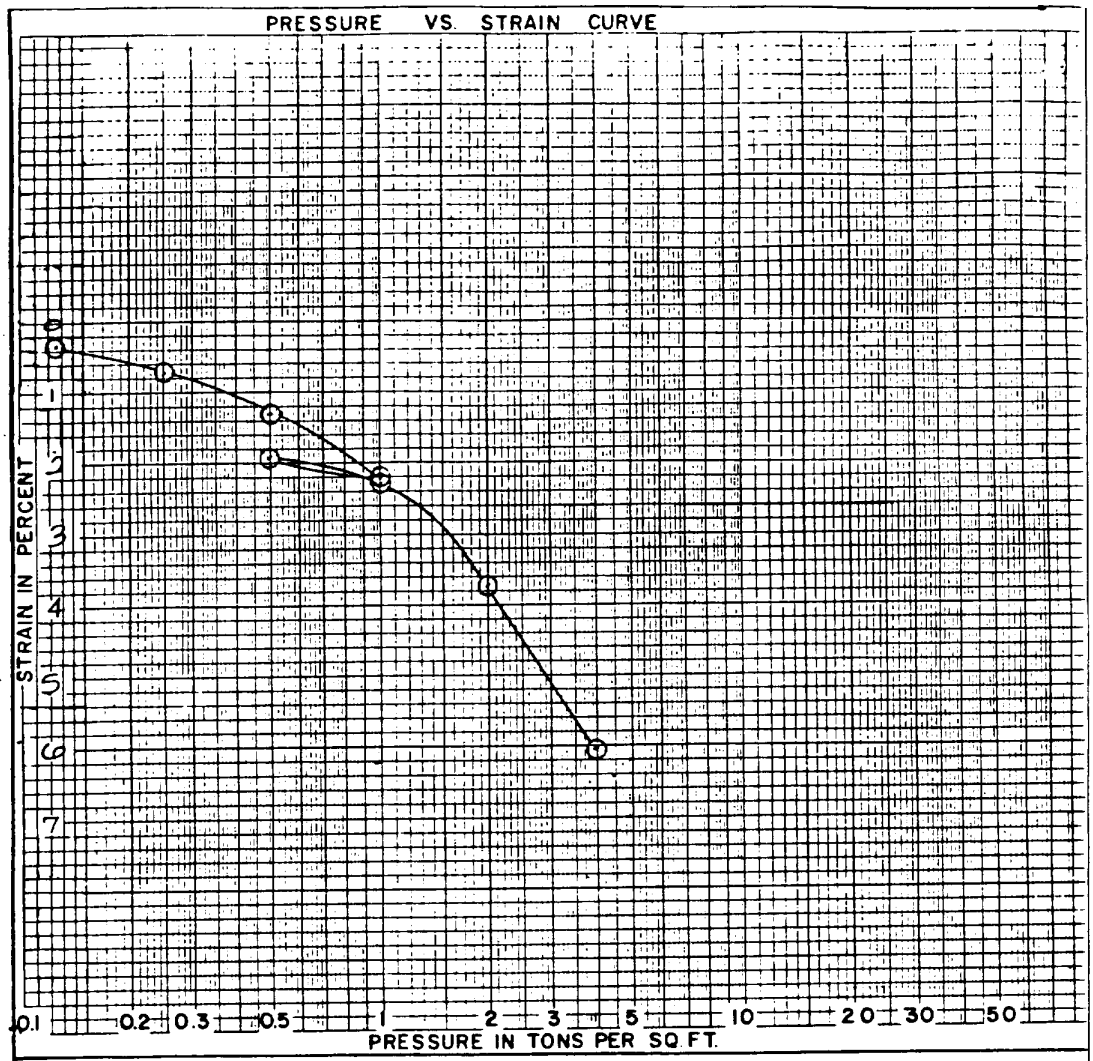
PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO., V

DATE 6/11/82

CONTRACT NO. V82182

SI020665

Figure 2.6-46 (SHEET 4 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:
CLAY, TRACE FINE SAND - LIGHT BROWN AND TAN

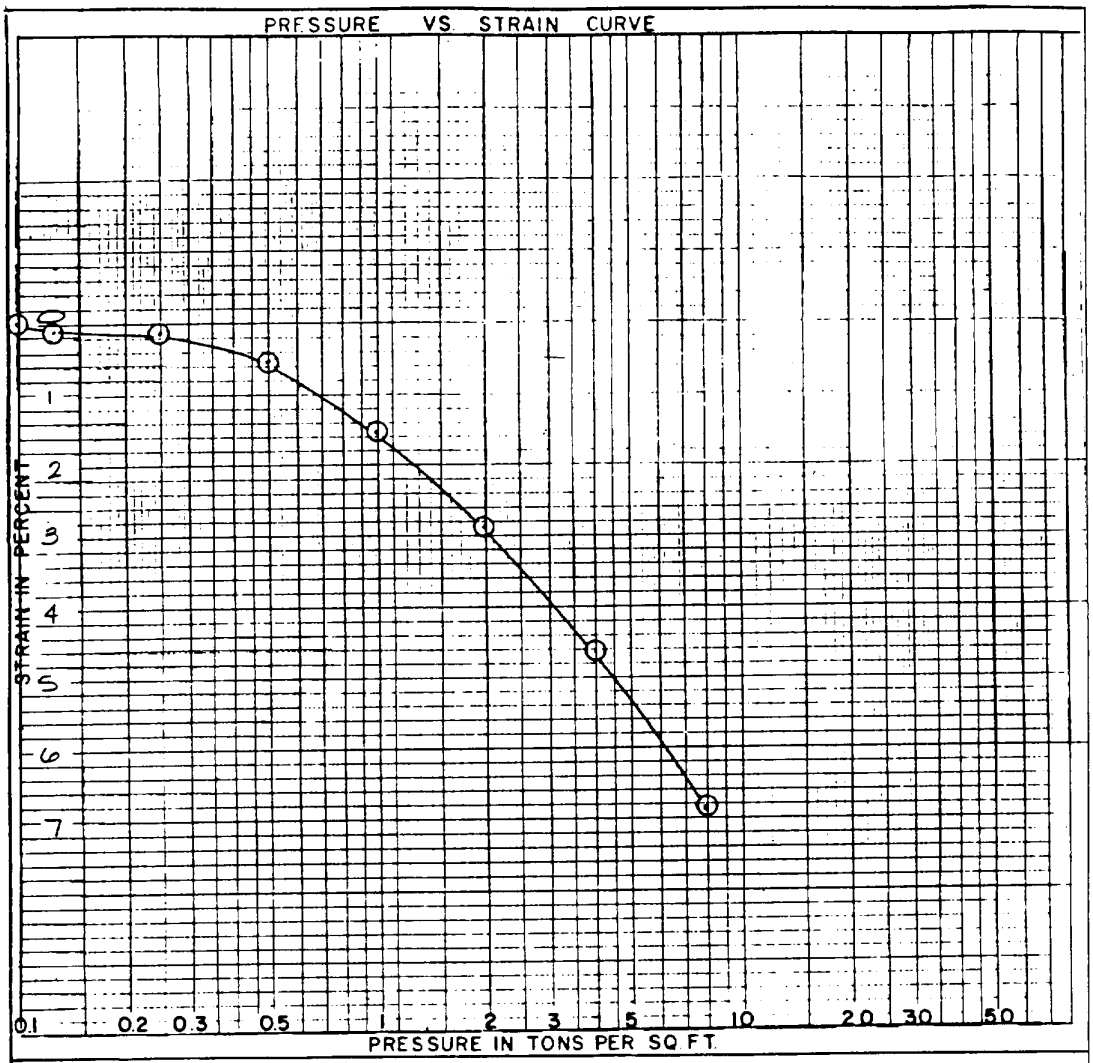
CLASSIFICATION: CH STRATUM DESIGNATION:

DIAMETER OF SPECIMEN (in.)	2.5
INITIAL THICKNESS OF SPECIMEN (in.)	1.0
INITIAL VOID RATIO, e_o	0.85
PROBABLE PRECONSOLIDATION STRESS (tsf) Pc	–
APPROXIMATE OVERBURDEN STRESS (tsf) Po	–
COMPRESSION RATIO; FROM 2 TO 4 (tsf)	0.078
COMPRESSION INDEX; FROM 2 TO 4 (tsf)	0.144
RECOMPRESSION RATIO; FROM 1/2 TO 1 (tsf)	0.010
RECOMPRESSION INDEX; FROM 1/2 TO 1 (tsf)	0.018

SCHNABEL ENGINEERING ASSOCIATES
CONSOLIDATION TEST
BORING NO.: B-5U DEPTH: 1' - 3'
PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO., V
DATE 6/11/82
CONTRACT NO. V82182

SI020666

Figure 2.6-46 (SHEET 5 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:
CLAYEY SILT, TRACE FINE SAND - GRAY AND BROWN

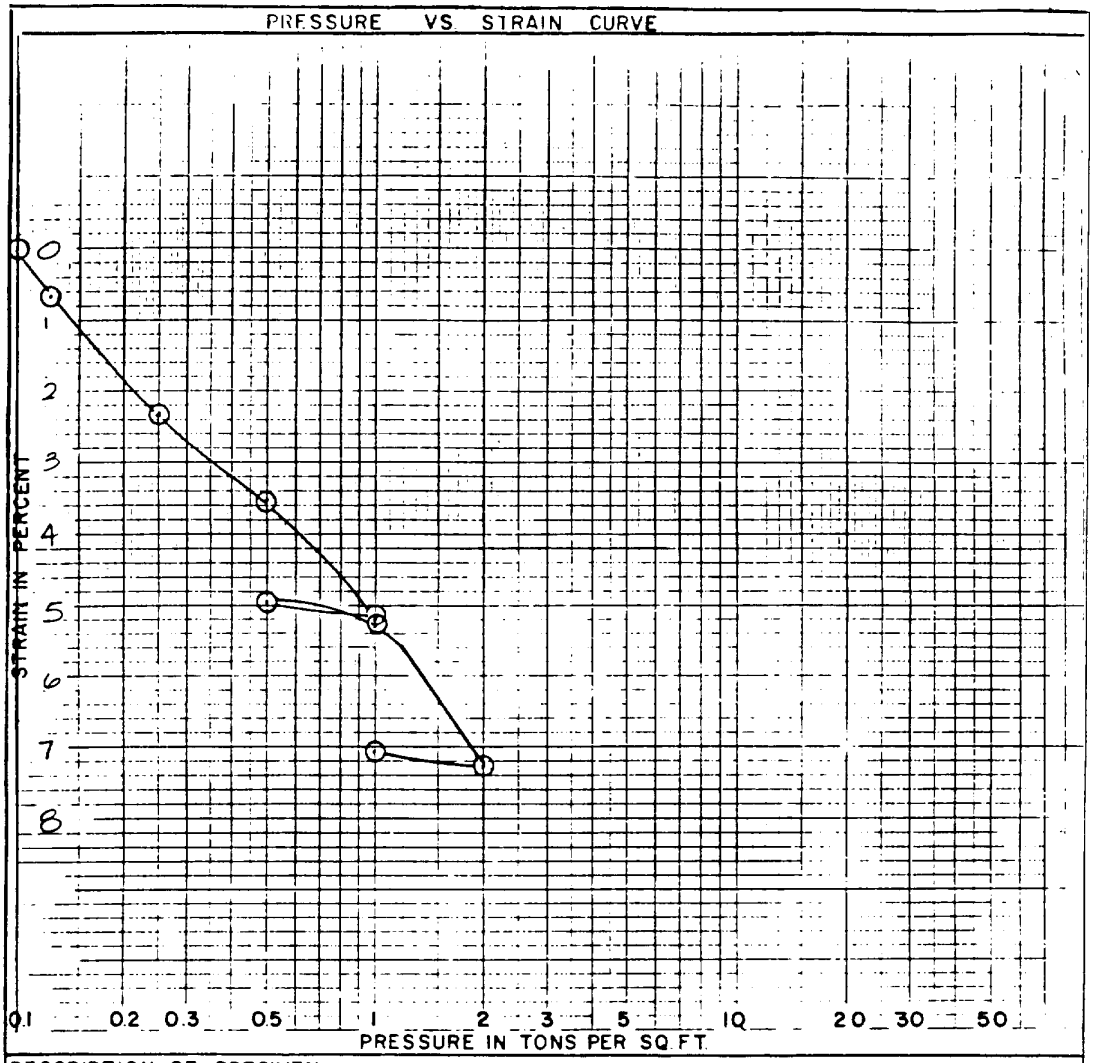
CLASSIFICATION: CH STRATUM DESIGNATION: -

DIAMETER OF SPECIMEN (in.)	2.50
INITIAL THICKNESS OF SPECIMEN (in.)	1.0
INITIAL VOID RATIO, e_o	0.78
PROBABLE PRECONSOLIDATION STRESS (tsf) Pc	-
APPROXIMATE OVERBURDEN STRESS (tsf) Po	-
COMPRESSION RATIO; FROM 4 TO 8 (tsf)	0.075
COMPRESSION INDEX; FROM 4 TO 8 (tsf)	0.133
RECOMPRESSION RATIO; FROM ___ TO ___ (tsf)	-
RECOMPRESSION INDEX; FROM ___ TO ___ (tsf)	-

SCHNABEL ENGINEERING ASSOCIATES
CONSOLIDATION TEST
BORING NO.: B-5U DEPTH: 4'-6'
PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO., VA.
DATE 6/11/82 CONTRACT NO. V82182

SI020667

Figure 2.6-46 (SHEET 6 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:
SILTY CLAY TRACE FINE SAND - GRAY

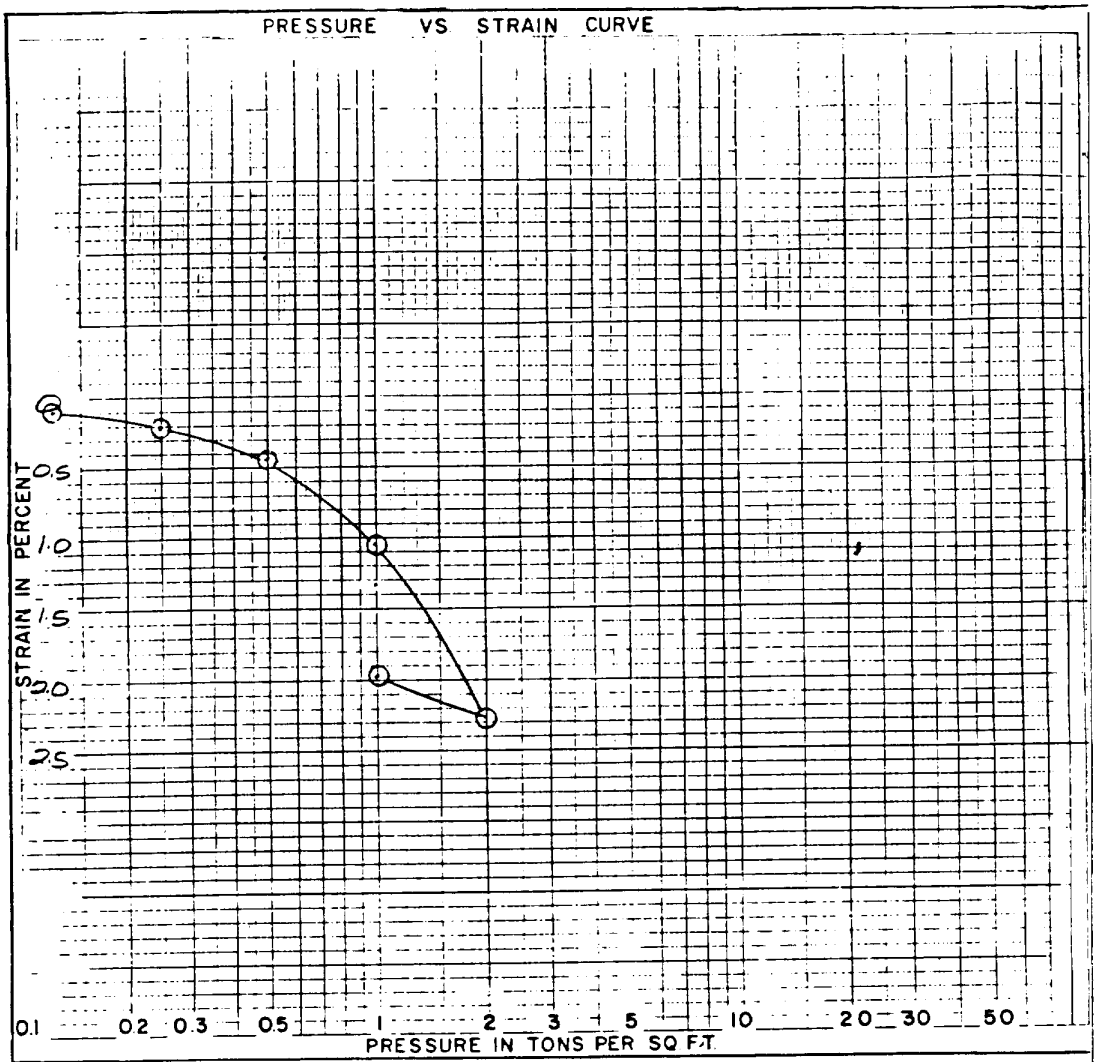
CLASSIFICATION: CL STRATUM DESIGNATION: -

DIAMETER OF SPECIMEN (in.)	2.5
INITIAL THICKNESS OF SPECIMEN (in.)	1.0
INITIAL VOID RATIO, e_o	0.60
PROBABLE PRECONSOLIDATION STRESS (tsf) Pc	-
APPROXIMATE OVERBURDEN STRESS (tsf) Po	-
COMPRESSION RATIO; FROM 1 TO 2 (tsf)	0.066
COMPRESSION INDEX; FROM 1 TO 2 (tsf)	0.110
RECOMPRESSION RATIO; FROM 1/2 TO 1 (tsf)	0.010
RECOMPRESSION INDEX; FROM 1/2 TO 1 (tsf)	0.018

SCHNABEL ENGINEERING ASSOCIATES
CONSOLIDATION TEST
BORING NO.: B-5U DEPTH: 7'-9'
PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO. VA
DATE 6/11/82 CONTRACT NO. VE-2162

SI020668

Figure 2.6-46 (SHEET 7 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:
CLAY, TRACE FINE SAND - LIGHT BROWN

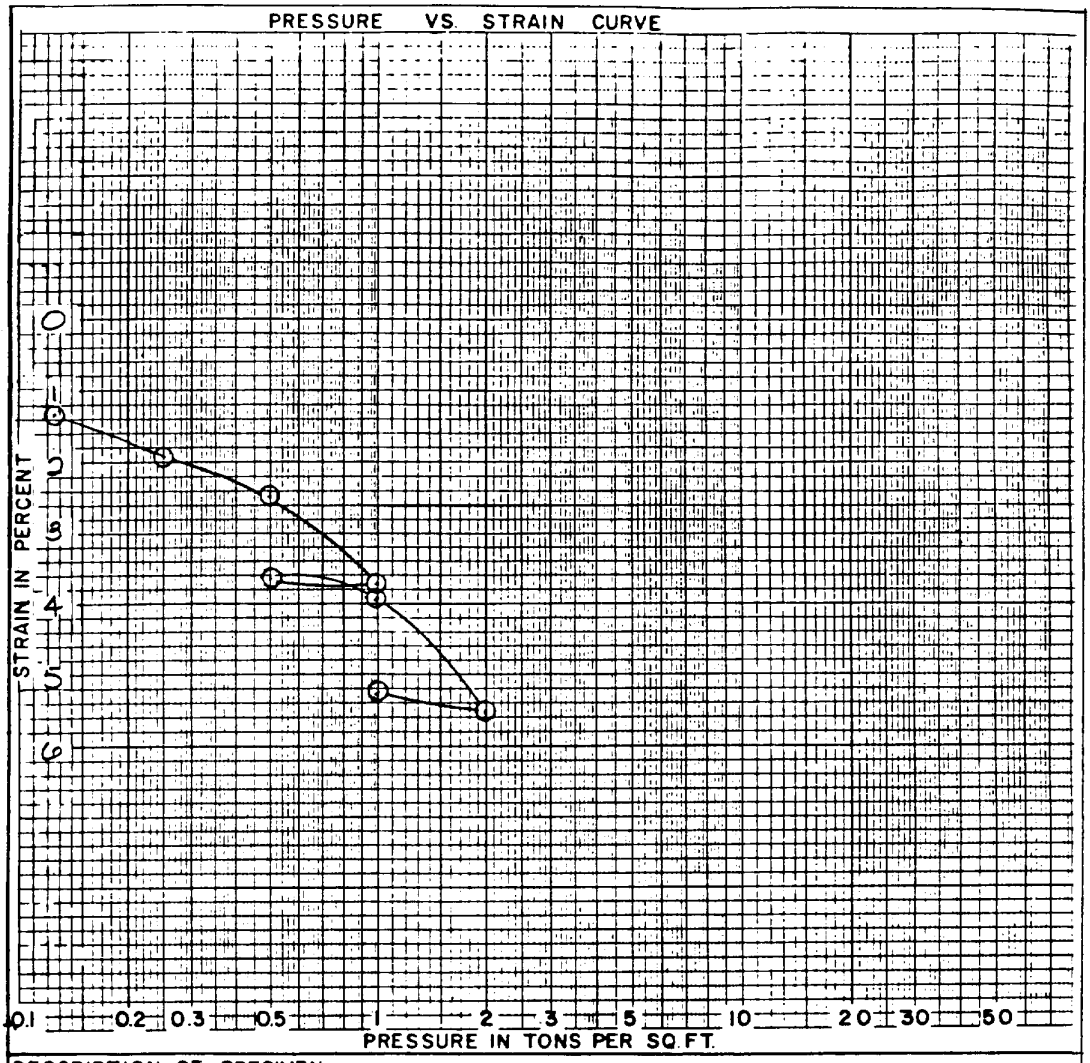
CLASSIFICATION: CH STRATUM DESIGNATION: –

DIAMETER OF SPECIMEN (in.)	2.50
INITIAL THICKNESS OF SPECIMEN (in.)	1.00
INITIAL VOID RATIO, e_o	–
PROBABLE PRECONSOLIDATION STRESS (tsf) Pc	–
APPROXIMATE OVERBURDEN STRESS (tsf) Po	–
COMPRESSION RATIO; FROM ___ TO ___ (tsf)	–
COMPRESSION INDEX; FROM ___ TO ___ (tsf)	–
RECOMPRESSION RATIO; FROM ___ TO ___ (tsf)	–
RECOMPRESSION INDEX; FROM ___ TO ___ (tsf)	–

SCHNABEL ENGINEERING ASSOCIATES
CONSOLIDATION TEST
BORING NO.: B-8 DEPTH: 2'-4'
PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO., VA.
DATE 6/11/82
CONTRACT NO. V82182

SI020669

Figure 2.6-46 (SHEET 8 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:

SILTY CLAY, SOME FINE SAND - LIGHT GRAY AND BROWN

CLASSIFICATION: CL STRATUM DESIGNATION:

DIAMETER OF SPECIMEN (in.)	2.50
INITIAL THICKNESS OF SPECIMEN (in.)	1.00
INITIAL VOID RATIO, e_o	0.959
PROBABLE PRECONSOLIDATION STRESS (tsf) Pc	–
APPROXIMATE OVERBURDEN STRESS (tsf) Po	–
COMPRESSION RATIO; FROM 1 TO 2 (tsf)	0.056
COMPRESSION INDEX; FROM 1 TO 2 (tsf)	0.110
RECOMPRESSION RATIO; FROM 1/2 TO 1 (tsf)	0.010
RECOMPRESSION INDEX; FROM 1/2 TO 1 (tsf)	0.019

SCHNABEL ENGINEERING ASSOCIATE

CONSOLIDATION TEST

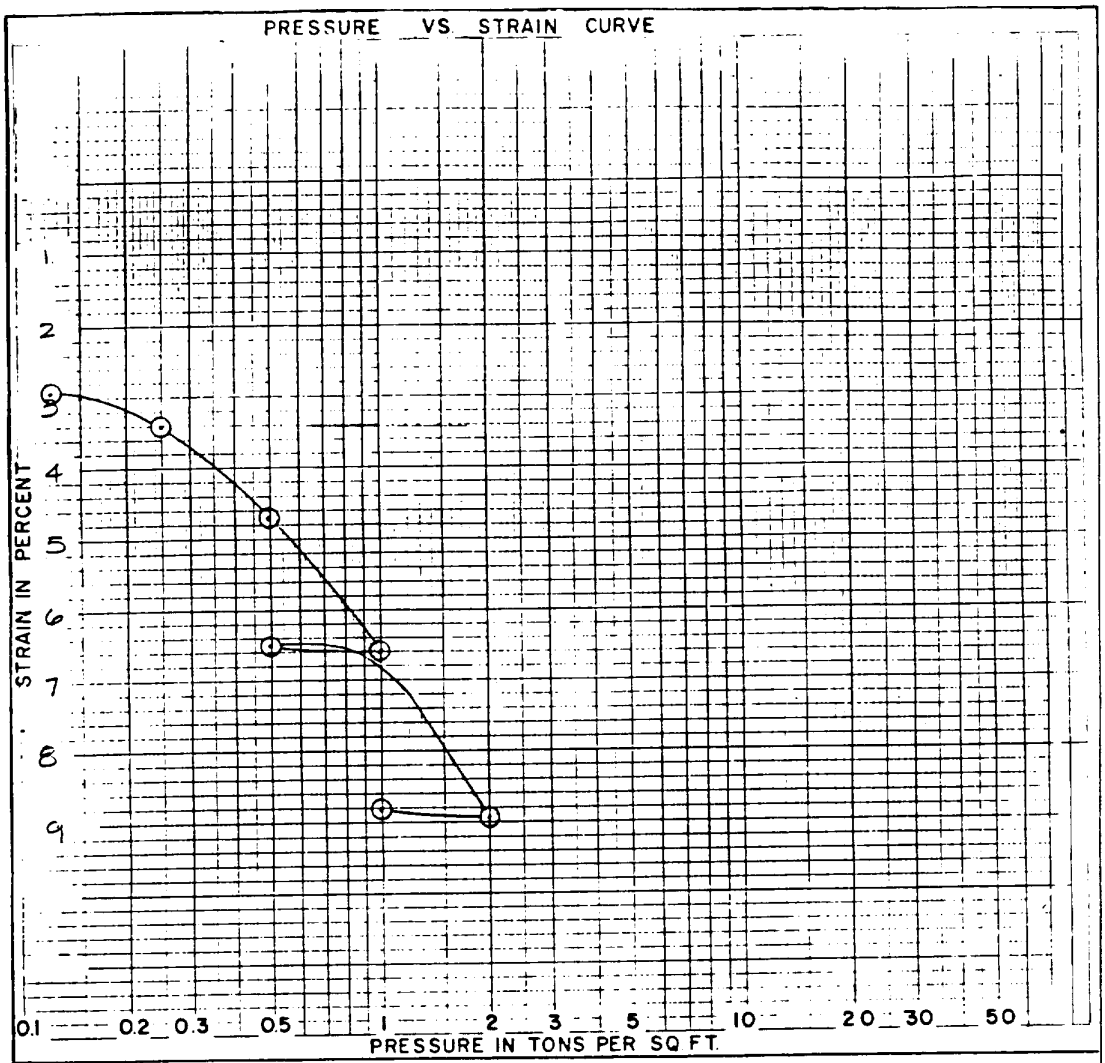
BORING NO.: B-8 DEPTH: 12'-14'

PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY COUNTY

DATE 6/11/82 CONTRACT NO. V82182

SI020670

Figure 2.6-46 (SHEET 9 OF 9)
CONSOLIDATION TEST



DESCRIPTION OF SPECIMEN:
FINE SILTY SAND WITH SHELL FRAGMENTS - DARK GLEENISH GRAY

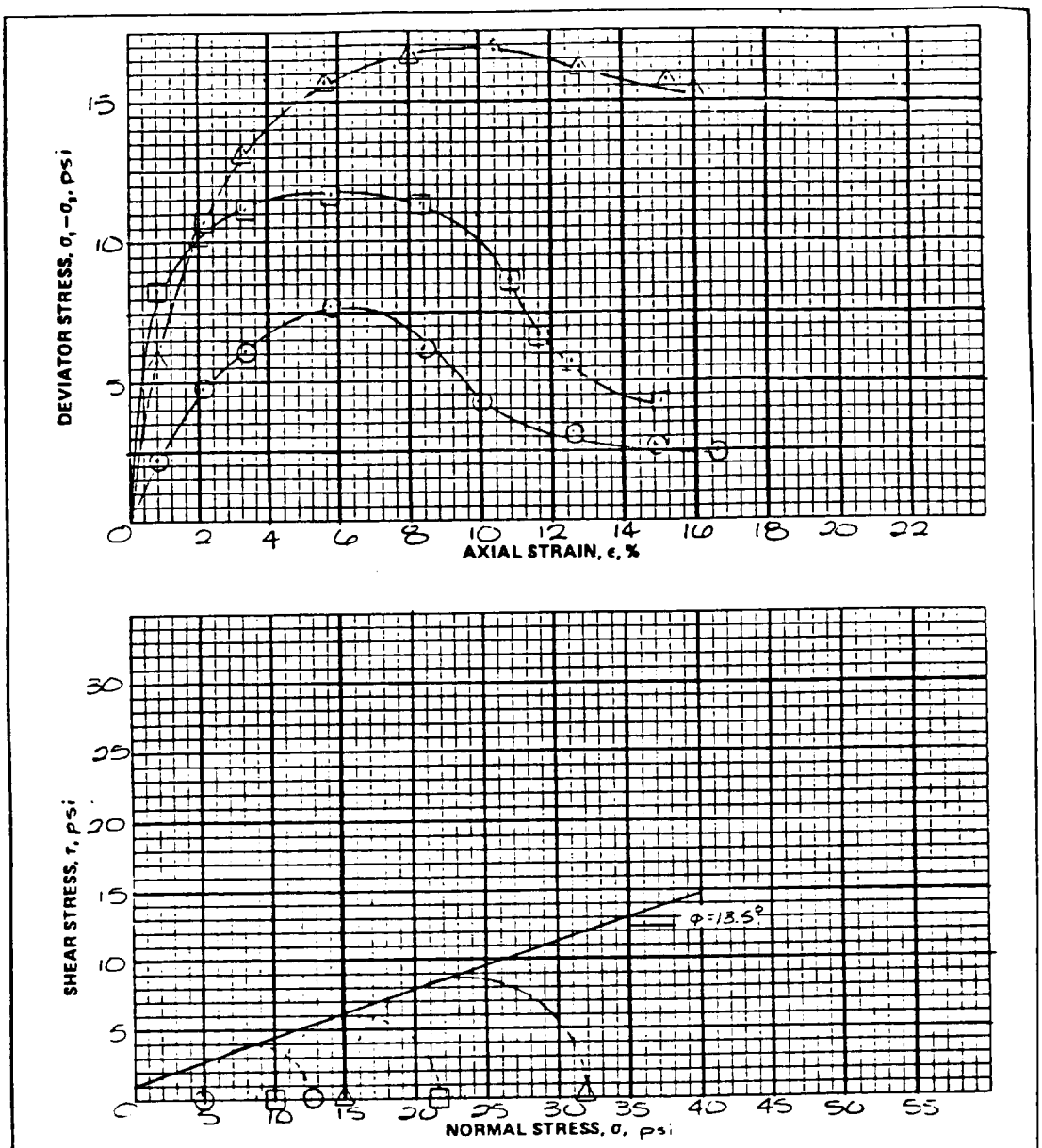
CLASSIFICATION: SM STRATUM DESIGNATION:

DIAMETER OF SPECIMEN (in.)	2.50
INITIAL THICKNESS OF SPECIMEN (in.)	1.00
INITIAL VOID RATIO, e_o	0.50
PROBABLE PRECONSOLIDATION STRESS (tsf) Pc	-
APPROXIMATE OVERBURDEN STRESS (tsf) Po	-
COMPRESSION RATIO; FROM 1 TO 2 (tsf)	0.041
COMPRESSION INDEX; FROM 1 TO 2 (tsf)	0.061
RECOMPRESSION RATIO; FROM ___ TO ___ (tsf)	-
RECOMPRESSION INDEX; FROM ___ TO ___ (tsf)	-

SCHNABEL ENGINEERING ASSOCIATES
CONSOLIDATION TEST
BORING NO.: B-8 DEPTH: 42'-44'
PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO, VA.
DATE 6/11/82 CONTRACT NO. VE2182

S1020671

Figure 2.6-47 (SHEET 1 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED							
SILTY CLAY, TRACE FINE SAND - BROWN & TAN (CL)							
KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST. CONT. % INITIAL	MOIST. CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET
○	B-2	2'-4'	5 psi	23.1	24.9	—	—
□	B-2	2'-4'	10 psi	23.1	25.9	99.4	122.3
△	B-2	2-4'	15 psi	23.1	26.3	95.7	117.8

SCHNABEL ENGINEERING ASSOCIATES

TRIAXIAL COMPRESSION TEST

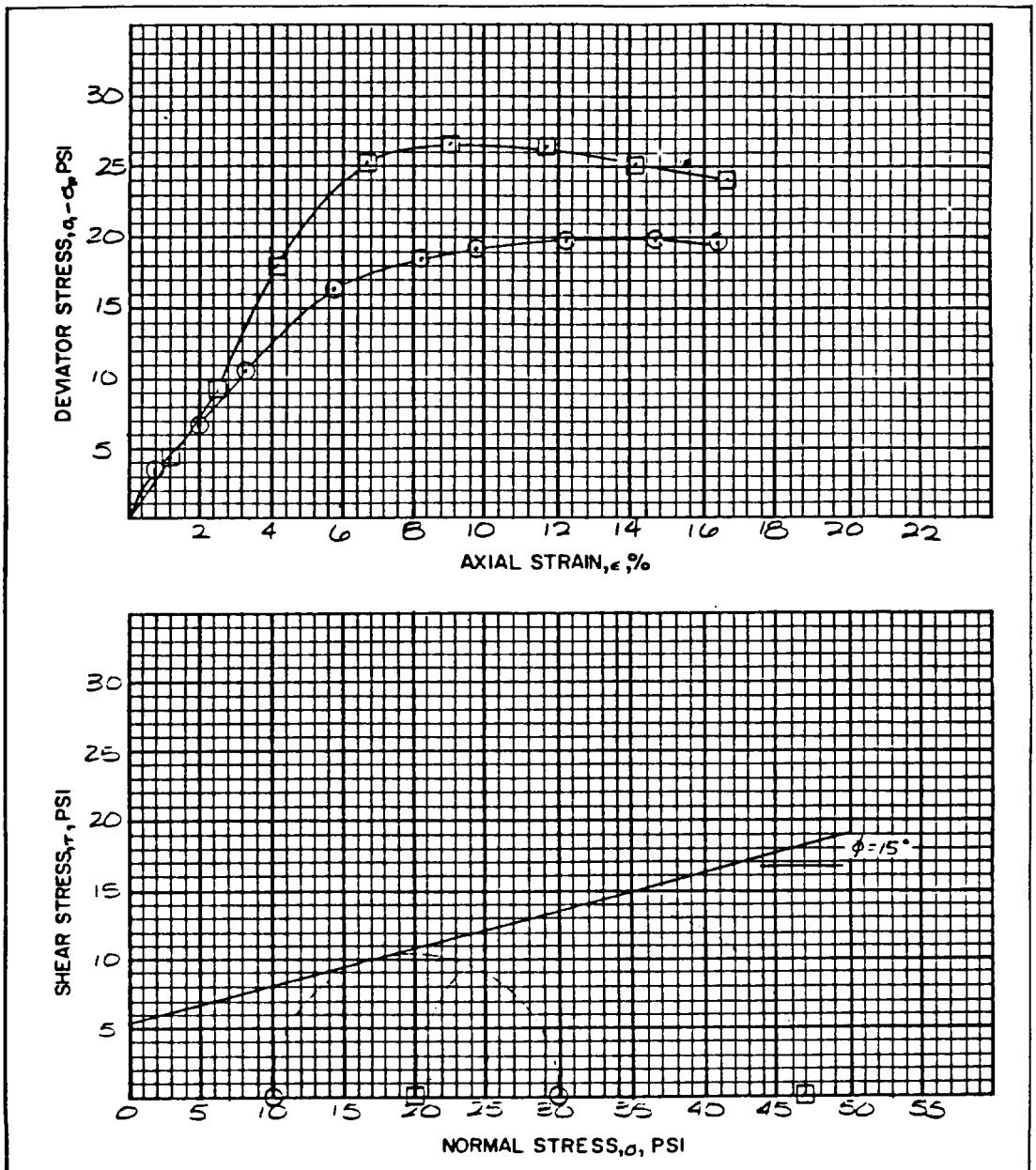
TYPE OF TEST: UU
RATE OF SHEAR: 1%/min

PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO. VA.

DATE: 6/11/82 CONTR. NO.: V85-151

SI020672

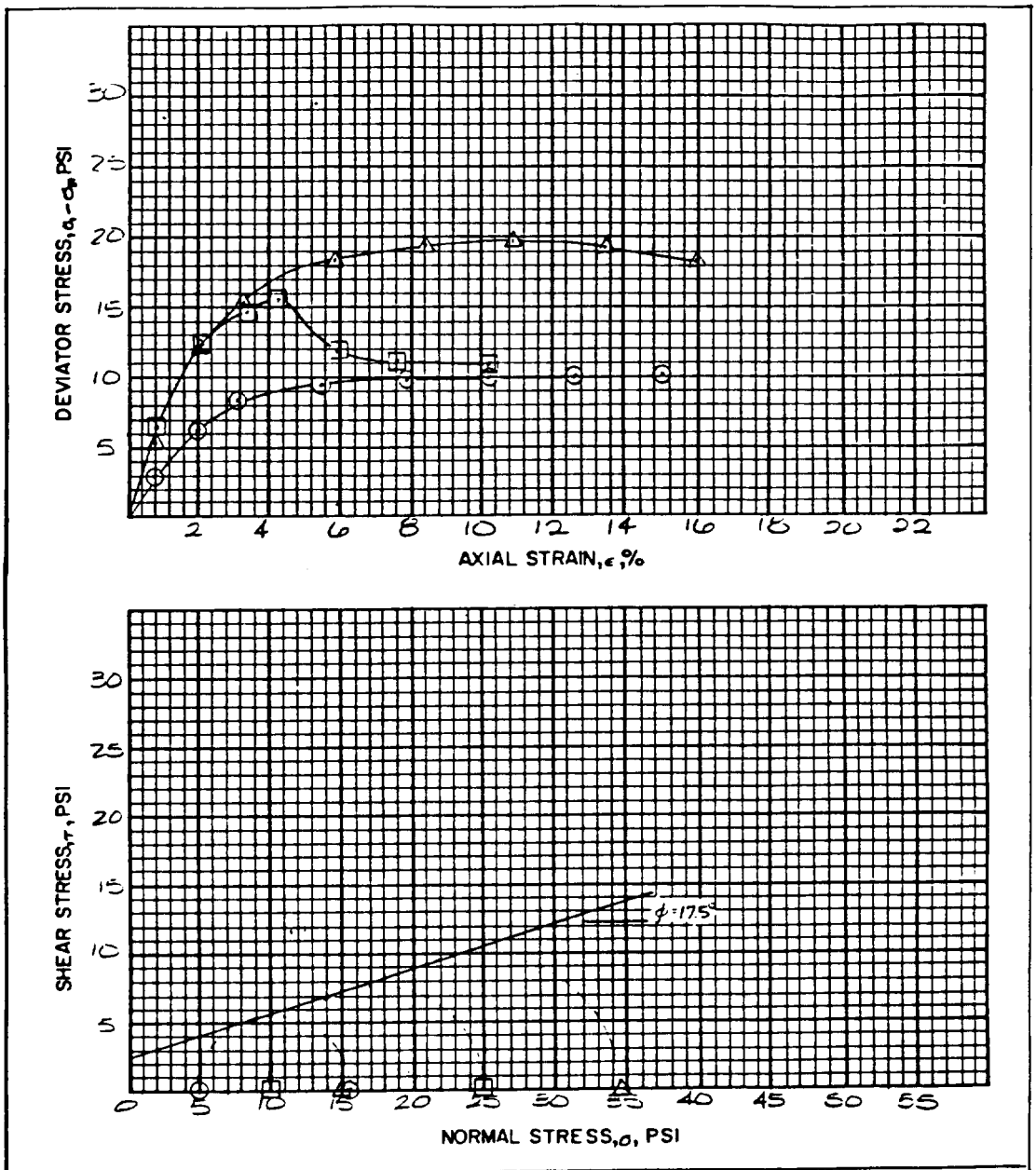
Figure 2.6-47 (SHEET 2 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED								SCHNABEL ENGINEERING ASSOCIATE
FINE SILTY SAND, WITH SHELL FRAGMENTS DARK GRAY (SM)								TRIAXIAL COMPRESSION TEST
KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST CONT. % INITIAL	MOIST CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET	TYPE OF TEST: UU RATE OF SHEAR: 1%/MIN
○	B-2	52'-54'	10	31.3	27.0	92.6	119.0	PROJECT: DRY CASK SPENT FUEL
□	B-2	52'-54'	20	31.3	30.0	90.7	119.1	FACILITY, SURRY CO, VA.
								DATE: 6/11/82 CONTRACT NO.: V8218

SI020673

Figure 2.6-47 (SHEET 3 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED							
SILTY CLAY, SOME FINE SAND - GRAY & BROWN (CL)							
KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST. CONT. % INITIAL	MOIST. CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET
○	B-2U	7'-9'	5	29.2	28.5	85.5	110.4
□	B-2U	7'-9'	10	31.2	24.5	93.3	122.4
△	B-2U	7'-9'	15	29.4	25.0	-	-

SCHNABEL ENGINEERING ASSOCIATES

TRIAXIAL COMPRESSION TEST

TYPE OF TEST: UU
RATE OF SHEAR: 1%/MIN

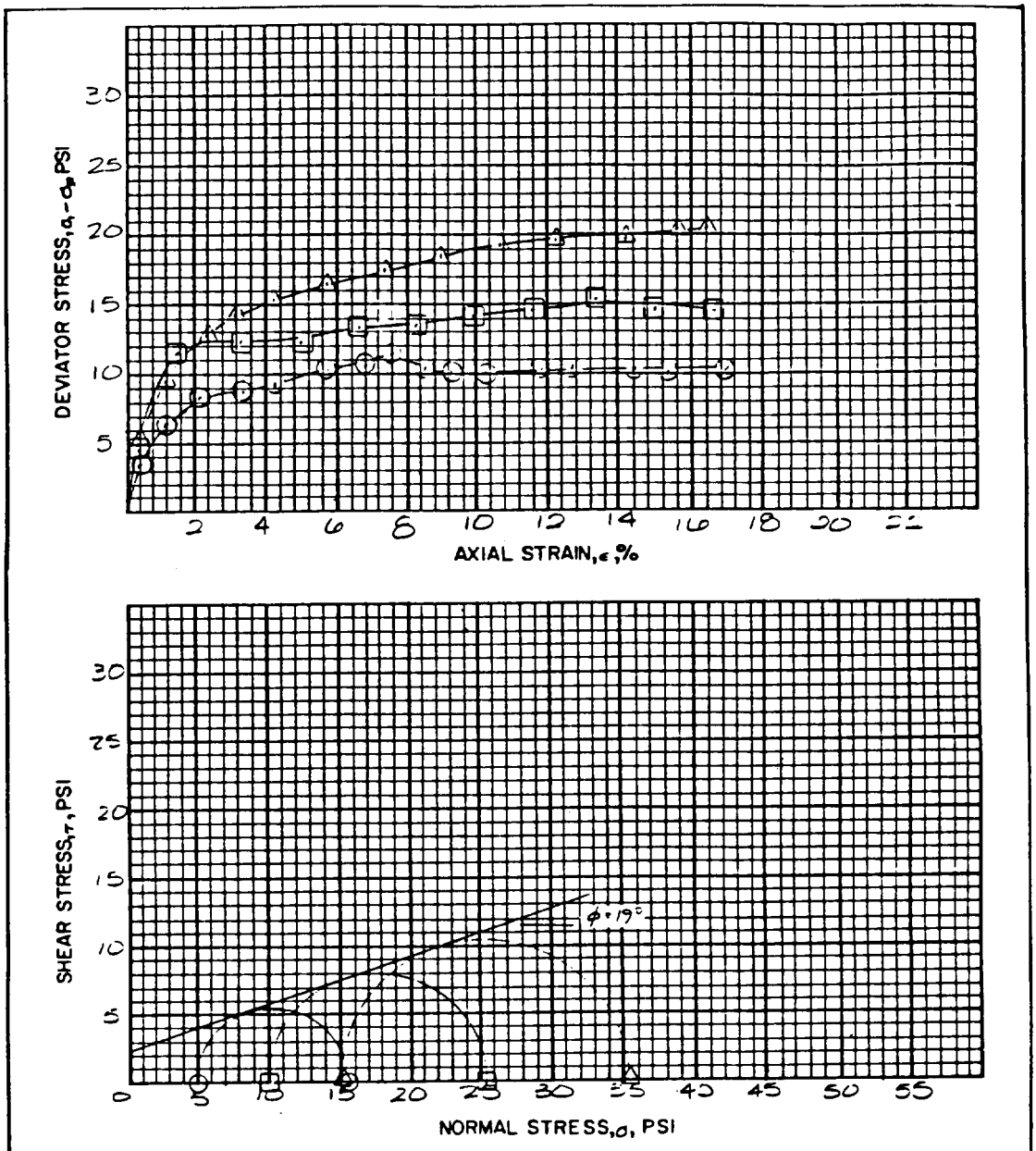
PROJECT: DRY CASK SPENT FUEL

FACILITY: SURRY CO, VA.

DATE: 6/11/82 CONTRACT NO.: V82182

SI020674

Figure 2.6-47 (SHEET 4 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED

CLAY, TRACE FINE SAND - LIGHT BROWN AND TAN (CH)

KEY	BORING NO.	DEPTH FT	LATERAL PRESS	MOIST CONT. % INITIAL	MOIST CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET
⊙	B-5U	1'-3'	5	29.0	35.8	90.5	116.7
□	B-5U	1'-3'	10	29.0	-	87.3	112.6
△	B-5U	1'-3'	15	29.0	33.4	87.9	113.4

SCHNABEL ENGINEERING ASSOCIATES

TRIAXIAL COMPRESSION TEST

TYPE OF TEST: UU
RATE OF SHEAR: 1%/MIN

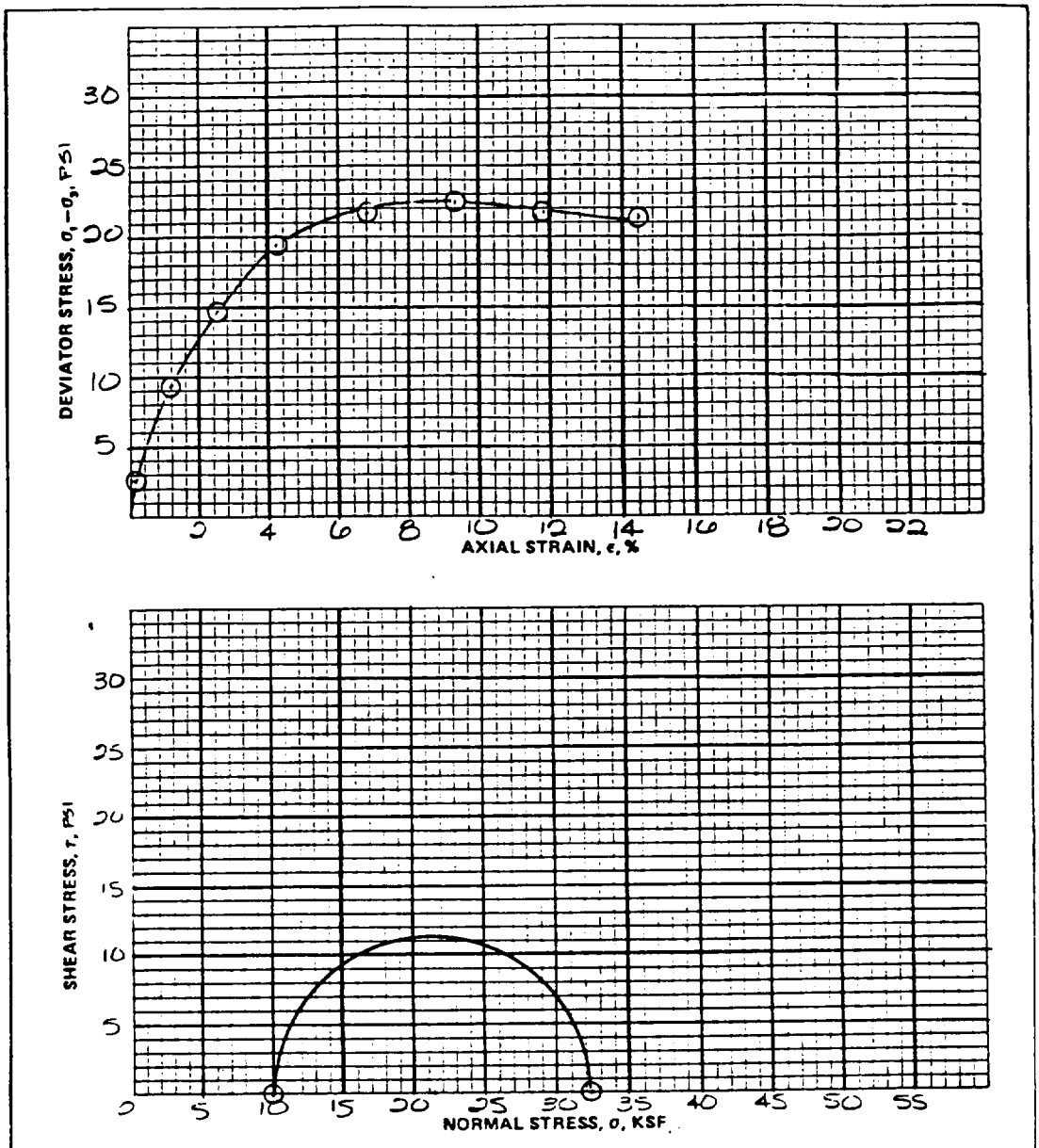
PROJECT: DRY CASK SPENT FUEL

FACILITY, SURRY CO, VA.

DATE: 6/11/82 CONTRACT NO.: V82182

SI020675

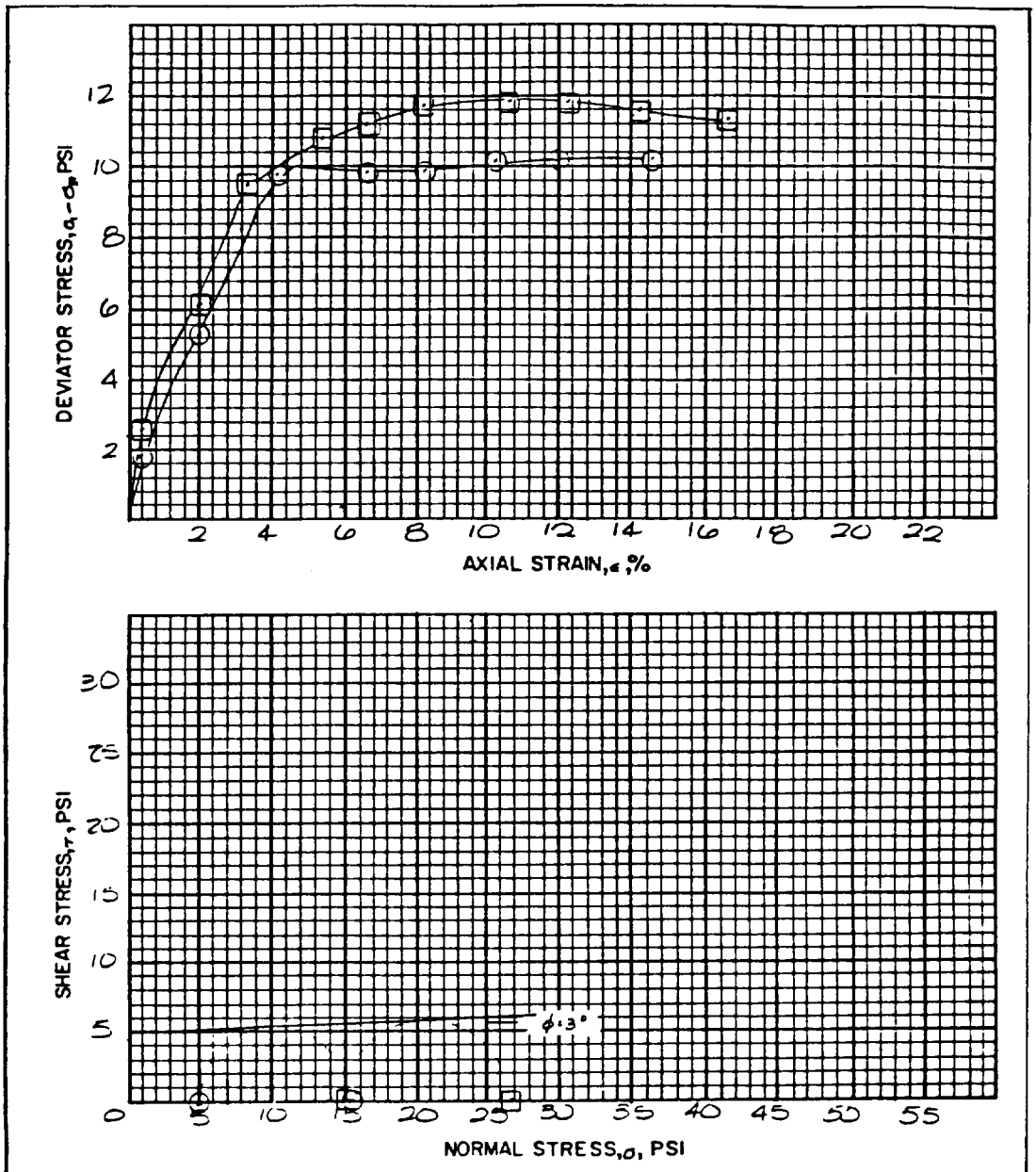
Figure 2.6-47 (SHEET 5 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED								SCHNABEL ENGINEERING ASSOCIATES
CLAY, TRACE FINE SAND - LIGHT BROWN (CH)								TRIAXIAL COMPRESSION TEST
KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST. CONT. % INITIAL	MOIST. CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET	TYPE OF TEST: UU RATE OF SHEAR: 1%/MIN
⊙	B-8	2'-4'	10 PSI	34.7	-	66.3	114.9	PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY, VA
								DATE: 6/11/82 CONTR. NO. V82-182

SI020676

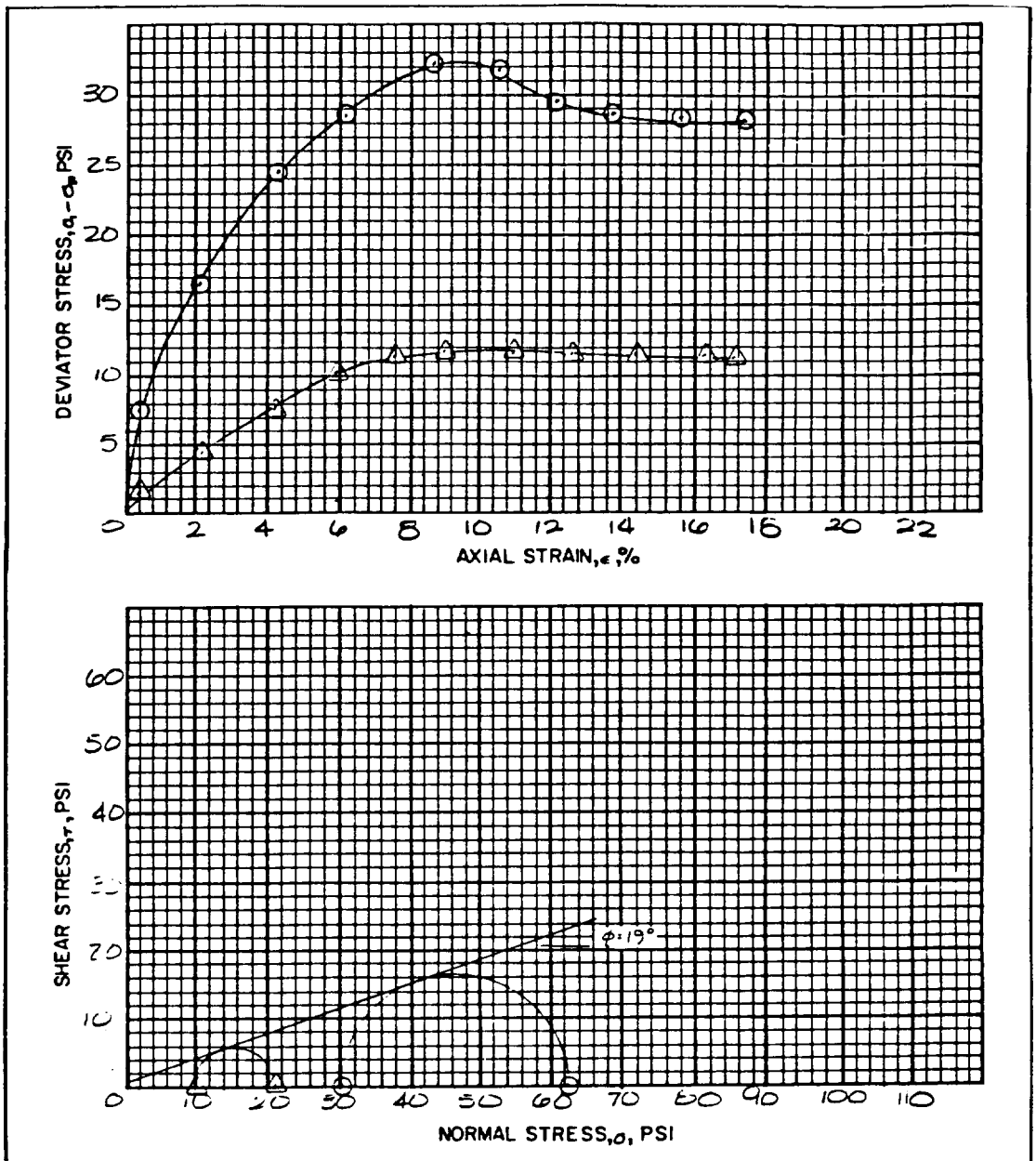
Figure 2.6-47 (SHEET 6 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED								SCHNABEL ENGINEERING ASSOCIATE
SILTY CLAY, SOME FINE SAND - LIGHT GRAY AND BROWN (CL)								TRIAXIAL COMPRESSION TEST
KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST CONT. % INITIAL	MOIST CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET	TYPE OF TEST: UU RATE OF SHEAR: 1%/MIN
○	B-8	12'-14'	5	29.5	31.1	93.3	120.9	PROJECT: DRY CASK SPENT FUEL
□	B-8	12'-14'	15	29.5	31.8	90.6	117.3	FACILITY, SURRY CO, VA.
								DATE: 6/11/82 CONTRACT NO.: V8318

SI020677

Figure 2.6-47 (SHEET 7 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED

FINE SILTY SAND WITH SHELL FRAGMENTS - DARK GREENISH GRAY (SM)

KEY	BORING NO.	DEPTH FT	LATERAL PRESS	MOIST CONT. % INITIAL	MOIST CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET
○	B-8	42'-44'	30 PSI	32.9	27.6	88.7	117.9
△	B-8	42'-44'	10 PSI	32.9	25.2	90.8	120.7

SCHNABEL ENGINEERING ASSOCIATES

TRIAXIAL COMPRESSION TEST

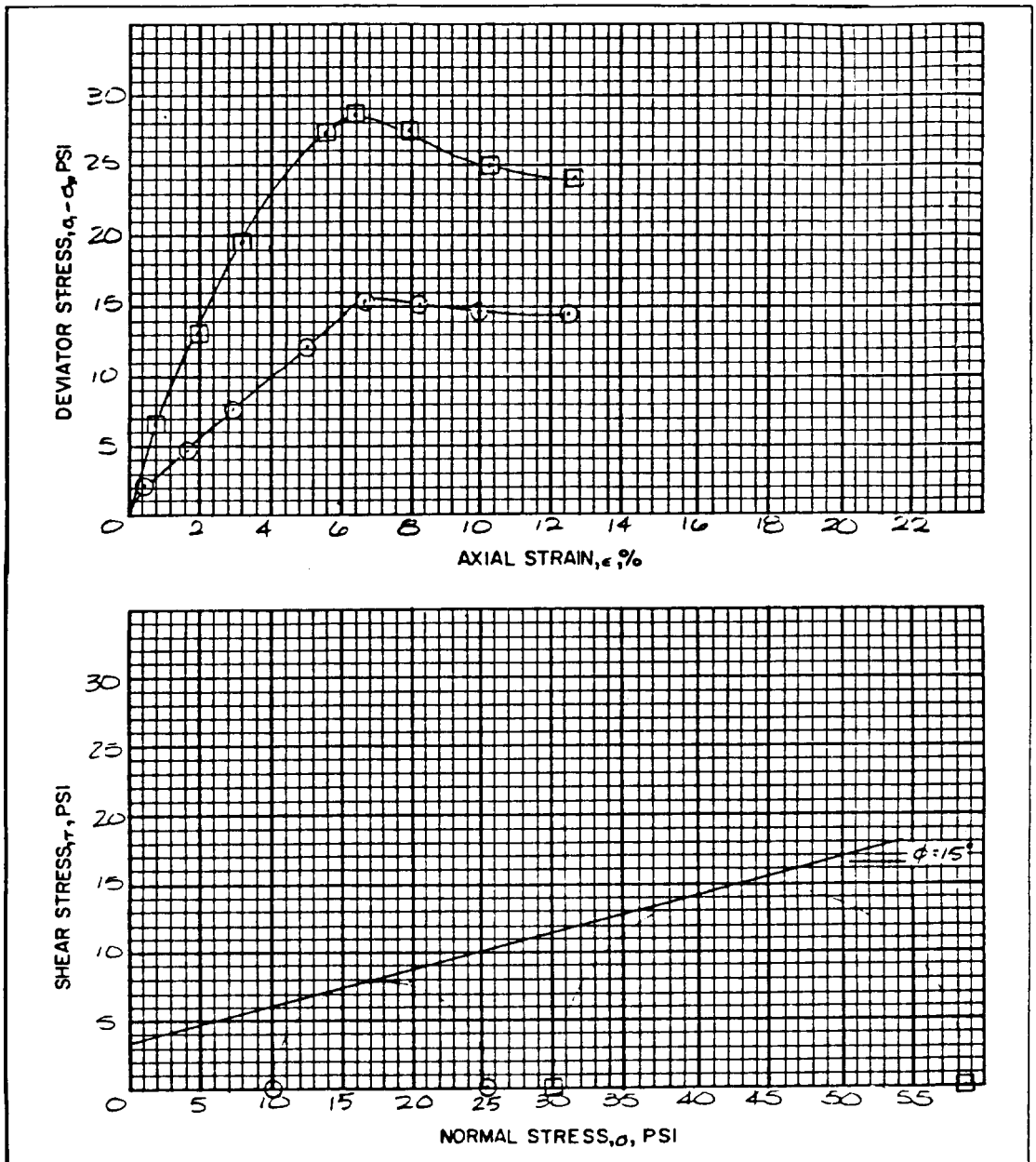
TYPE OF TEST: UU
RATE OF SHEAR: 1%/MIN

PROJECT: DRY CASK SPENT FUEL FACILITY, SURRY CO. VA.

DATE: 6/11/82 CONTRACT NO.: V82182

SI020678

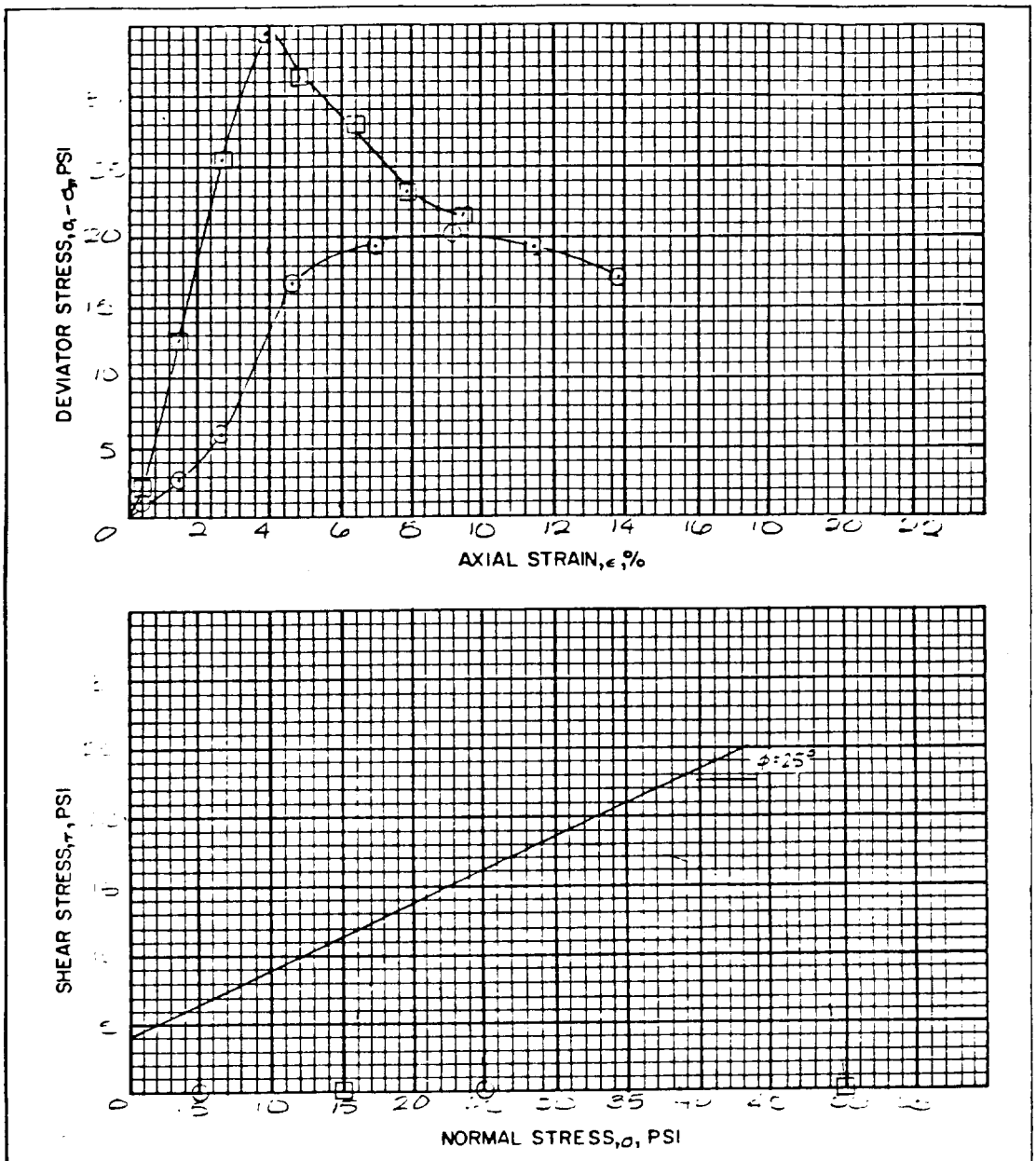
Figure 2.6-47 (SHEET 8 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED								SCHNABEL ENGINEERING ASSOCIATES
FINE SILTY SAND WITH SHELL FRAGMENTS - DARK GRAY (SM)								TRIAXIAL COMPRESSION TEST
KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST CONT. % INITIAL	MOIST CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET	TYPE OF TEST: UU RATE OF SHEAR: 1%/MIN
⊡	B-8	62'-64'	30	33.8	32.7	86.0	117.7	PROJECT: DRY CASK SPENT FUEL
⊙	B-5	62'-64'	10	30.8	28.9	90.6	118.0	FACILITY, SURRY CO, VA.
								DATE: 6/11/82 CONTRACT NO: V82182

S1020679

Figure 2.6-47 (SHEET 9 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED

CLAY, TRACE FINE SAND, WITH SHELL FRAGMENTS - DARK GREENISH GRAY (CH)

KEY	BORING NO.	DEPTH FT.	LATERAL PRESS	MOIST CONT. % INITIAL	MOIST CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET
○	B-6	82-84	5	44.7	45.2	70.5	101.8
□	B-8	82-84	15	45.0	45.6	73.6	106.9

SCHNABEL ENGINEERING ASSOCIATES

TRIAXIAL COMPRESSION TEST

TYPE OF TEST: UU
RATE OF SHEAR: 1%/MIN

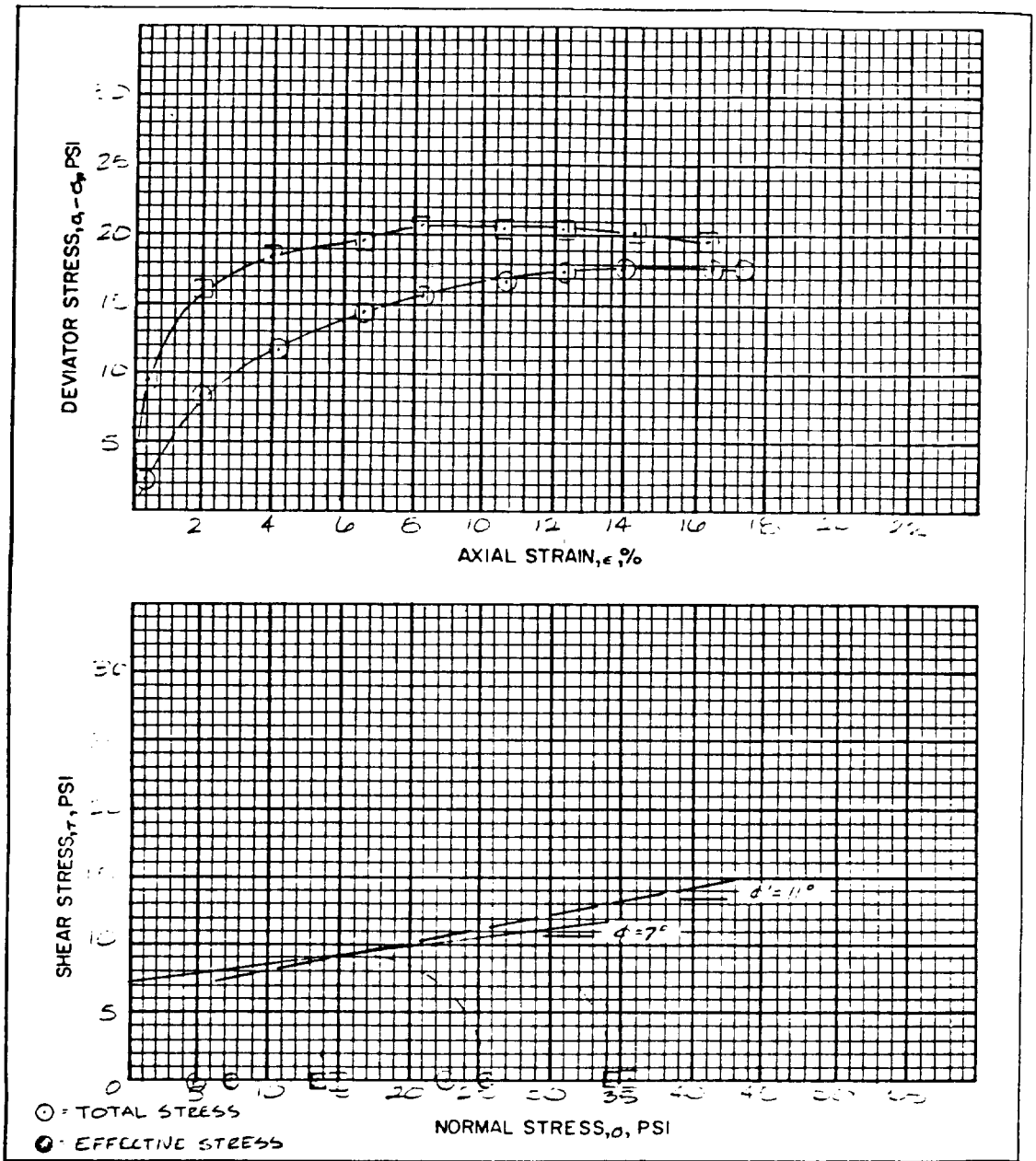
PROJECT: DEY [illegible]

FACILITY: [illegible]LEY CO, VA.

DATE: 6/11/82 CONTRACT NO.: [illegible]

SI020680

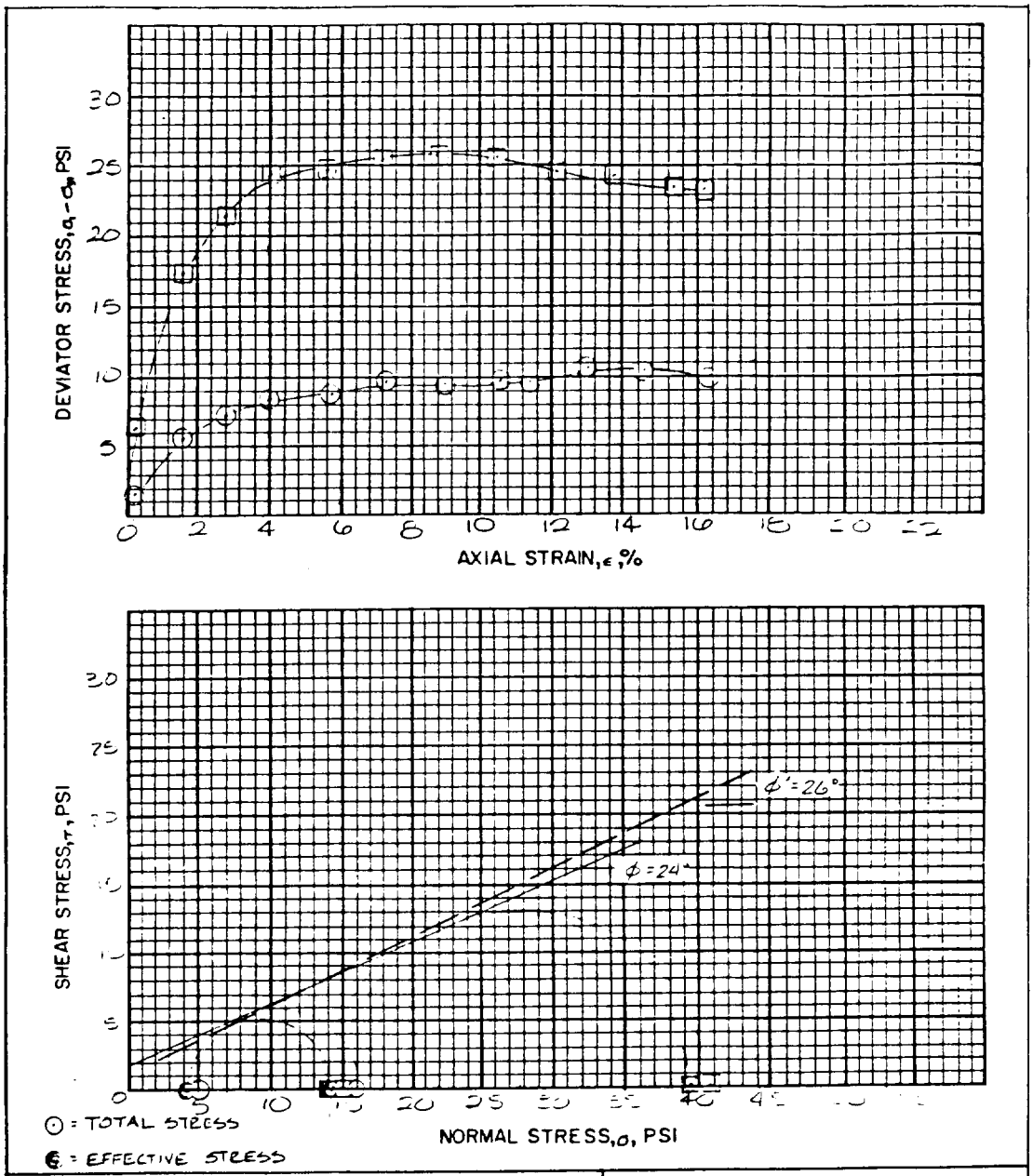
Figure 2.6-47 (SHEET 10 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED								SCHNABEL ENGINEERING ASSOCIATES
SILTY CLAY, TRACE FINE SAND - BROWN AND TAN (CL)								TRIAXIAL COMPRESSION TEST
KEY	BORING NO.	DEPTH FT.	LATERAL PRESS.	MOIST CONT. % INITIAL	MOIST CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET	TYPE OF TEST: CU RATE OF SHEAR: 1% / MIN
⊙	B-2	2'-4'	5	34.9	-	85.3	114.1	PROJECT: DRY CASK SPENT FUEL
⊡	B-2	2'-4'	15	32.9	28.7	81.5	110.3	FACILITY: SURRY CO., VA.
								DATE: 6/11/82 CONTRACT NO.: [illegible]

SI020681

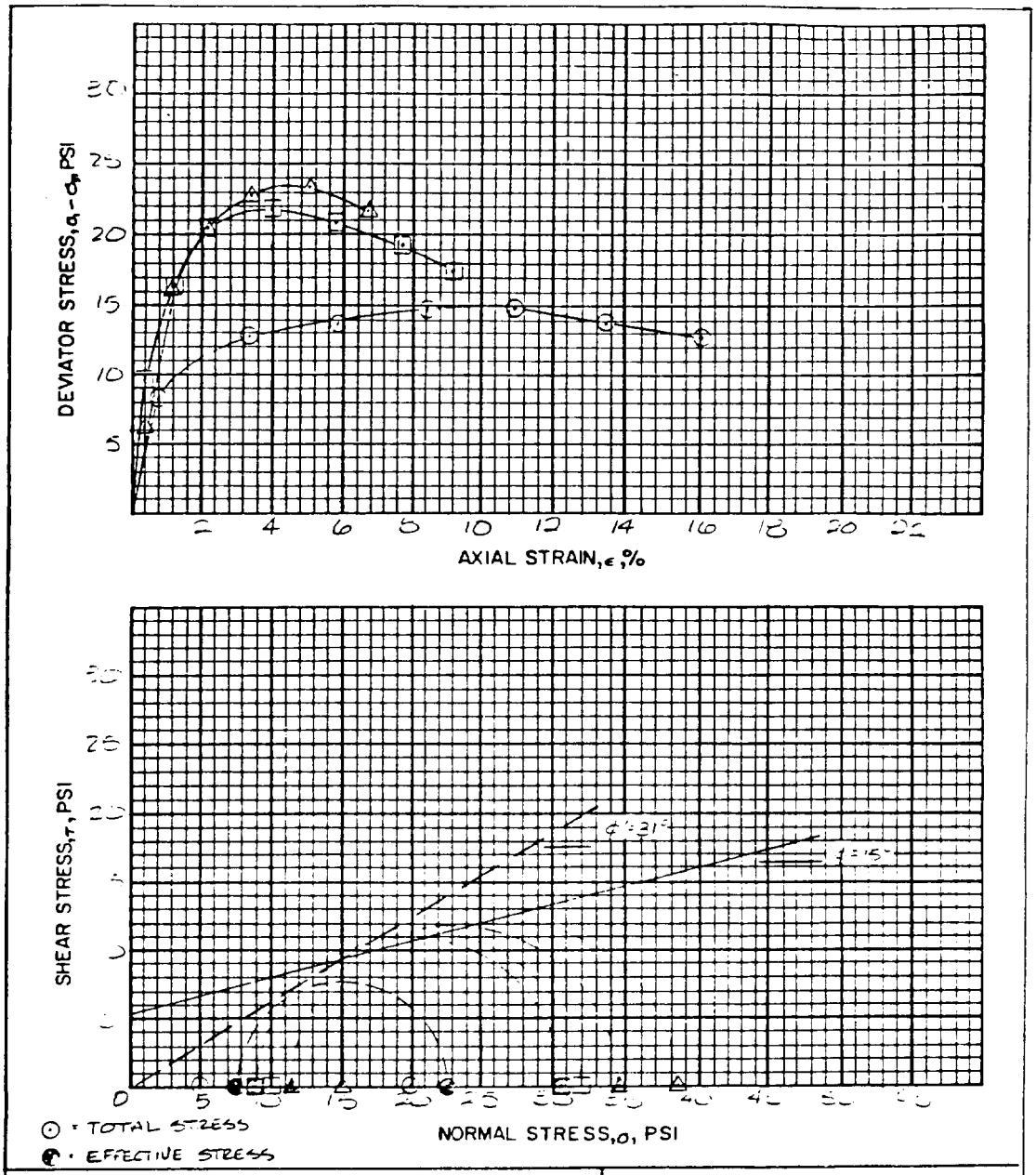
Figure 2.6-47 (SHEET 11 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED								SCHNABEL ENGINEERING ASSOCIATES
CLAY, TRACE FINE SAND - GRAY & BROWN (CH)								TRIAXIAL COMPRESSION TEST
KEY	BORING NO.	DEPTH FT	LATERAL PRESS	MOIST CONT % INITIAL	MOIST CONT % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET	TYPE OF TEST: CU RATE OF SHEAR: [illegible]
⊙	B-2U-1	7-9	[illegible]	[illegible]	[illegible]	92.4	110.8	PROJECT: DEV CASE [illegible]
□	B-2U-2	7-9	[illegible]	27.4	27.5	92.4	118	FACILITY: SURRY CO VA
								DATE: 6/11/82 CONTRACT NO: [illegible]

SI020682

Figure 2.6-47 (SHEET 12 OF 12)
TRIAXIAL COMPRESSION TEST



DESCRIPTION OF SOIL SAMPLE TESTED								SCHNABEL ENGINEERING ASSOCIATES
SILTY CLAY, TRACE FINE SAND-GRAY (CL)								TRIAXIAL COMPRESSION TEST
KEY	BORING NO.	DEPTH FT.	LATERAL PRESS	MOIST CONT. % INITIAL	MOIST CONT. % FINAL	DENSITY, PCF DRY	DENSITY, PCF WET	TYPE OF TEST: CU RATE OF SHEAR 1%/MIN
○	B-SU	7'-9'	5	24.1	35.6	91.7	115.8	PROJECT: DRY CASK SHENT FUEL
□	B-SU	7'-9'	10	24.1	-	94.1	116.8	FACILITY: SURRY CC VA.
△	B-SU	7'-9'	15	24.1	-	93.9	116.5	DATE: 6/11/82 CONTRACT NO.: VE[illegible]

SI020683

Figure 2.6-48
SOIL PROFILE A-A'

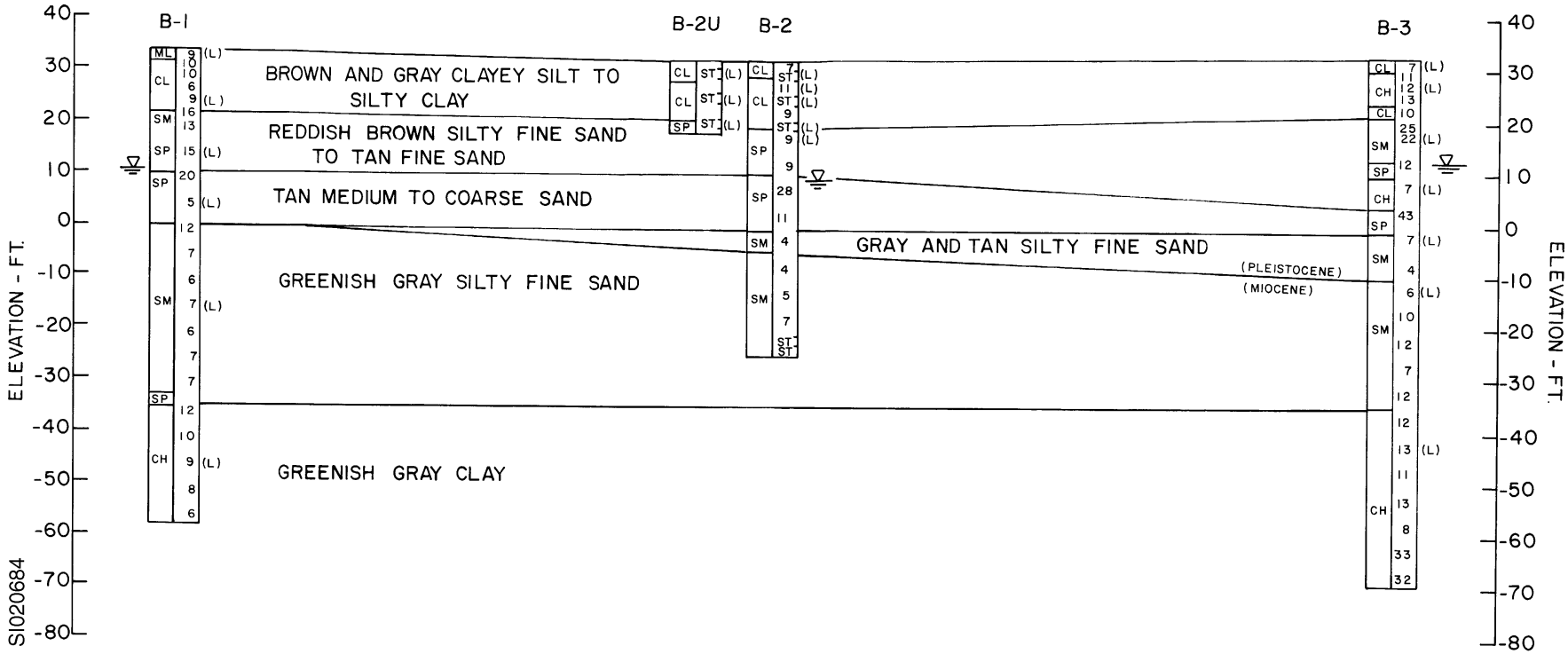


Figure 2.6-49
SOIL PROFILE B-B'

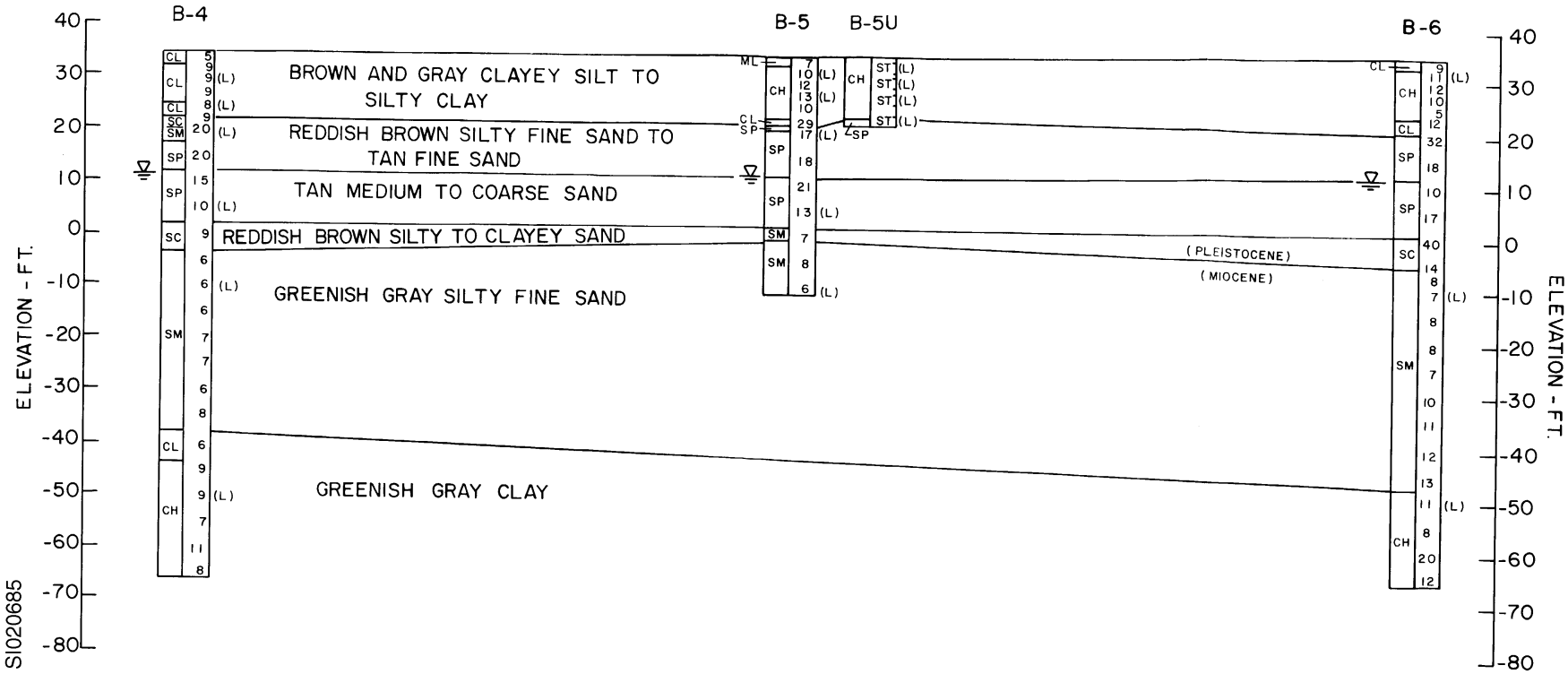
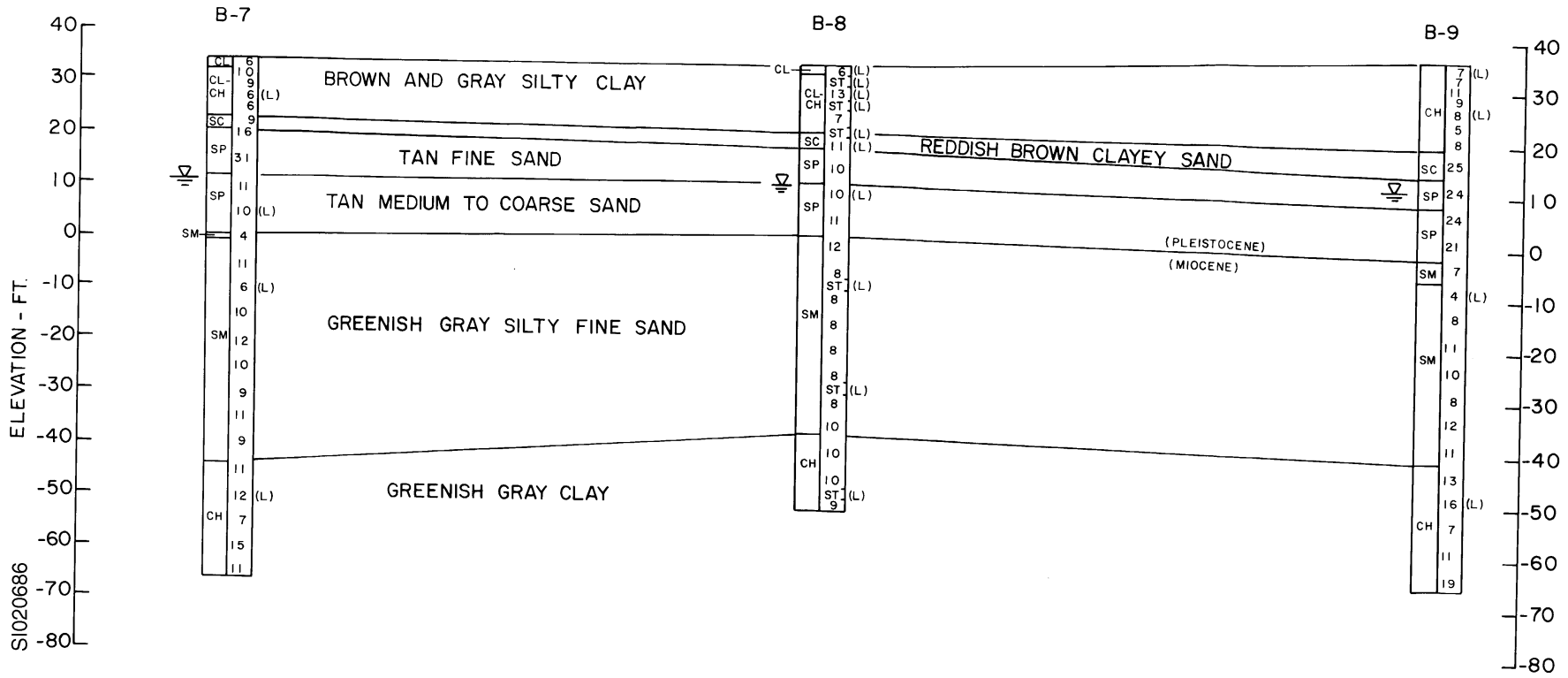


Figure 2.6-50
SOIL PROFILE C-C'



SI020686

Figure 2.6-51
EXCAVATION PLAN AND PROFILE

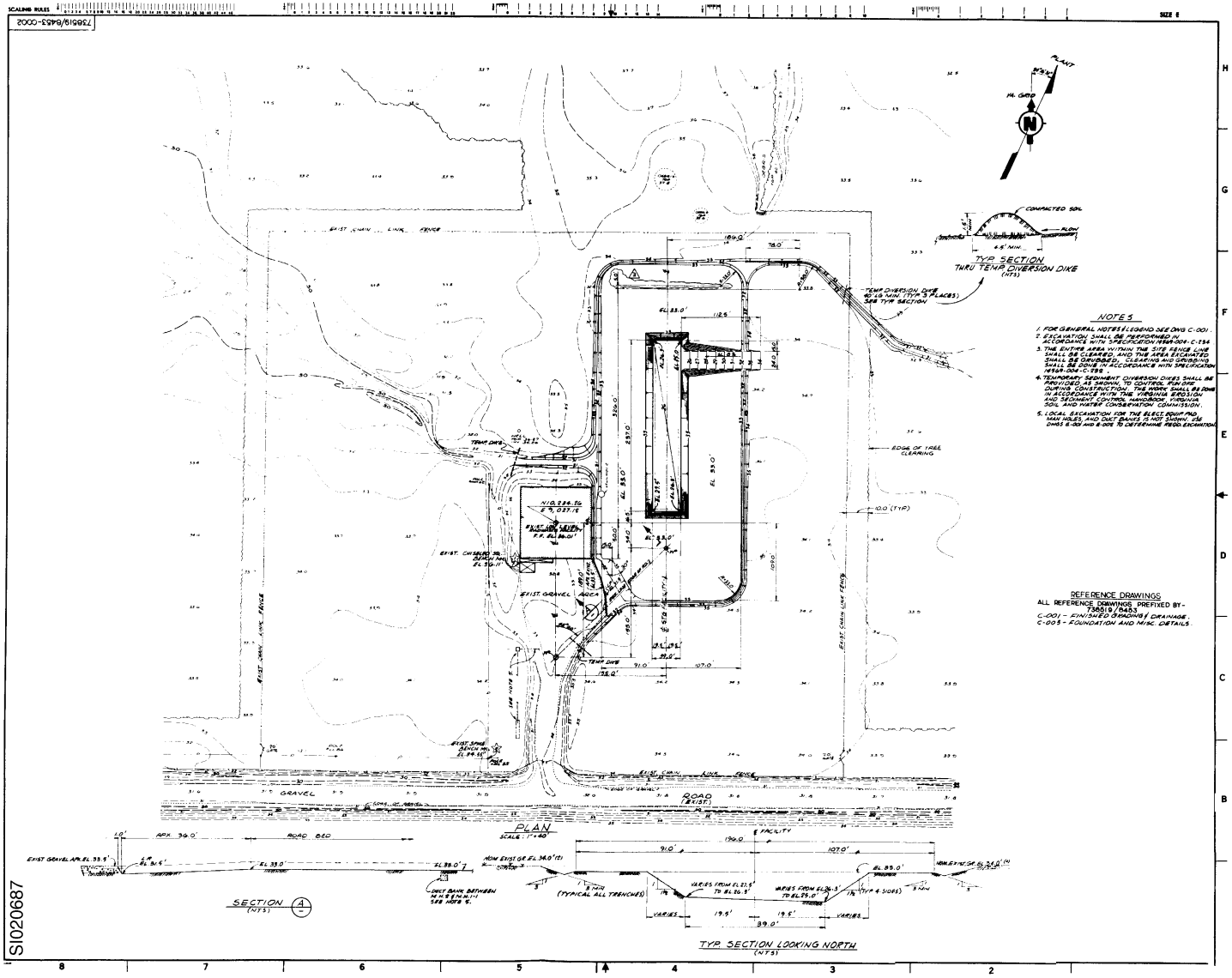


Figure 2.6-52
OBSERVATION WELL CONSTRUCTION DETAIL

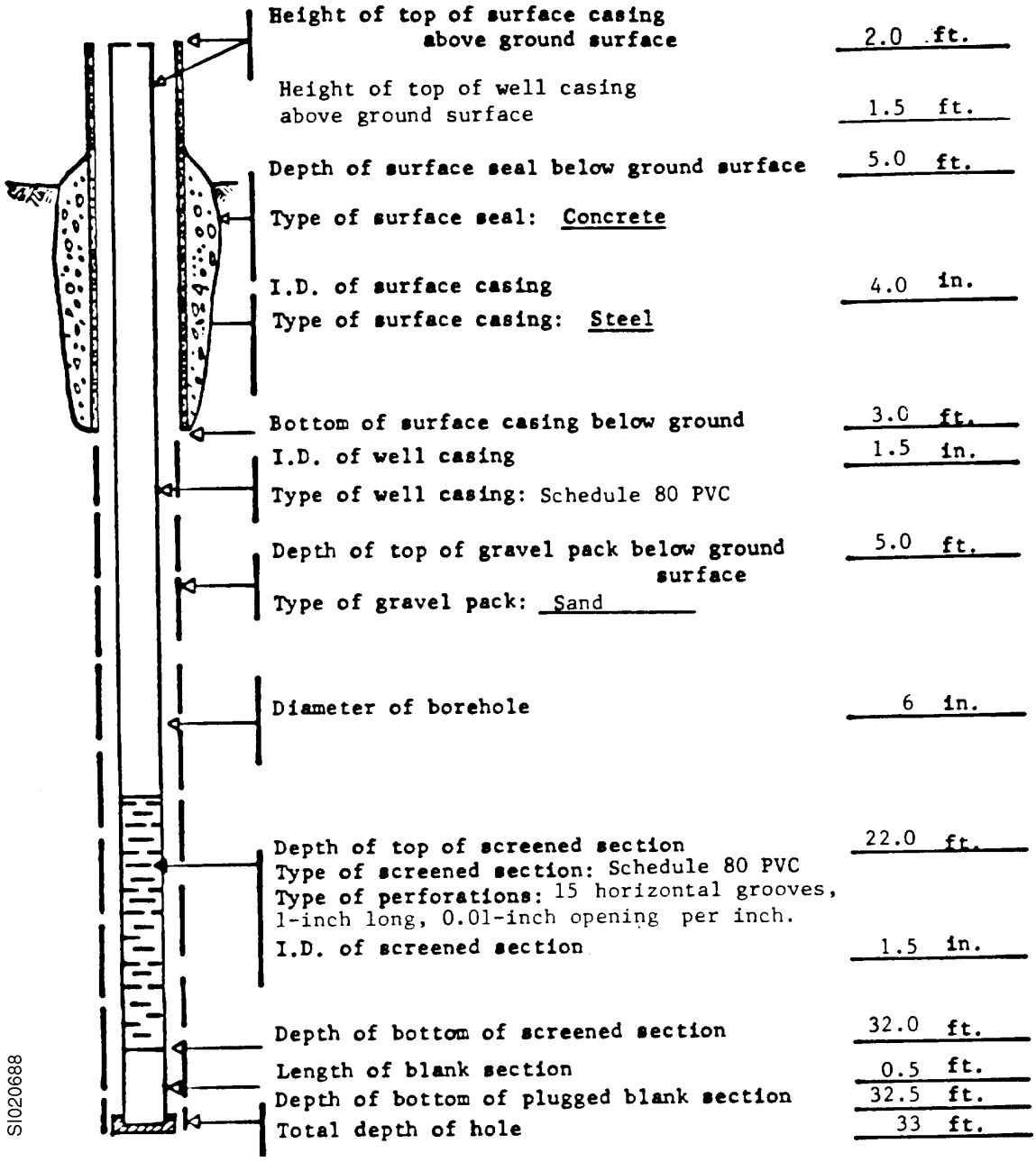


Figure 2.6-53
STRESS REDUCTION FACTOR

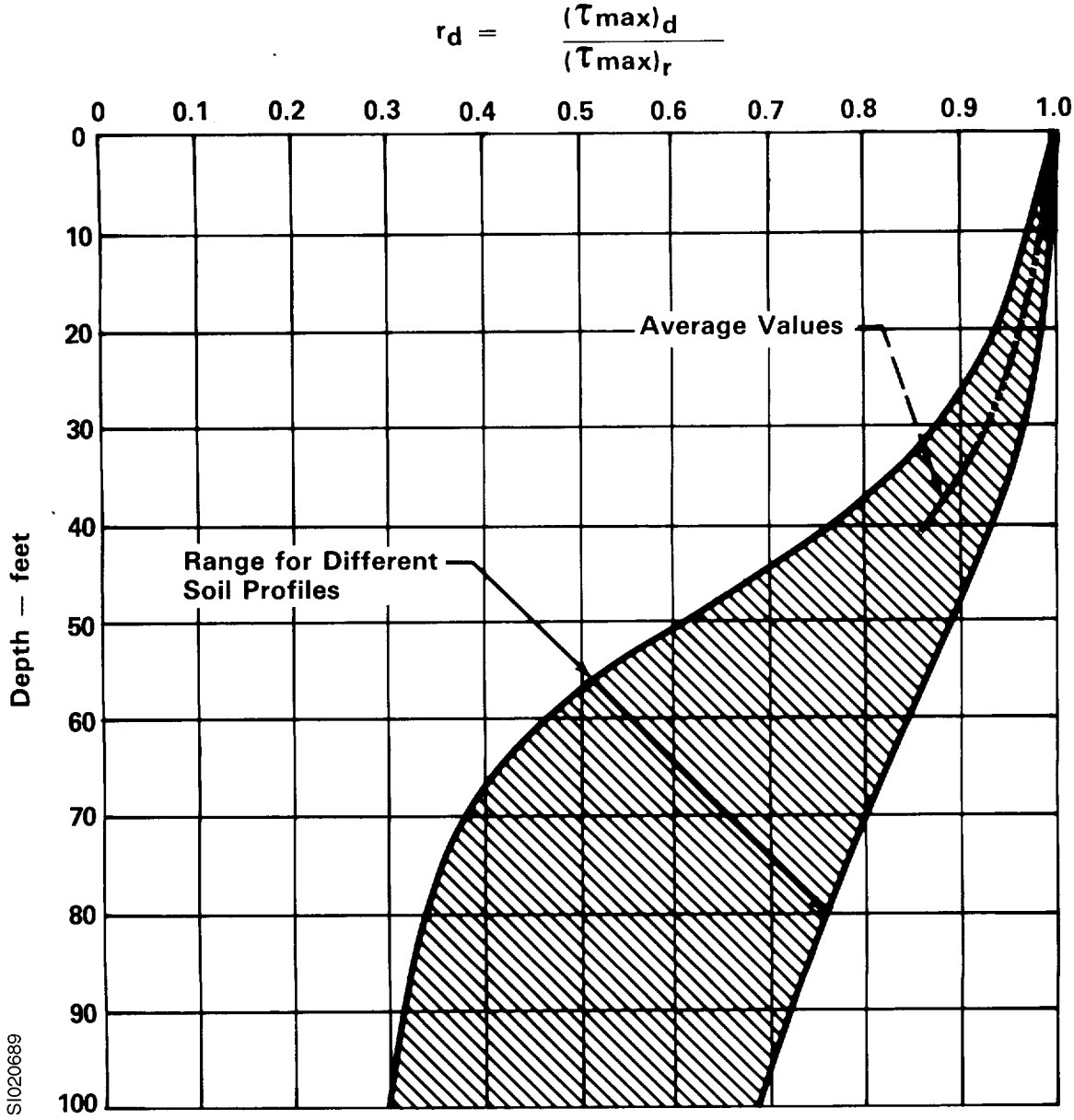


Figure 2.6-54
CHART FOR EVALUATION OF LIQUIFICATION POTENTIAL
FOR DIFFERENT MAGNITUDE EARTHQUAKES

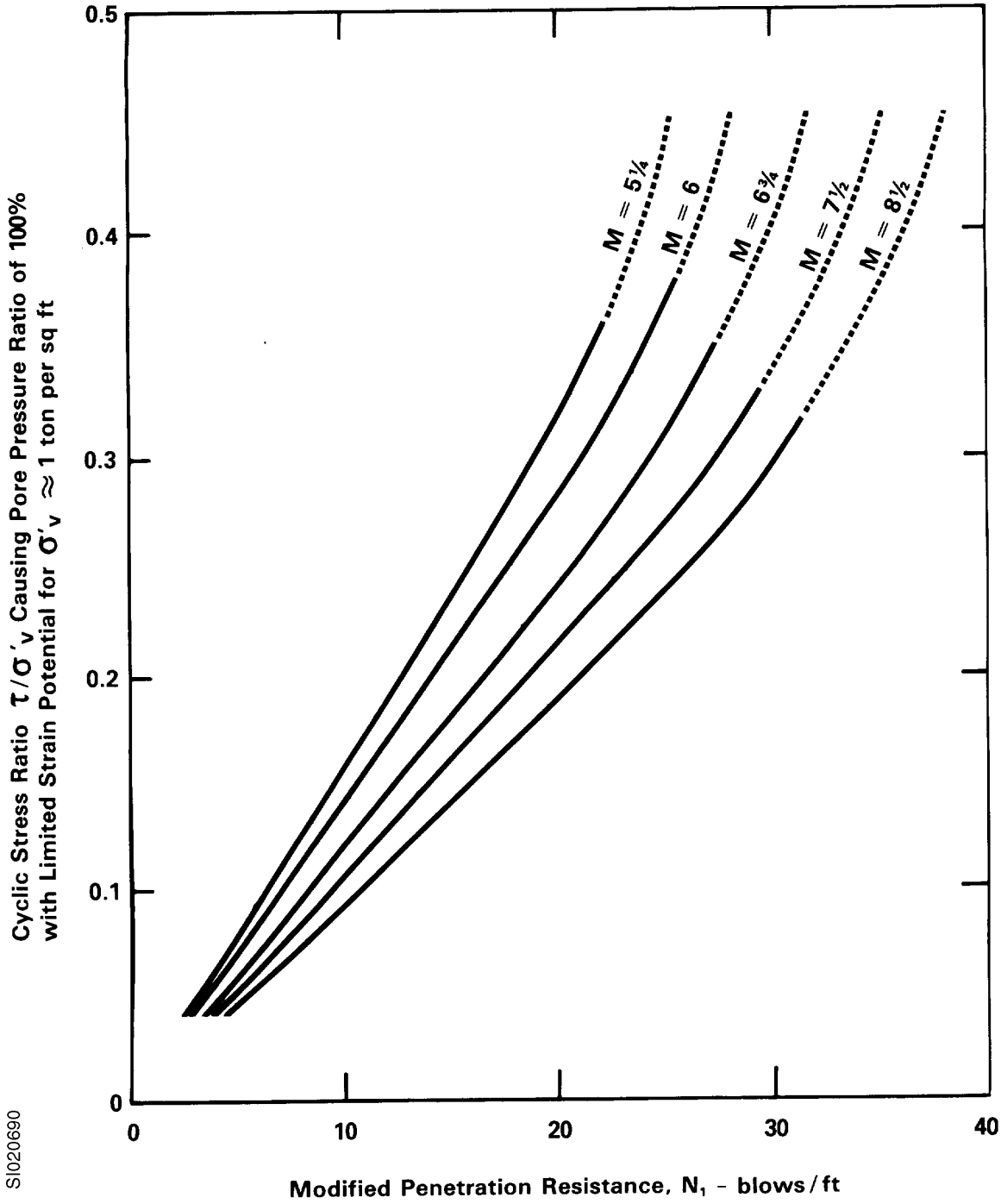
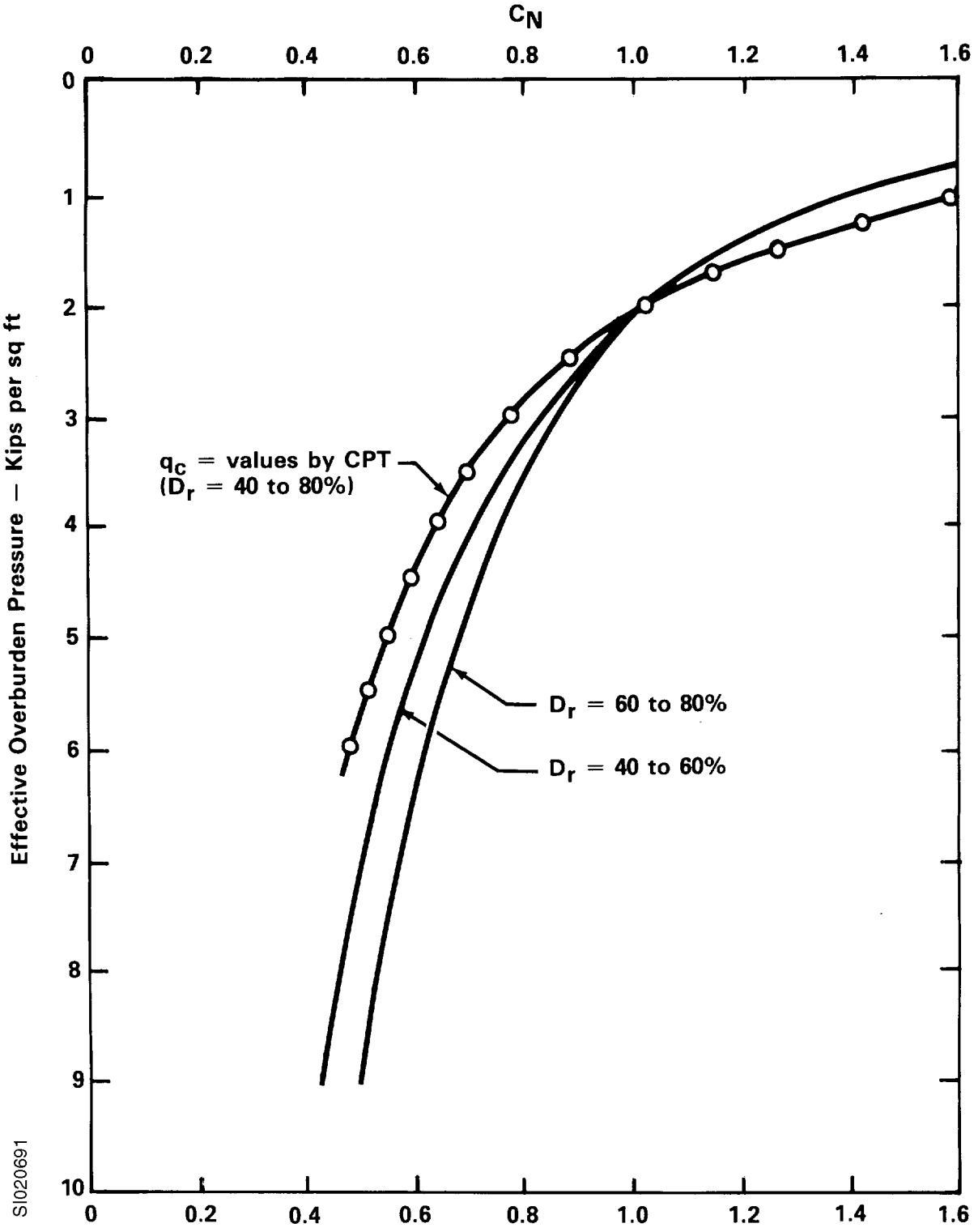


Figure 2.6-55
STANDARD PENETRATION ADJUSTMENT FACTORS



2.7 SUMMARY OF SITE CONDITIONS AFFECTING CONSTRUCTION AND OPERATING REQUIREMENTS

The site specific phenomena and characteristics described in this chapter have been used to define appropriate design criteria, as described in Chapter 3. See Table 2.7-1 for a summary of site specific information either newly established for the ISFSI or previously established for the Surry Power Station.

Table 2.7-1 (SHEET 1 OF 6)
SITE CHARACTERISTICS SUMMARY

	FACTOR	ISFSI SAR SECTION(S) REFERENCE	VALUE OR RANGE	SOURCE	COMPARISON TO SURRY POWER STATION UNITS 1 AND 2 (SPS)
1.	Ambient temperature	2.3.1.1, 2.3.2.1, 3.2.1.1	-20°F to 115°F	Range bands extreme temperatures reported in ISFSI SAR Section 2.3.5, References 1-3 and 11-14 and actual site data. See also the response to NRC Question 1.3.1.	Newly developed for the ISFSI. References cited are identical to References 1-6 and 9 of SPS UFSAR Section 2.2. Site data are also discussed in SPS UFSAR Section 2.2.1.
2.	Direct exposure to sunlight	3.2.1.1	0.800 cal/cm^2	Based on NRC Regulatory Guide 7.8; ISFSI SAR Section 3.2.6, Reference 1; and the response to NRC Question 1.3.2.	Newly developed for the ISFSI. Not applicable to SPS.
3.	Ambient humidity	3.2.1.1	0 to 100%	Range encompasses all possible values.	Range encompasses all possible values.
4.	Tornado pressure drop	2.3.1, 3.2.1.1	3 psi in 3 seconds	SPS UFSAR Section 2.2.1 and References 13 and 14 of SPS UFSAR Section 2.2.	Same value as established for Surry Power Station. See the discussion in SPS UFSAR Section 2.2.2.1.
5.	Tornado winds	2.3.1, 3.2.1.1	Rot. vel. -300 mph Trans. vel. -60 mph or RG 1.76	SPS UFSAR Section 2.2.2.1 RG 1.76	RG 1.76 values may be used in lieu of those established for SPS in SPS UFSAR Section 2.2.2.1

Table 2.7-1 (SHEET 2 OF 6)
SITE CHARACTERISTICS SUMMARY

FACTOR	ISFSI SAR SECTION(S) REFERENCE	VALUE OR RANGE	SOURCE	COMPARISON TO SURRY POWER STATION UNITS 1 AND 2 (SPS)
6. Wind direction	2.3.2.1.2	Predominantly from southwest and south southwest	Based on ISFSI SAR Section 2.3.5, Reference 1-3 and 11-14, and actual site data.	Predominant wind directions are the same as established for Surry Power Station in SPS UFSAR Section 2.2.1. References cited are identical to References 1-6 and 9 of SPS UFSAR Section 2.2.
7. Wind direction persistence	2.3.2.1.3	30 hrs (30.3 ft) 28 hrs (147.4 ft)	Based on ISFSI SAR Section 2.3.5, Reference 1-3 and 11-14, and actual site data.	Wind direction persistence is the same value as established for Surry Power Station in SPS UFSAR Section 2.2.1. References cited are identical to References 1-6 and 9 of SPS UFSAR Section 2.2.
8. Average wind speed	2.3.2.1.2	5.8 mph (30.3 ft) 9.8 mph (147.4 ft)	Based on ISFSI SAR Section 2.3.5, Reference 1-3 and 11-14, and actual site data.	Annual average wind speeds are the same as established for Surry Power Station in SPS UFSAR Table 2.2-5. References cited are identical to References 1-6 and 9 of SPS UFSAR Section 2.2.

Table 2.7-1 (SHEET 3 OF 6)
SITE CHARACTERISTICS SUMMARY

	FACTOR	ISFSI SAR SECTION(S) REFERENCE	VALUE OR RANGE	SOURCE	COMPARISON TO SURRY POWER STATION UNITS 1 AND 2 (SPS)
9.	Maximum winds (V_{30})	2.3.1.3.1, 3.2.1.1	105 mph	ISFSI SAR Section 2.3.5, Reference 4	Same value as established for Surry Power Station in SPS UFSAR Section 2.2.2.2. Reference cited is the same as Reference 17 of SPS UFSAR Section 2.2.
10.	Gustiness factor	2.3.1.3.1, 3.2.1.1	1.3	ISFSI SAR Section 2.3.5, Reference 5	Same value as established for Surry Power Station in SPS UFSAR Section 2.2.2.2. Reference cited is the same as Reference 18 of SPS UFSAR Section 2.2.
11.	Maximum flood level	2.4, 3.2.2	28.2 ft msl.	Based on ISFSI SAR Section 2.4.10, References 1-6	Same value as established for Surry Power Station in SPS UFSAR Section 2.3.1.2. References cited are identical to References 3, 5, 7-9, and 11 of SPS UFSAR Section 2.3.

Table 2.7-1 (SHEET 4 OF 6)
SITE CHARACTERISTICS SUMMARY

	FACTOR	ISFSI SAR SECTION(S) REFERENCE	VALUE OR RANGE	SOURCE	COMPARISON TO SURRY POWER STATION UNITS 1 AND 2 (SPS)
12.	Explosive peak over-pressure	2.2.3.1	1 psi	Established based on calculations and assumptions in ISFSI SAR Section 2.2.4, References 1 and 3-8.	Same value as established for Surry Power Station in SPS UFSAR Section 2.1.4.3. References cited are identical to References 9 and 11-15 of SPS UFSAR Section 2.1. Reference 5 of ISFSI SAR Section 2.2.4 was a personal communication that served to provide additional background information on the non-explosive behavior of unconfined gasoline vapor clouds.
13.	Atmospheric dilution value (χ/Q)	2.3.4	1.56×10^{-3} sec/m^3	Calculations based on NRC Regulatory Guide 1.145. See also the responses to NRC Questions 1.3.5E and 1.3.6.	Same value as developed for the Low Level Waste Storage Facility.
14.	Fires	2.2.3.2	Maximum increase of 8°F over ambient temperature	Calculations based on ISFSI SAR Sections 2.2.3.2 and 2.2.4, References 9-11.	Newly developed for the ISFSI.

Table 2.7-1 (SHEET 5 OF 6)
SITE CHARACTERISTICS SUMMARY

	FACTOR	ISFSI SAR SECTION(S) REFERENCE	VALUE OR RANGE	SOURCE	COMPARISON TO SURRY POWER STATION UNITS 1 AND 2 (SPS)
15.	Population distributions	2.1.3	Updated population distributions are provided in the responses to NRC Questions 1.1.1 and 1.1.2E through 1.1.5E.	Population distributions were determined based on References 1 and 2 of the response to Question 1.1.1 and References l-5 of the response to Question 1.1.5E.	The population data contained in the responses to NRC Questions 1.1.1 and 1.1.2E through 1.1.5E update the information in SPS UFSAR Section 2.1. References cited were either previously submitted to NRC for SPS or are reports developed by state or federal agencies.
16.	Lightning surge	2.3.1.3.6 (Future)	See the response to NRC Question 1.3.3.	See the response to NRC Question 1.3.3	Newly developed for the ISFSI.

Table 2.7-1 (SHEET 6 OF 6)
SITE CHARACTERISTICS SUMMARY

	FACTOR	ISFSI SAR SECTION(S) REFERENCE	VALUE OR RANGE	SOURCE	COMPARISON TO SURRY POWER STATION UNITS 1 AND 2 (SPS)
17.	Design earthquake peak acceleration	2.6, 3.2.3	0.07g	References contained in ISFSI SAR Section 2.6.6. See also the response to NRC Question 1.4.1.	Newly developed for the ISFSI. In ISFSI SAR Sections 2.6.1 and 2.6.2 the basic geology and tectonic information developed for the ISFSI is the same as established for the Surry Power Station. However, due to the passive safety function, the ISFSI design value is lower. ISFSI SAR Section 2.6.6 indicates references from the SPS PSAR for Units 3 and 4. Selected references utilized are taken from SPS UFSAR Sections 2.4 and 2.5.

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Appendix 2A
NRC COMMENT/RESPONSE 2.59 TO SURRY POWER STATION UNITS 3 & 4 PSAR

2A.1 Introduction

This Appendix contains the NRC Comment 2.59 to the PSAR for Surry Units 3 and 4 (1973) and the response generated for the Units 3 and 4 PSAR. It is presented in order to further explain the evidence or lack of evidence concerning the postulated Hampton Roads fault.

2A.2 General

COMMENT 2.59 (Section 2.5.1.1.(6), Tectonics) It is the staff's position that the applicant shall present evidence to demonstrate on sound geological and geophysical arguments whether the Hampton Roads fault postulated by Cederstrom, Bull, AAPG, Vol. 29, p 71, 1945, and supported by Rogers and Spencer, Bull GSA, Vol. 82, p 2314, 1971, is or is not a fault. If the feature proves to be a fault, the applicant is required to provide information to demonstrate the age of the most recent movement that it has experienced.

RESPONSE

The Hampton Roads fault was first proposed by Cederstrom in 1945 on the basis of well and geophysical data available at the time. The fault was proposed to explain apparent differences in thickness of Eocene sediments north and south of the James River. Primary in his hypothesis are three deep wells near Chesapeake Bay (Section F-F, Figure 2A-1). Figure 2A-2 shows the geologic cross section. The oil prospecting well at Mathews struck rock at El. -2297 and the well at Fort Monroe encountered rock at El. -2236. The well at Norfolk never reached bedrock before it was abandoned at El. -1750 ft.

Cederstrom (Reference 1) states on page 81:

> "Sets of samples from old deep wells at Fort Monroe were restudied in this laboratory and it was found that... Eocene foraminifers were present from 604 to 1440 feet; in addition, as already noted, Eocene macrofossils have been determined from material collected at 1440 feet; thus the lower boundary of the Eocene at Fort Monroe is about 725 feet lower than where the base of the Eocene was placed by early investigators." (Cederstrom (Reference 2) later changed the base of the Eocene to agree with that of the "early investigators.")

"The thickening of the Eocene deposits from Norfolk city waterworks to Fort Monroe is from 75 feet to more than 800 feet as shown in the cross sections EE' and FF'," Figures 2A-3 and 2A-2 respectively.

Using similar data and extrapolating known stratigraphic indexes westward, Cederstrom postulated a continuous trend of abrupt Eocene thickening along the James River and Hampton Roads area. Geologic cross sections developed by Cederstrom are located on Figure 2A-1 and presented on Figures 2A-2 to 2A-5.

Cederstrom summarizes his observations as follows:

Reference 1, page 85:

> "When the thicknesses of Eocene sediments on either side of James River and Hampton Roads are considered.... it is apparent that either subsidence occurred in the area north of the river in pre-Eocene time, allowing a much greater thickness of Eocene sediments to accumulate there than in the area on the south, or the pre-Eocene surface was deeply channeled with the same result.
>
> "The short distance in which thickening occurs, the apparent uniform thickness of the Eocene sediments in the whole Virginia Coastal Plain north of James River and Hampton Roads, and the progressive decrease in thickening upward seem to indicate that a basin formed in pre-Eocene time, probably by faulting action."

Reference 2, page 71:

> "The fault is thought to trend westward along the James River and approach the Fall Zone; the maximum displacement along the postulated fault, from 300 to 600 feet, occurs in the Hampton Roads area."

Reference 2, page 88:

> "In the Hampton Roads areas the Miocene boundaries, as shown in Section EE' and FF', are apparently unaffected, and it seems that movement along the fault ceased before Miocene time began."

Cederstrom postulated the fault occurred in the area of abrupt thickening, but refrained from showing it in his sections. He conceded that some of the northward thickening of the Eocene sediments might have resulted from deposition in a pre-Eocene channel. The topography of the Coastal Plan convinced Cederstrom that 700-foot erosion channels were improbable and therefore he postulated the Hampton Roads fault. Since the bottom of the Norfolk well in Figure 2A-2 was 486 feet higher than the rock encountered at Fort Monroe it was possible to postulate a fault with somewhat less than 486 feet of displacement. This reduced the required depth of pre-Eocene channeling to about 250 feet; something that Cederstrom considered "not too easily visualized." IL should be noted that rock was not encountered at Norfolk but that this line of reasoning amounts to assuming it was just below the bottom of the well.

Later in 1945, Cederstrom (Reference 3) expressed some concern about the classification of soils from wells south of the James River. He states:

"It may be recalled here that the Upper Cretaceous strata described by Darton are characterized by thin indurated layers but, on the other hand, recent studies show that indurated strata are by no means confined to Upper Cretaceous deposits and the possibility that these strata and overlying brightly colored beds may be of Eocene age must be borne in mind pending further information."

In Cederstrom's last study of the area (Reference 4), published in 1957, he concludes that his original (1945) classification and stratigraphic indexing was wrong. He explains (page 1) that "some previously held conceptions of Eocene and pre-Eocene stratigraphy have been greatly revised." He further states (page 25):

> "In previous publications (Cederstrom, 1945a, p. 36-37, pl. 1, and 1945c, p. 81-82, Fig. 6-7) the Eocene was said to be as much as 800 feet thick. This conclusion was based on the presence of Eocene foraminifera as reported by Cushman, on the presence of glauconitic sand in sediments thus designated, and by the report of Eocene macrofossils found at 1440 feet in the old U.S. Army well at Fort Monroe.
>
> "The pre-Eocene Mattaponi formation is characteristically glauconitic; the writer is satisfied that the Eocene foraminifera found at depth in the well cuttings from Fort Monroe are forms first appearing much higher and were washed down. The Eocene macrofossils found at 1440 feet at Fort Monroe are believed to have fallen from above or to have been improperly labeled when collected. It may be noted that no "rock" layer is reported in well 8c (Table 36) in which the fossils are said to have occurred but, on the other hand, a "calcareous rock crust and pebble conglomerate with some wood and shells" is logged between 840 and 850 feet in the Chamberlain Hotel well (9, Table 36). This log description is the only one in the two wells that fits the fossiliferous material shown to the writer by L. W. Stephenson.
>
> "The thickness of all the Eocene formations in Newport News may be as much as 240 feet, if the macrofossil was taken at that depth. The writer is inclined to believe it may not be much more than 125 feet thick. In any event, grating a thickness of 240 feet, the thickening of the Eocene section is hardly more than moderate."

Cederstrom's 1957 reclassification of Eocene and Cretaceous stratigraphy north and south of the James River shows only moderate Eocene thickening and no structural disturbance. The 1957 geologic cross sections are shown on Figures 2A-6 and 2A-7.

In effect, Cederstrom's interpretations of stratigraphy in 1957 were essentially the same as those of the earlier investigators referred to in his 1945 paper (Reference 1). There is no thickening in Eocene, no erosion channel and therefore no need for Cederstrom to postulate the Hampton Roads fault.

Brown's (Reference 5) work in 1972, based on closer well control and more reliable data than the limited regional data available to Cederstrom (Reference 1) in 1945, further substantiates

the lack of structural disturbance of the Eocene and other sedimentary units. Brown's structural contours shown on Figure 2.6-9 and Figures 2A-8 through 2A-18 show no structural disturbance in the James River area.

The bedrock structural contours on Figure 2.6-9 show no disturbance. The same 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.

A geological cross section across the James River near the plant site is shown on Figure 2A-19. The location of the Hampton Roads fault as proposed by Rogers and Spencer (Reference 6) is shown on this section. No structural disturbance is evident.

Rogers and Spencer (Reference 6) list localized dip reversals observed by Cederstrom (Reference 1) in 1945 as a reason for Cederstrom postulating the Hampton Roads fault. Cederstrom cited the dip reversals as examples of anomolous deformations in the Coastal Plain. He never related them directly to the proposed fault. Cederstrom (Reference 1) cited examples of dip reversal from Washington, D.C. to North Carolina and related them to general regional deformation, lensing, or to localized differential compaction. The dip reversal near Yorktown, Virginia was formed by differential compaction of underlying sediments as discussed in response to Comment 2.16. At Waverly, Virginia, Cederstrom (Reference 3) described the following:

> "From Disputanta to Waverly (Section B-B') the base of the Miocene deposits descends a minimum of 93 feet 7-l/2 miles in a west-east direction, but at Waverly it rises 11 feet in less than 1 mile eastward. However, the base of the Eocene glauconite beds falls 24 feet in this distance and hence the structure may be due to lensing rather than to deformation."

The cited dip reversals are therefore probably controlled by general regional subsidence, lensing, or to localized differential compaction rather than to any faulting.

Differences in stratigraphic position (sequence) of sediments north and south of the river were first presented by Cederstrom (Reference 1) in 1945. South of the James River Eocene sediments overlie Upper Cretaceous sediments whereas north of the river they overlie thinned Lower Cretaceous sediments. This difference was postulated as due to erosion not faulting. Cederstrom in 1957 (Reference 4) presents new evidence which shows that the Upper Cretaceous is present on both sides of the James River.

Cederstrom (Reference 1) never reported different bedrock depths north and south of the James River. He postulated them to circumvent the need for a 700-foot erosion channel which he considered impossible. The erosion channel was necessary in 1945 to explain a 700-foot increase

in the thickness of Eocene sediments north of the river. As shown above, Cederstrom (Reference 4), in 1957, no longer shows an increased Eocene thickness north of the river and therefore his postulated bedrock depth is not necessary. In fact, Figure 2.6-9 from Brown et al. (Reference 5) based on recent data (1972) shows no structural bedrock details indicative of faulting in the Hampton Roads area.

The conclusion from the above is that the geologic data which led Cederstrom to postulate the Hampton Roads fault in 1945 were disproved by him in 1957.

Gravity and magnetic data show a generally featureless area near the site. Interpretations of these geophysical data presented in responses to Comments 2.13 and 2.17 also show no structure in the vicinity of the site.

Rogers and Spencer (Reference 6) in 1971 published a paper which claimed to support the existence of the Hampton Roads fault based on their interpretations of the following:

1. Differences in chloride content in ground water north and south of the James River.
2. Different piezometric surface north and south of the river drill
3. Reversal in dip of strata indicated on electric logs of wells.

These are considered in the following:

1. Rogers and Spencer (Reference 6) present contours of groundwater chloride content in the York-James Peninsula. In general, a wedge of high chloride concentrations was found north of the James River and low concentrations are found south of the river. This is in accordance with Cederstrom's data (Reference 2) published in 1943 and shown on Figure 2A-20. Rogers and Spencer note an abrupt change in chloride concentration and conclude this is a result of a fault. Figure 2A-21 shows that the log of chloride concentration varies smoothly with distance. This form of variation has been observed in coastal aquifers (Reference 7) and is not the result of structural control. It is the result of hydrodynamic dispersion occurring at the boundary between salt water and fresh water.

   The location of the chloride wedge was explained by Cederstrom in 1943 (Reference 2). He concluded that his zones of high chloride content were a depositional remnant that had not been flushed out by fresh ground water. The contours presented by Rogers and Spencer are not referenced to individual wells. Cederstrom's data is shown on Figure 2A-20. Well depths are shown along with the chloride concentration in the ground water. It may be seen that deeper wells generally have higher chloride concentrations.

   Cederstrom also reported that variations in chloride concentration result from differences in permeability. This is consistent with the flushing of saline water concept. Rogers and Spencer (Reference 6) state:

"The Cretaceous and Eocene water-bearing sands may be considered as a unit since fluid communication exists between them; the result is that there are no great differences in water quality in these sands (Cederstrom 1943, 1945a, 1957)."

Cederstrom (Reference 4) page 81 states the following for Newport News:

"A chloride concentration of 1080 ppm was found at 400 feet, 600 ppm at 813 feet, 690 ppm at 900 feet; and 1680 ppm of chloride was present in water from well 13 (Table 37) at a depth of 820 feet. The excessively high chloride water sample from 400 feet was from a poorly producing stratum. The two samples lowest in chloride are from wells that are rather good producers and are in constant use, and the sample second highest in chloride is from a poor producer."

On page 46:

"There was also the possibility that chloride content might increase with pumping."

Cederstrom therefore recognized that the effect of depth, pumping rate, and permeability of the strata as well as the location, controlled chloride concentration. Recent evidence (References 8 & 9) shows that the aquifers are separated by aquitards and therefore direct hydraulic and chloride communications does not exist between aquifers and their response will be very time dependent. Chloride concentrations have been observed as a function of time (References 10 & 11).

A further complicating factor in the analysis of chloride from wells is that many of the wells are screened in more than one aquifer and that increased ground water pumping is changing the hydrodynamic and dispersion behavior of the saline-fresh water zone.

In summary it appears from geological evidence (Reference 4) that the high chloride wedge is depositional in nature; that Rogers and Spencer's (Reference 6) "abrupt" change in chloride content is only the normal coastal contact between fresh and salt water; and that the assumption of hydraulic communication vertically is not true.

2. Rogers and Spencer (Reference 6) make frequent references to the structural interpretation proposed by Cederstrom in 1945. As shown earlier in this response Cederstrom in 1957 greatly revised his previously held conceptions of Eocene and pre-Eocene stratigraphy and the structural data supporting the proposed Hampton Roads fault was thereby destroyed.

   Rogers and Spencer contour piezometric data "based on Cretaceous and Eocene static levels because of their fluid communication." As discussed in part a above, aquifers in the York/James area can be separated by aquitards and therefore fluid communication is retarded. Static water levels can be influenced by adjacent pumping wells as shown in Reference 11. Recharge, which is considered to provide a significant percentage of water to the aquifers (Reference 9), is not considered steady state recharge to a peninsula between two saline rivers, and would show a potentiometric high between them similar to Figure 2 by Rogers and Spencer. Nonsteady conditions complicate the potentiometric surface by highs

and should probably still occur if fresh water recharge continues. Recent studies in the area (Reference 8) show that the anomolous lows and highs are influenced by pumping and aquifer (Reference 9) thickness and permeability. Figure 2A-22 shows the potentiometric surface in 1900, Figure 2A-23 from 1937 to 1939, Figure 2A-24 from 1945 to 1948, and Figure 2A-25 from 1966 to 1969. It may be seen that the potentiometric surface is dropping with largest drops in the areas of highest pumping. The pumping has been greatest on the south side of the James River as explained by Cederstrom (Reference 4) and the potentiometric level has therefore decreased most there. One area near Franklin has been pumped so heavily that the potentiometric surface has dropped as much as 180 feet (Reference 11).

It is therefore evident that the potentimetric surface will continue to change with time as a function of pumping rates, local stratigraphic conditions, the aquifer or aquifers from which the wells pump, the proximity to wells or well groups, and the recharge occurring to the aquifers and aquitards from the surface. To conclude that structural controls are present requires that the hydrodynamic effects be considered, corrected for and interpreted. Rogers and Spencer (Reference 6) have not considered these effects and it is therefore concluded that no indication of structural control is evident in the potentiometric data.

3. Rogers and Spencer (Reference 6) interpret electric logs to show a vertical offset at the James River. Rogers and Spencer's Figure 3 shows no wells closer than 8 miles to the proposed fault. In addition, they arbitrarily draw horizontal lines to represent the Eocene stratum. When these are projected 8 miles to the proposed fault there is a resulting offset of 60 feet. They appear to have correlated their electric logs by presupposing the existence of the Hampton Roads fault.

   It should first be pointed out that electric logs are no more than indirect geophysical methods and must therefore be considered interpretive not primary. In terms of clarity and uniqueness of interpretation, electric logs are no substitute for first-hand sampling of well materials. In this respect, Rogers and Spencer's section based on electric logs is subordinate to the stratigraphic sections by Cederstrom (Reference 24), Brown (Reference 9), and to interpretations of well data in the vicinity of the site as shown on Figure 2A-26. Since these stratigraphic sections show no fault, the electric logs cannot independently support a fault.

The following conclusions can be made from the above discussions:

1. The reversals in dip are not fault controlled.
2. There is no abrupt thickening of the Eocene sediments north of the James River as first proposed in 1945 and later refuted in 1957 by D. J. Cederstrom
3. No different stratigraphic positions in the Eocene north and south of the James River are evident. This was first proposed in 1945 and later refuted in 1957 by D. J. Cederstrom.
4. There is no evidence of different depths to basement north and south of the James River. In fact, recent evidence by Brown (Reference 6) shows that there is not a difference. The

original difference in depth was postulated to describe 1945 stratigraphic and coastal interpretations.

5. The high chloride wedge north of the James River is probably a result of incomplete flushing of sea water which once saturated the sediments. Chloride concentrations are a function of depth, permeability, flow or pumping rates, time and location, and are representative of coastal aquifer conditions.

6. The potentiometric surface is variable but does not indicate fault control. The potentiometric surface is variable depending on pumping rates, local stratigraphic conditions, the aquifer or aquifers from which the wells pump, the proximity to other wells or groups of wells and recharge from the surface to underlying aquifers and aquitards.

7. Electric log interpretation is an indirect method of developing geologic sections. Direct logging of wells does not show a fault. The data and geologic, geotechnical, and geohydrologic interpretations thereof show no evidence of fault control. The data and the anomalies have been reinterpreted and controls other than faulting are evidenced. The Hampton Roads fault therefore does not exist.

2A.3 References[1]

1. Cederstrom, D. J., *Structural Geology of Southeastern Virginia,* American Association of Petroleum Geologists, Bulletin, Vol. 29, No. 1, 1945.(†)

2. Cederstrom, D. J., *Chloride in Ground Water in the Coastal Plain of Virginia,* Bulletin 58, Virginia Geological Survey, 1943.(†)

4. Cederstrom, D. J., *Geology and Ground-Water Resources of the York-James Peninsula, Virginia,* USGS Water Supply Paper 1361, 1957, pp. 237, 1957.(†)

5. Brown, P., Miller, and Swami, *Structural and Stratigraphic Framework, and Spatial Distribution of Permeability of the Atlantic Coastal Plain North Carolina to New York,* United States Geol. Survey Prof. Paper 796, 1972.(†)

6. Rogers, W. S., and Spencer, R. S., *Groundwater Quality and Structural Control in Southeastern Virginia,* GSA Bulletin 82, pp 2313-2318, 1971.(†)

7. Cooper, H. H., Jr., *A Hypothesis Concerning the Dynamic Balance of Fresh Water and Salt Water in a Coastal Aquifer,* Journal of Geophysical Research, Vol. 64, No. 4, April 1959.(†)

8. Virginia Division of Water Resources, *Ground Water of Southeastern Virginia,* Planning Bulletin 261, 1970.(†)

9. Virginia Bureau of Water Control Management, *Ground Water of the York-James Peninsula, Virginia,* Basic Data Bulletin 39, June 1973.(†)

1. References noted with an (†) indicate an original reference from Surry Power Station Units 3 and 4 PSAR.

10. Virginia Bureau of Water Control Management, *Ground Water in Virginia: Quality and Withdrawals,* Basic Data Bulletin 38, June 1973.(†)

11. Brown, G. Allan, and Cosner, O. J., *Ground Water Conditions in the Franklin Area, Southeastern, Virginia,* Open File Report, USGS, Richmond Virginia, 1973.(†)

Figure 2A-1
MAP OF COASTAL PLAIN AREA IN VIRGINIA SOUTH OF POTOMAC RIVER
SHOWING LOCATIONS OF CROSS SECTIONS

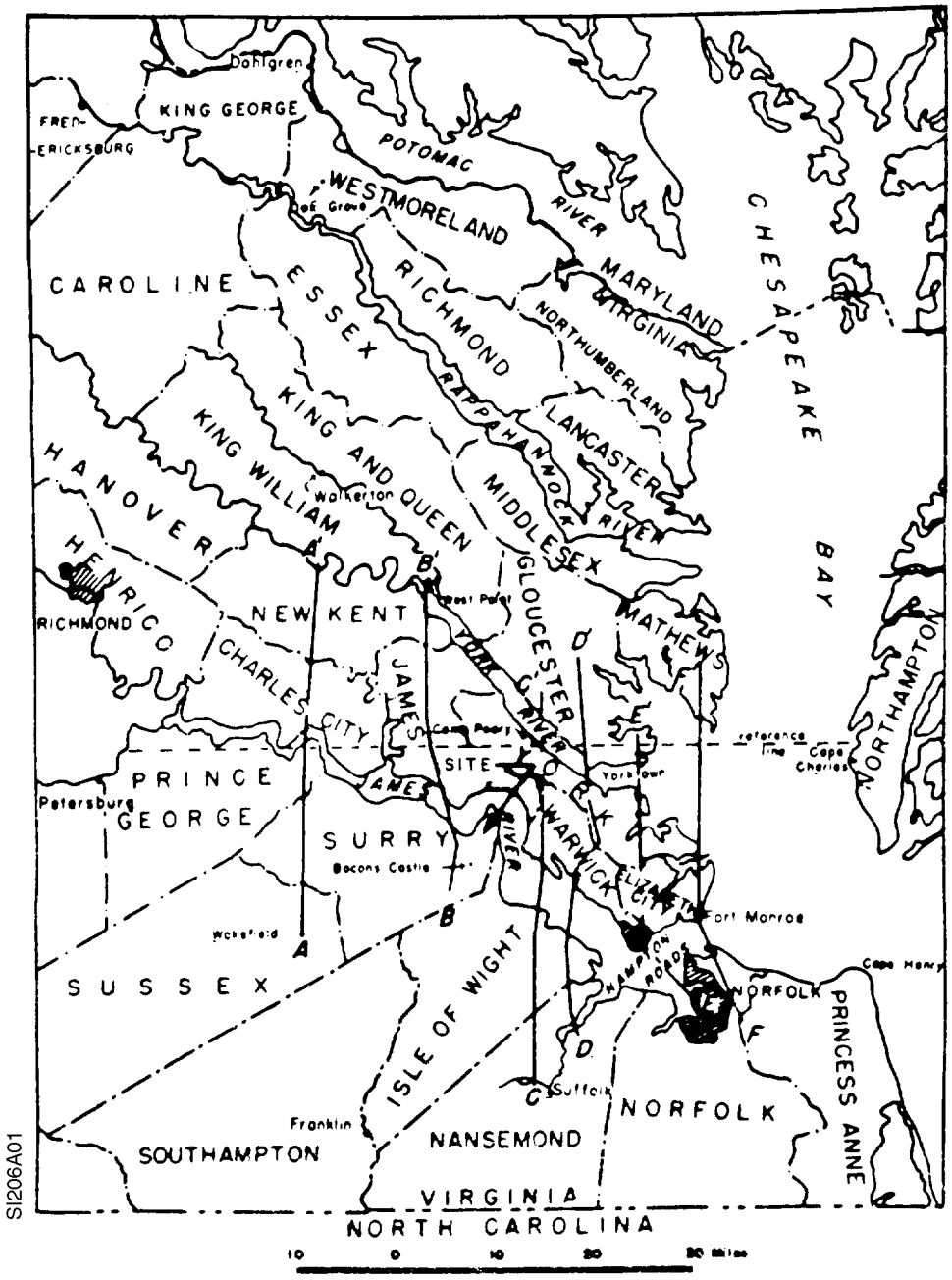

Figure 2A-2
GEOLOGICAL CROSS SECTION FF

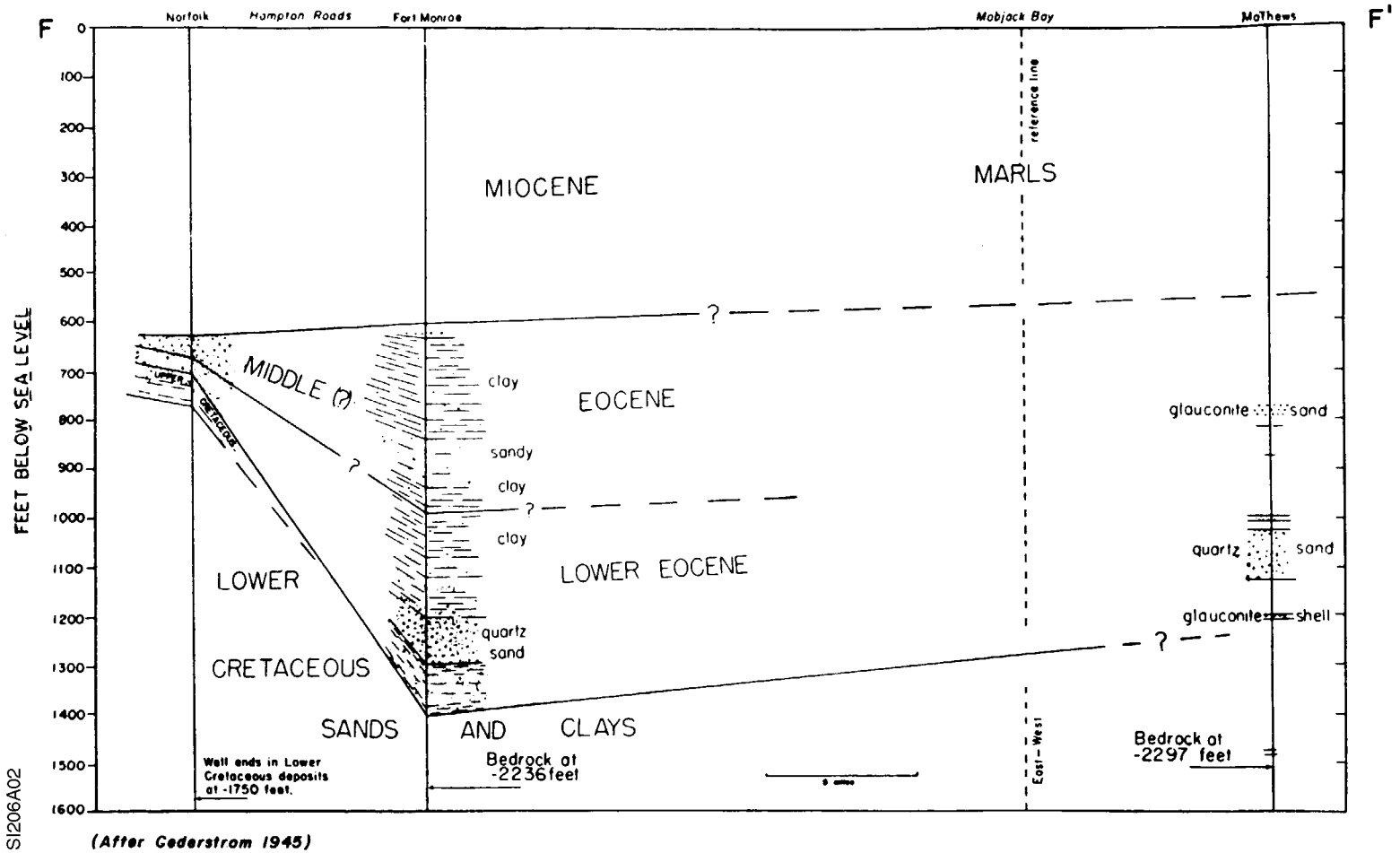

Figure 2A-3
GEOLOGICAL CROSS SECTION EE

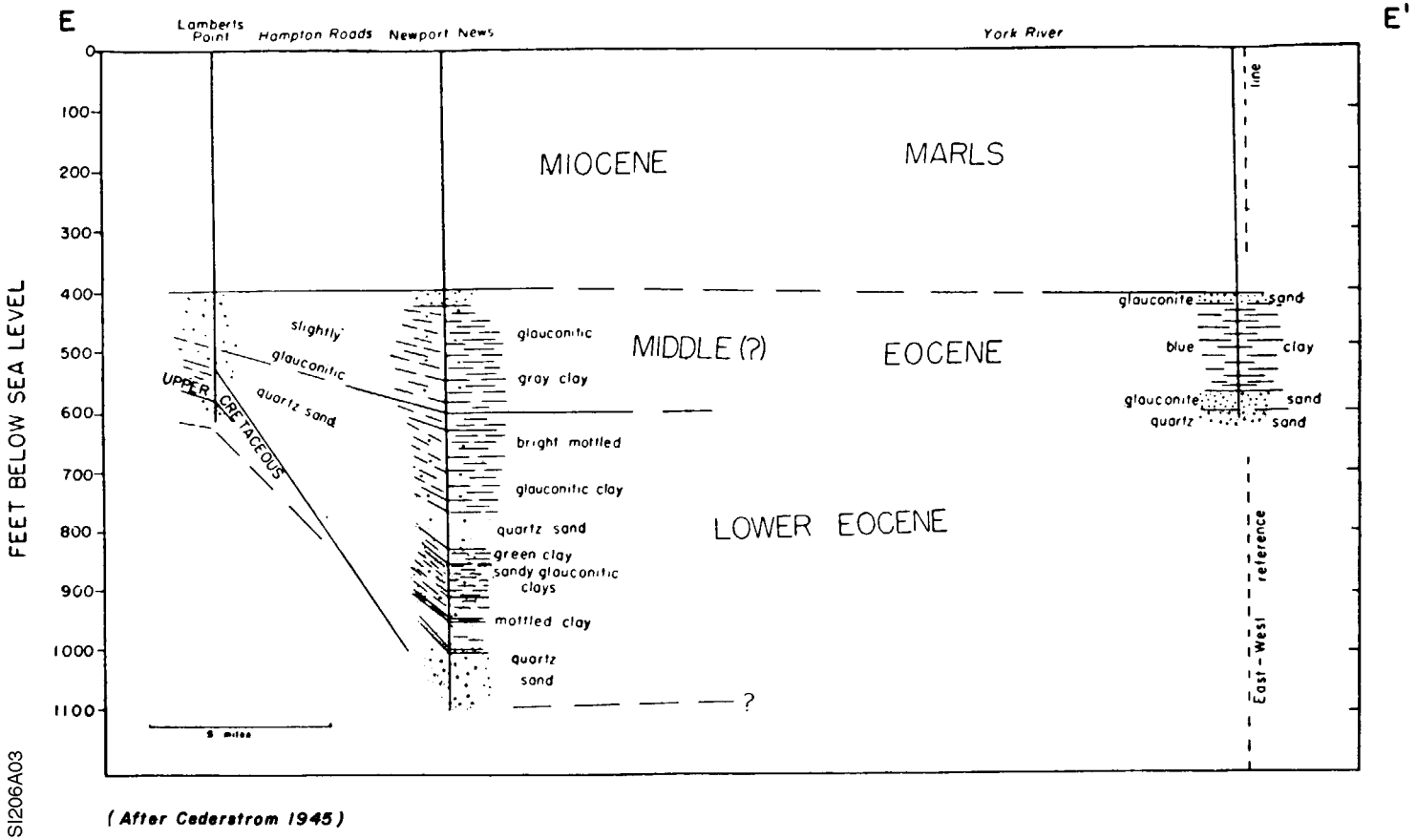

Figure 2A-4
GEOLOGICAL CROSS SECTION BB

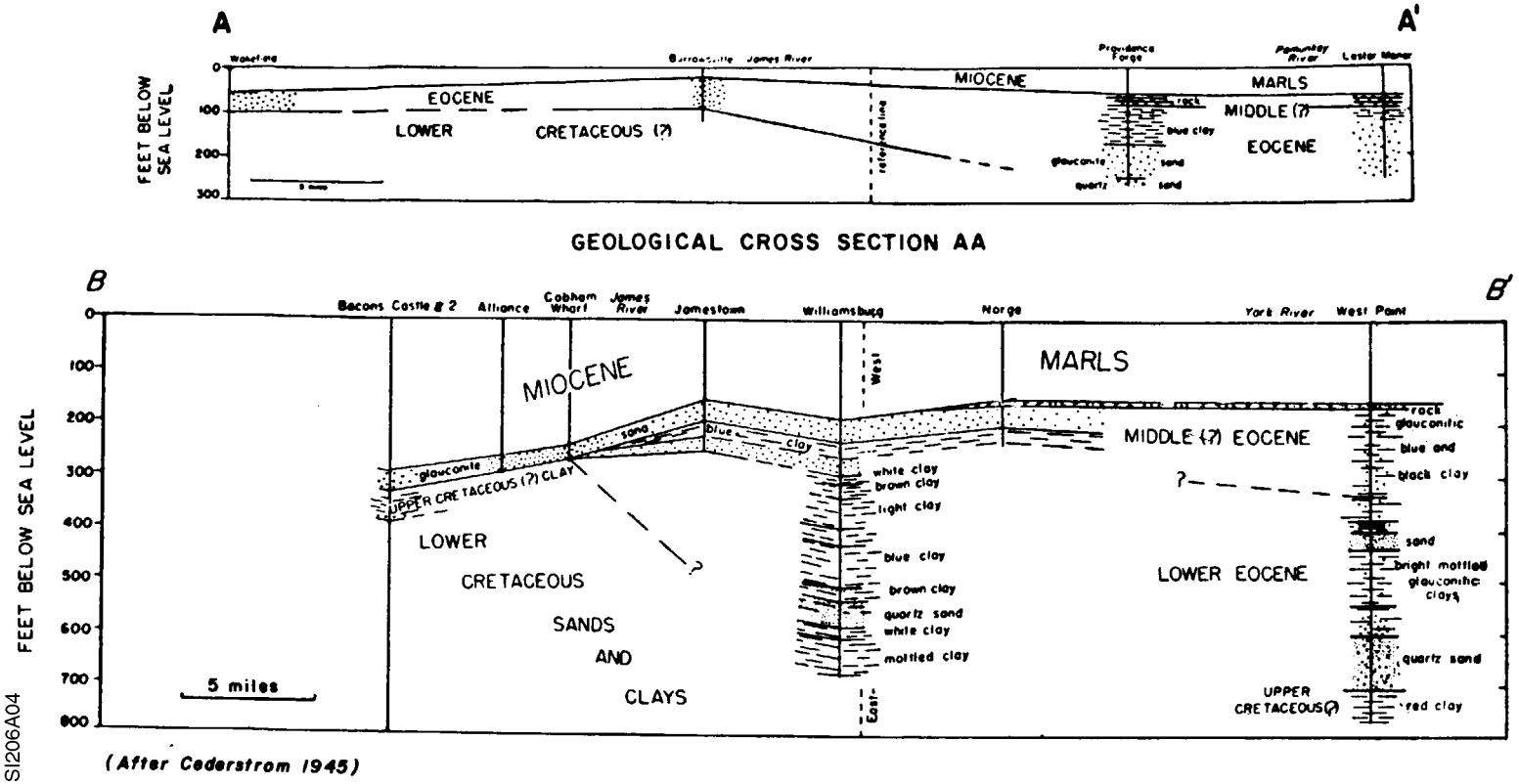

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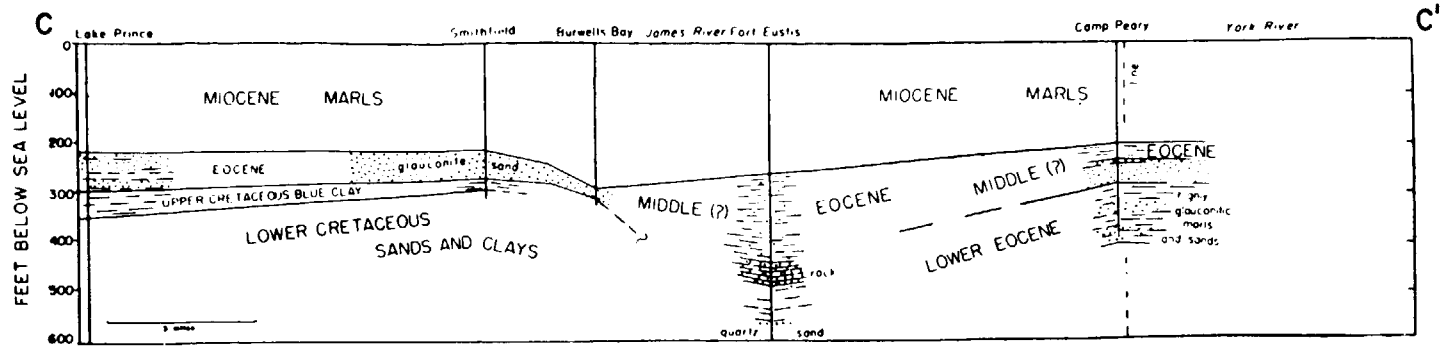
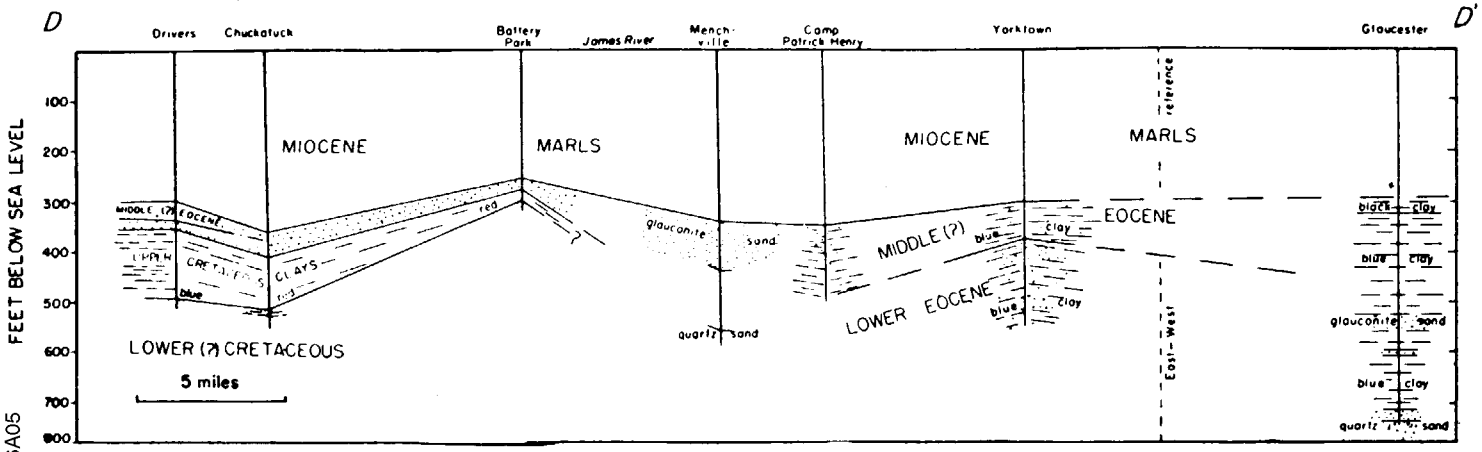
Figure 2A-5
GEOLOGICAL CROSS SECTION DD



GEOLOGICAL CROSS SECTION CC



SI206A05

(After Cederstrom 1945)

Figure 2A-6
INDEX SHOWING LOCATION
OF AREA AND OF CROSS SECTIONS

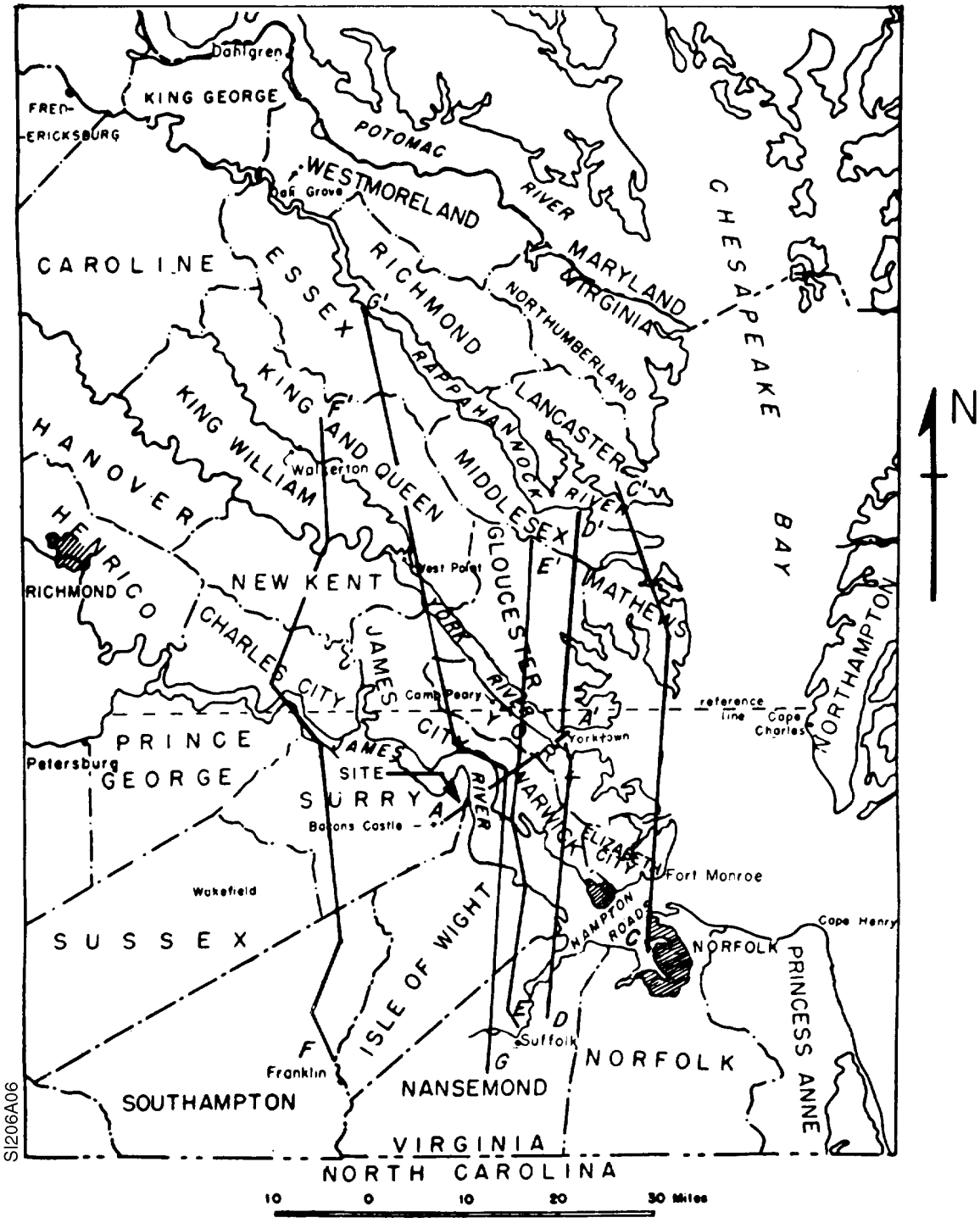
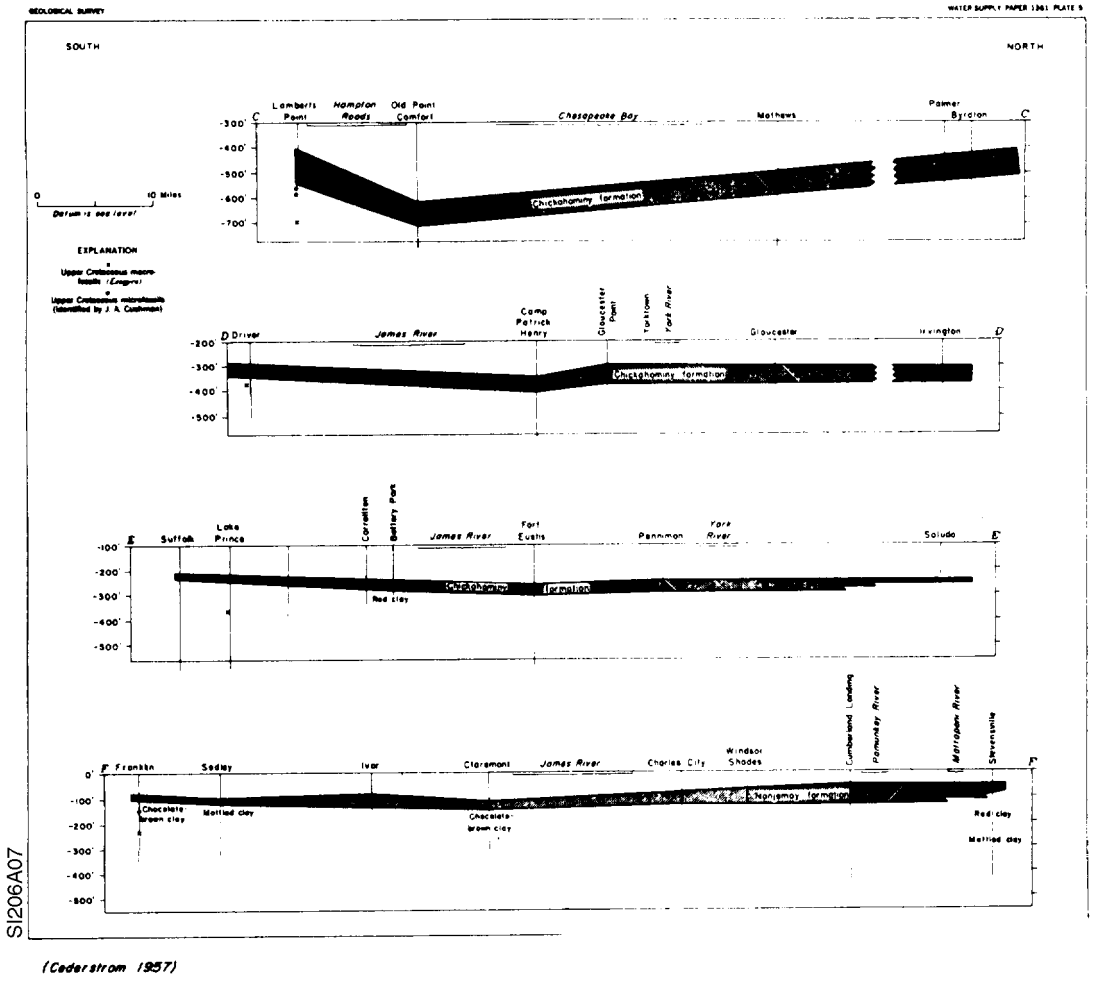


Figure 2A-7
CROSS SECTIONS SHOWING POSITION OF FORMATION IN THE YORK - JAMES PENINSULA, VIRGINIA RELATIVE TO AREAS NORTH AND SOUTH



(Cederstrom 1957)

Figure 2A-8
STRUCTURAL CONTOURS; CRETACEOUS AND LATE JURASSIC (UNIT H)

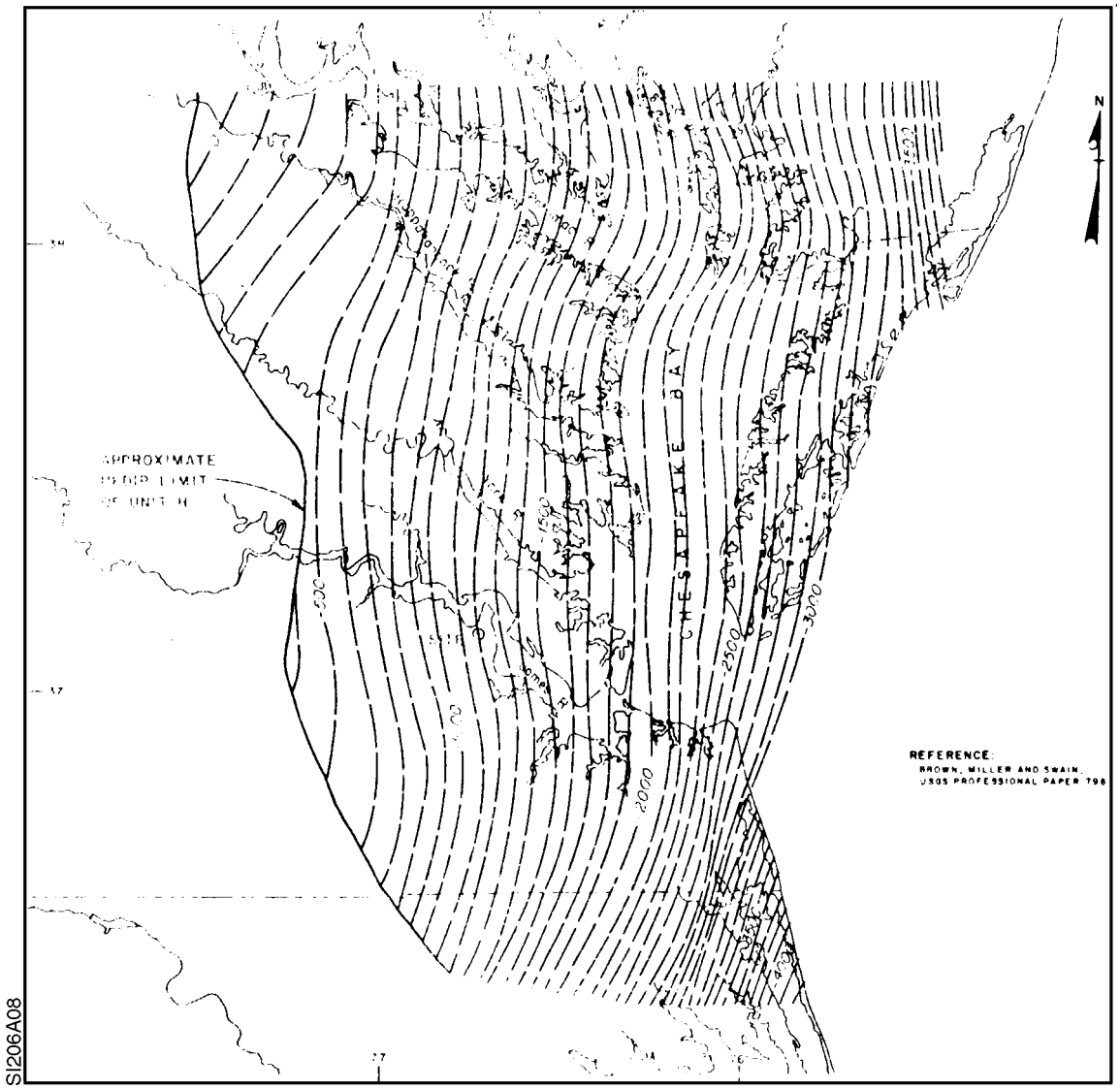


Figure 2A-9
STRUCTURAL CONTOURS; CRETACEOUS (UNIT G)

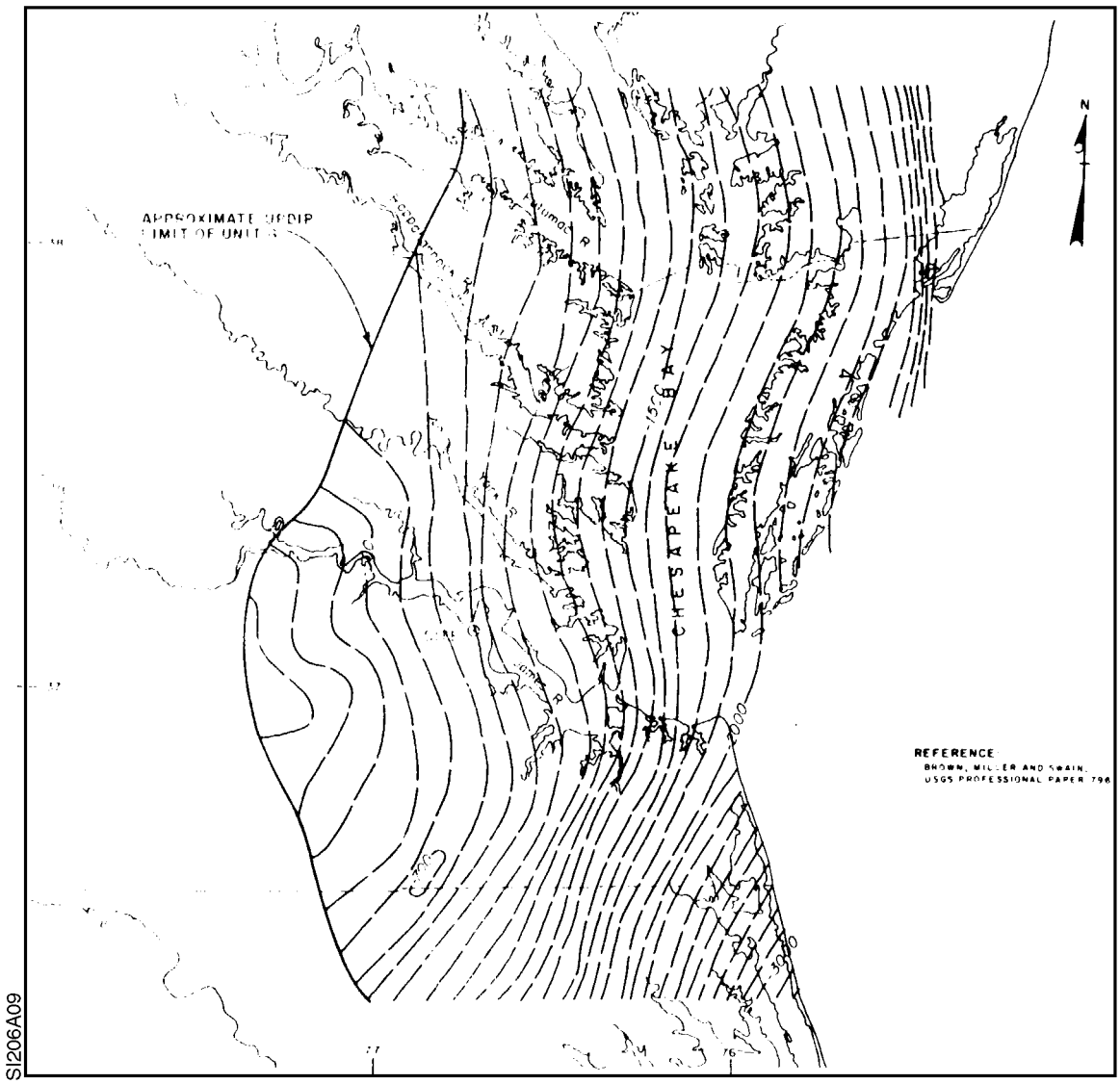


Figure 2A-10
STRUCTURAL CONTOURS; CRETACEOUS (UNIT F)

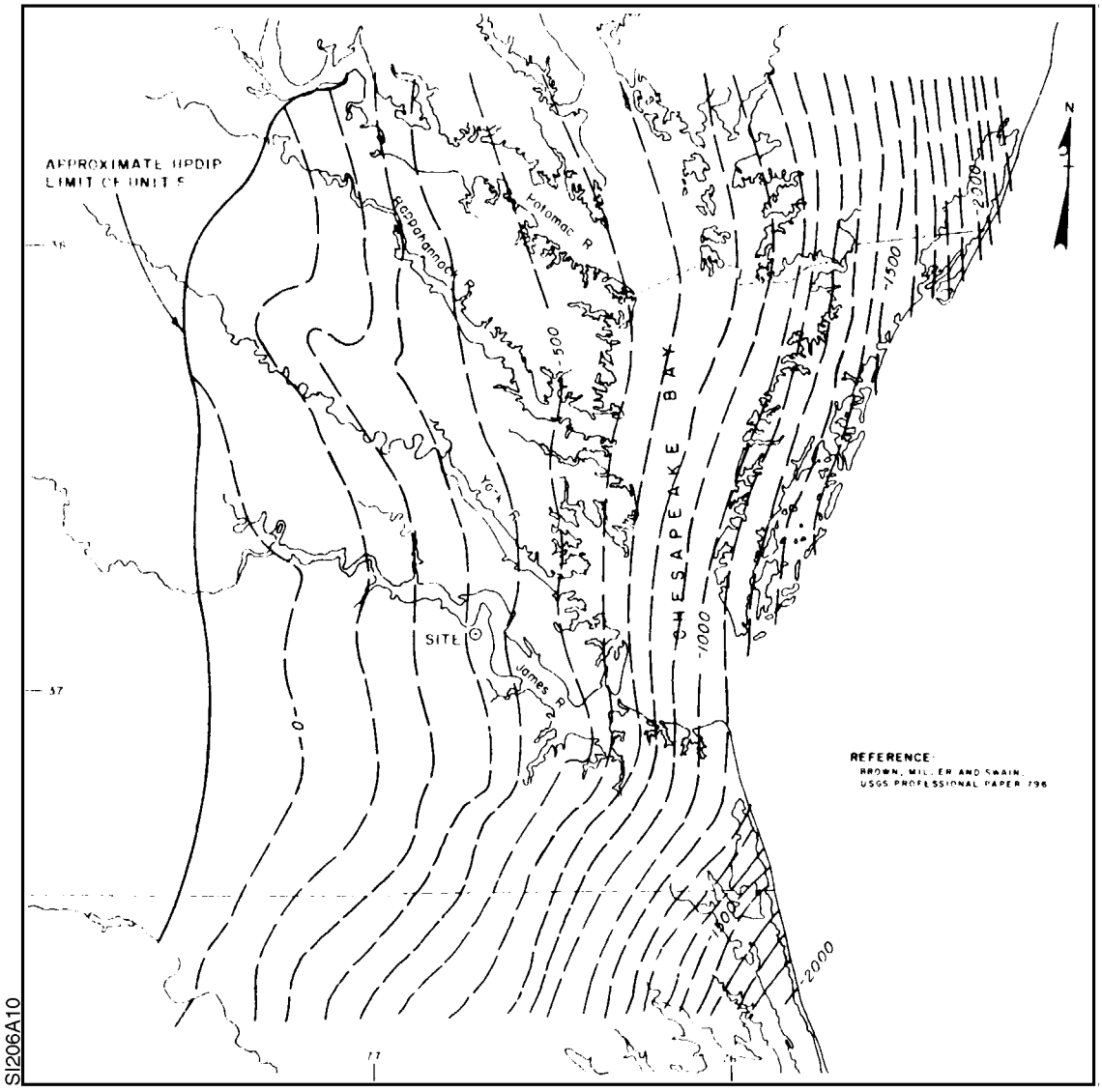


Figure 2A-11
STRUCTURAL CONTOURS; CRETACEOUS (UNIT C)

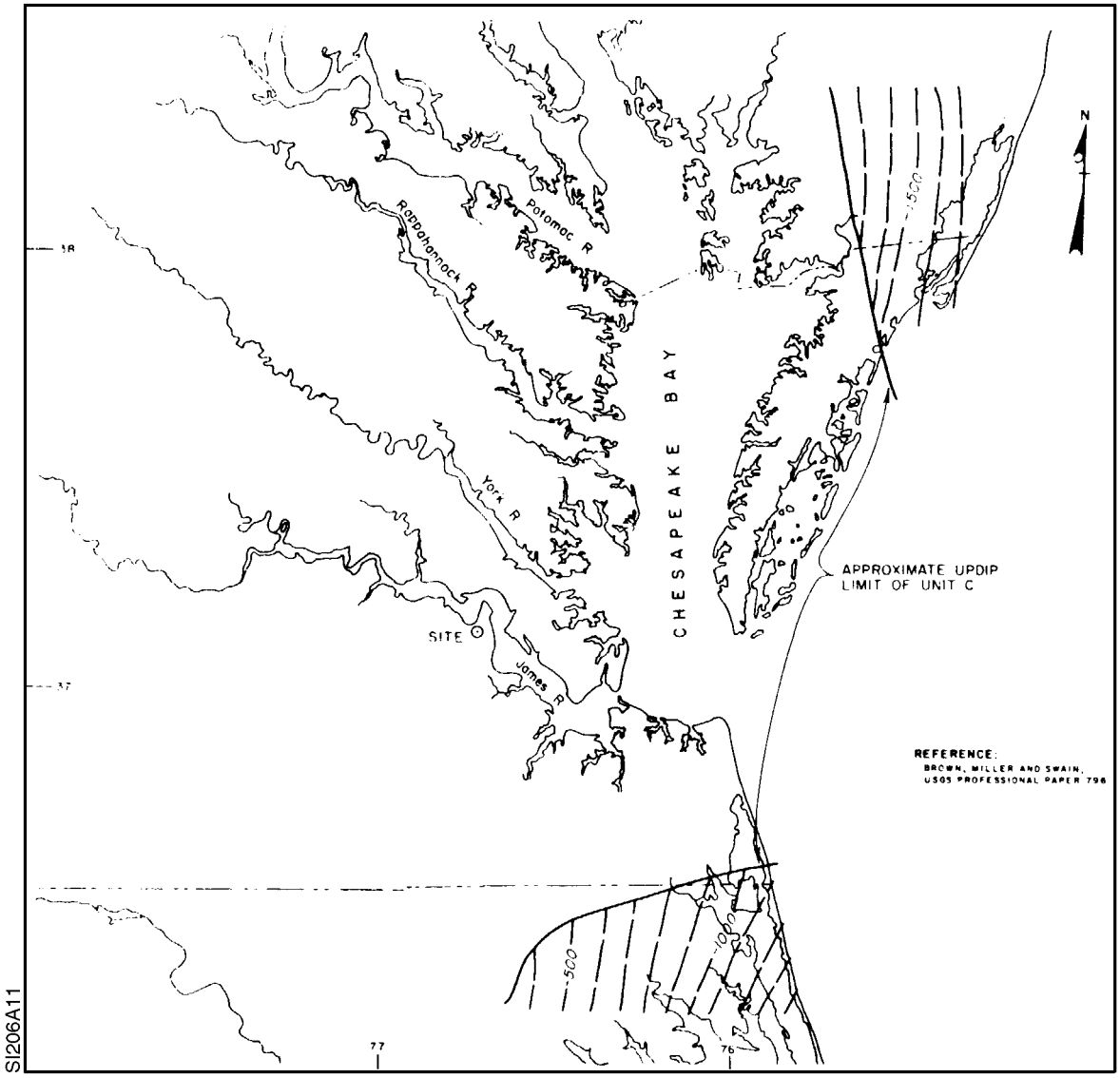


Figure 2A-12
STRUCTURAL CONTOURS; CRETACEOUS (UNIT B)

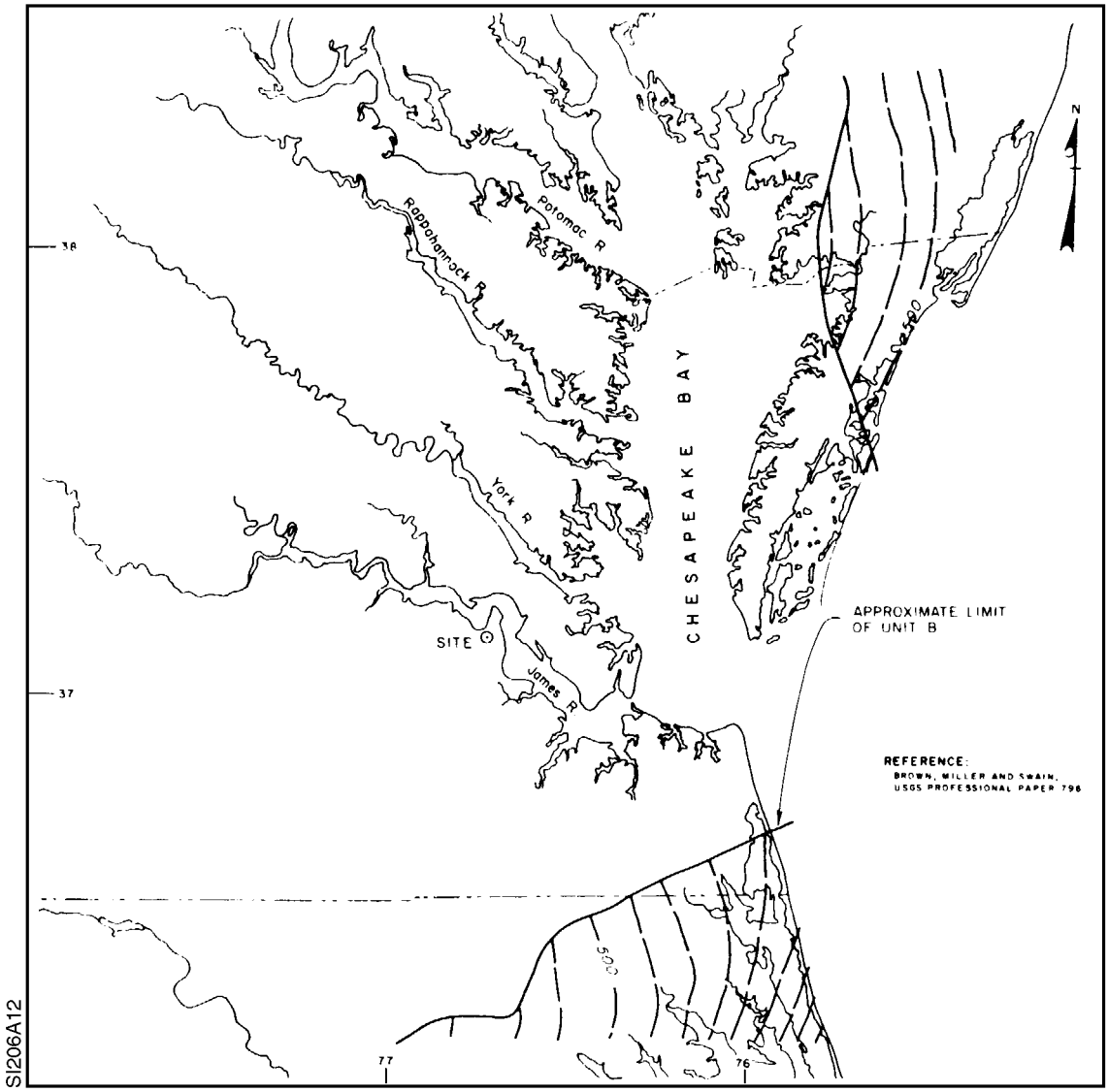


Figure 2A-13
STRUCTURAL CONTOURS; MIDWAY AGE ROCKS

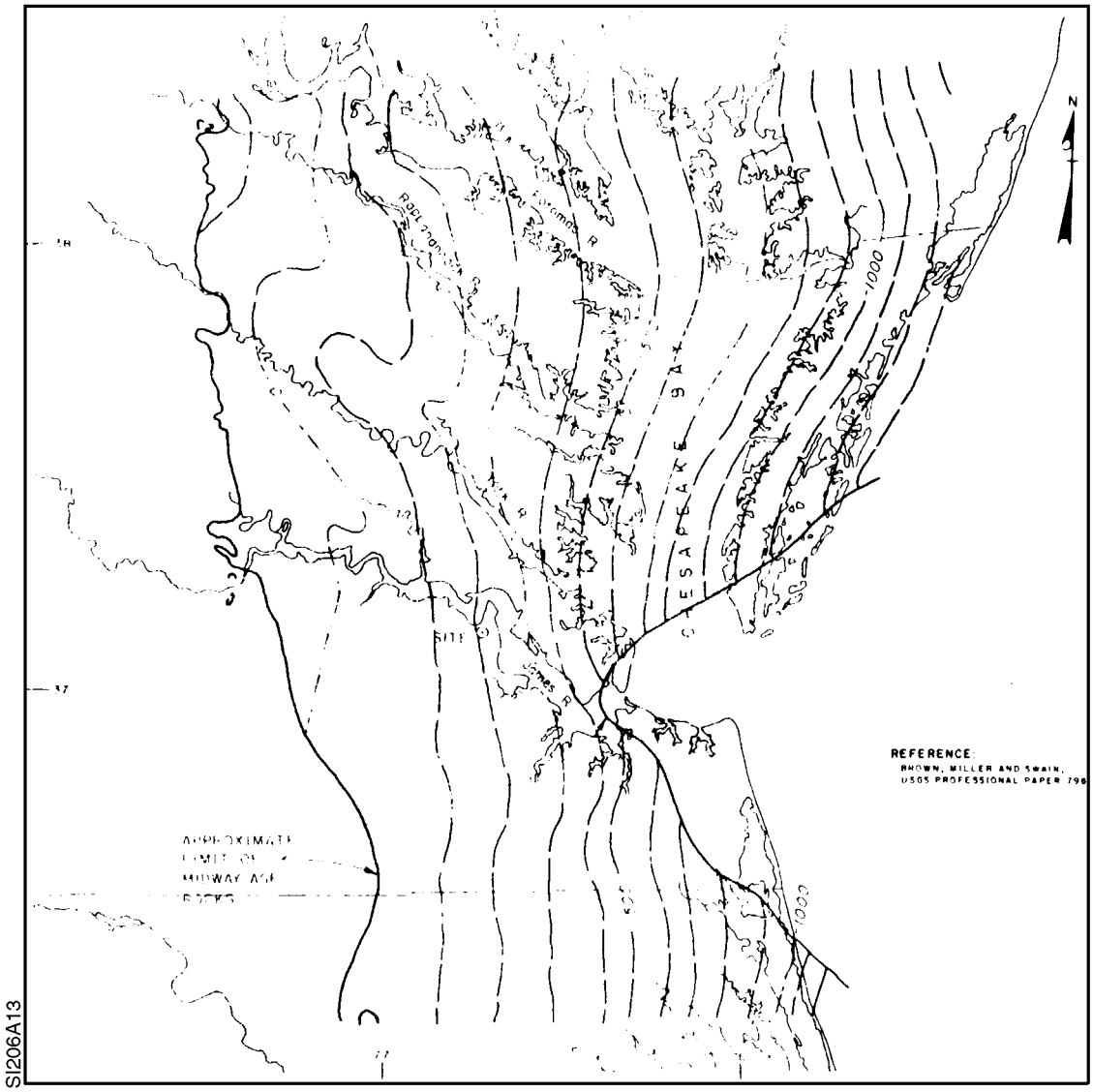


Figure 2A-14
STRUCTURAL CONTOURS; CLAIBORNE AGE ROCKS

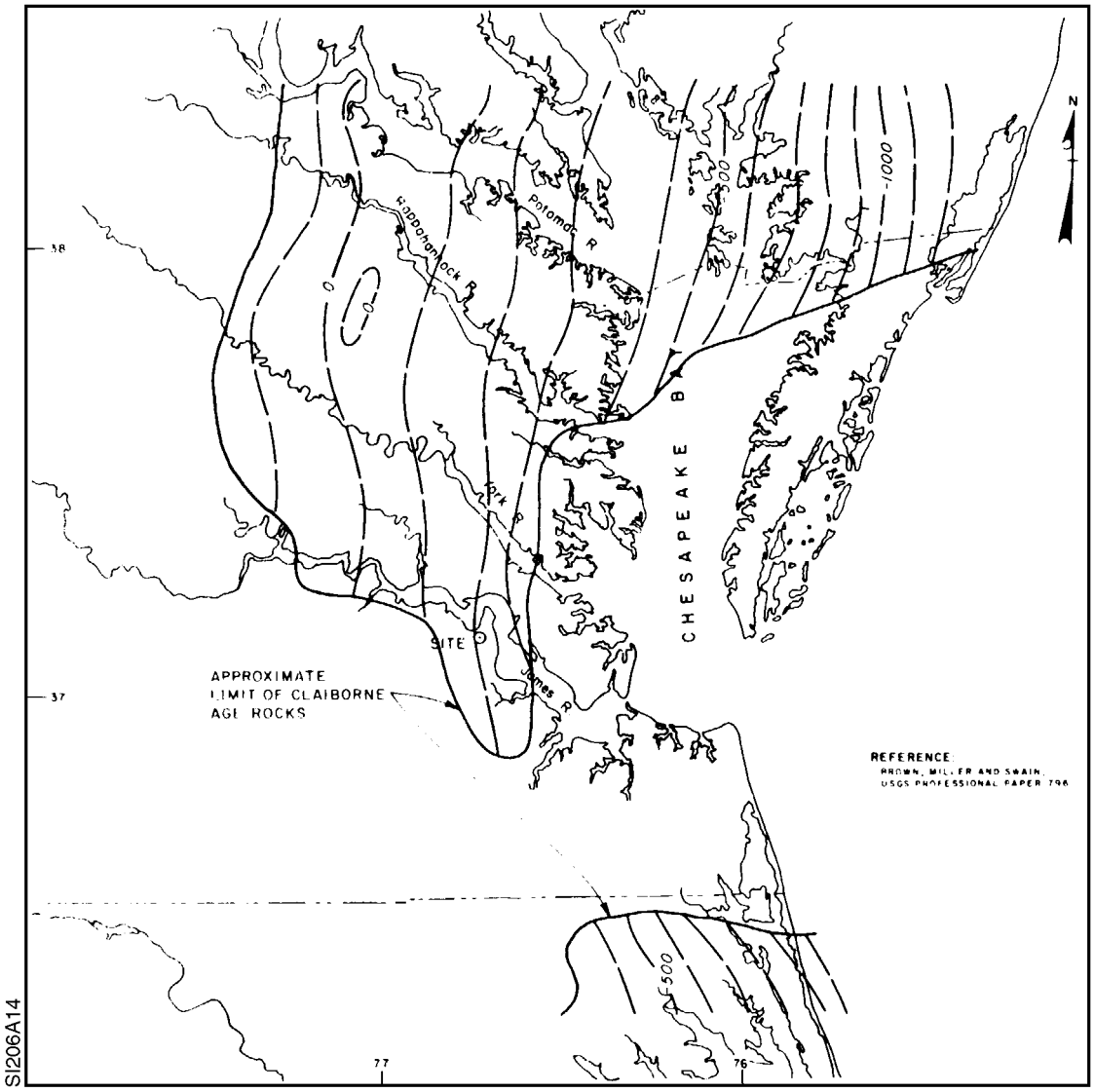


Figure 2A-15
STRUCTURAL CONTOURS; JACKSON AGE ROCKS

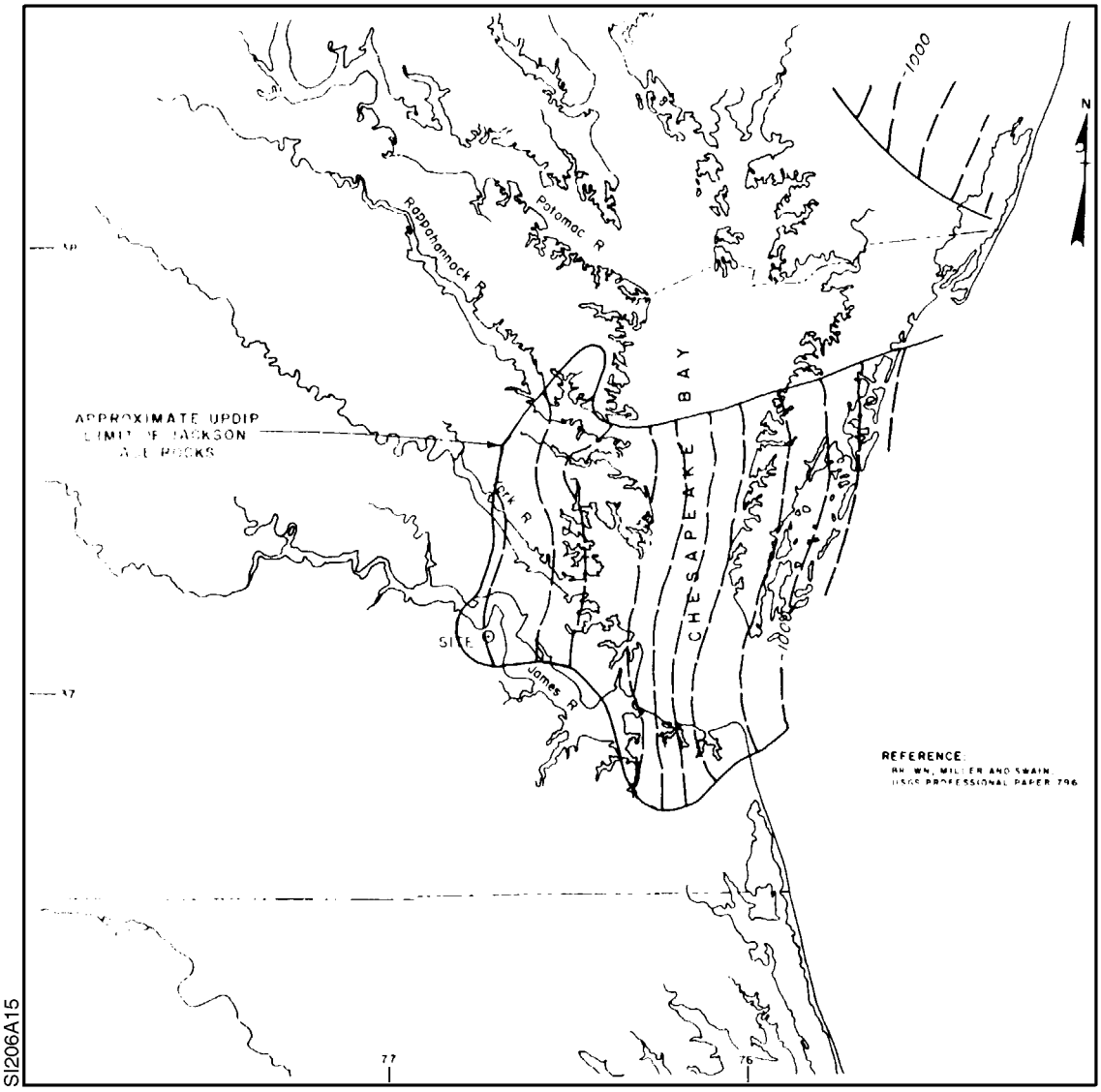


Figure 2A-16
STRUCTURAL CONTOURS; MIDDLE MIOCENE

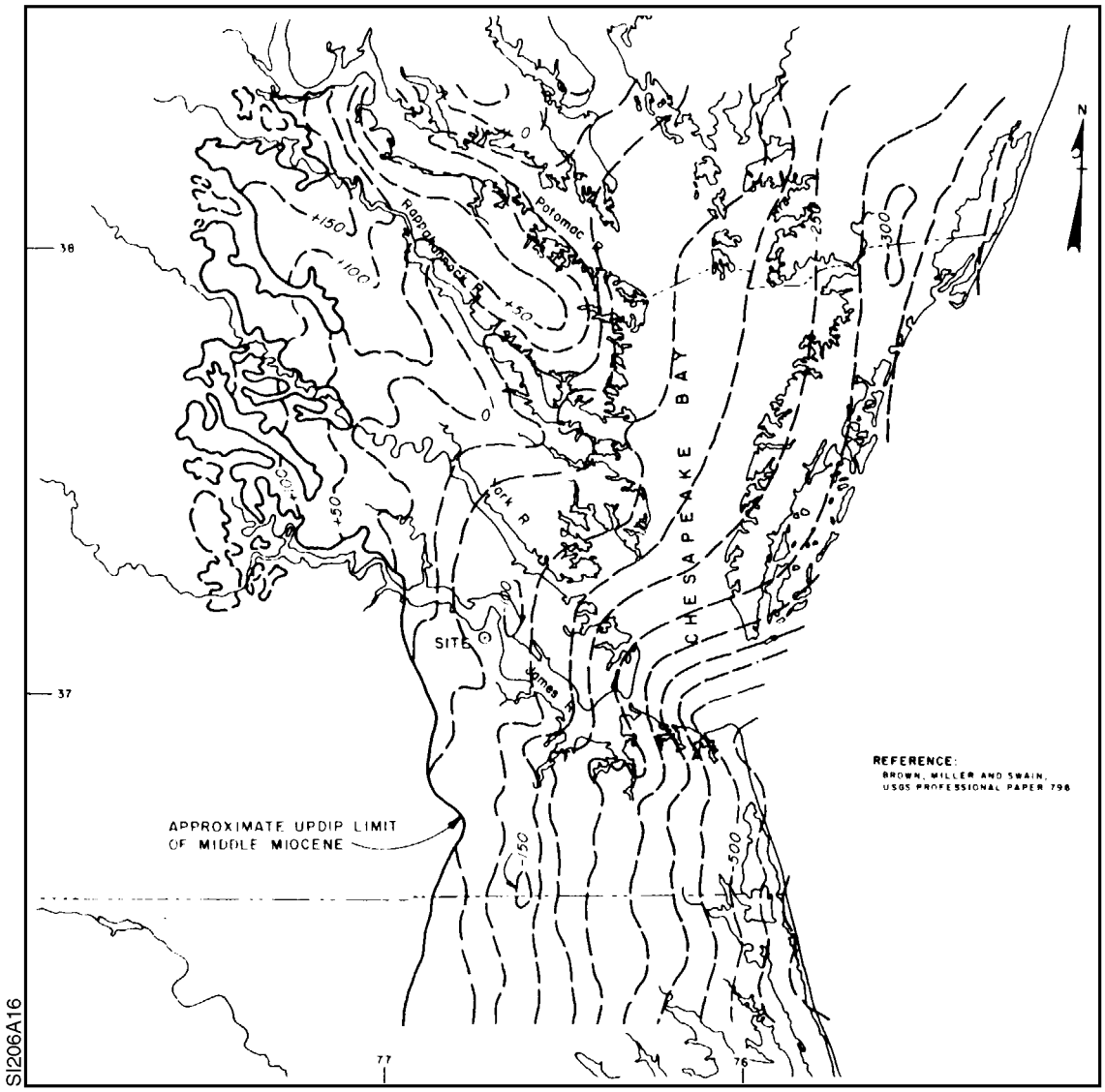


Figure 2A-17
STRUCTURAL CONTOURS; LATE MIOCENE

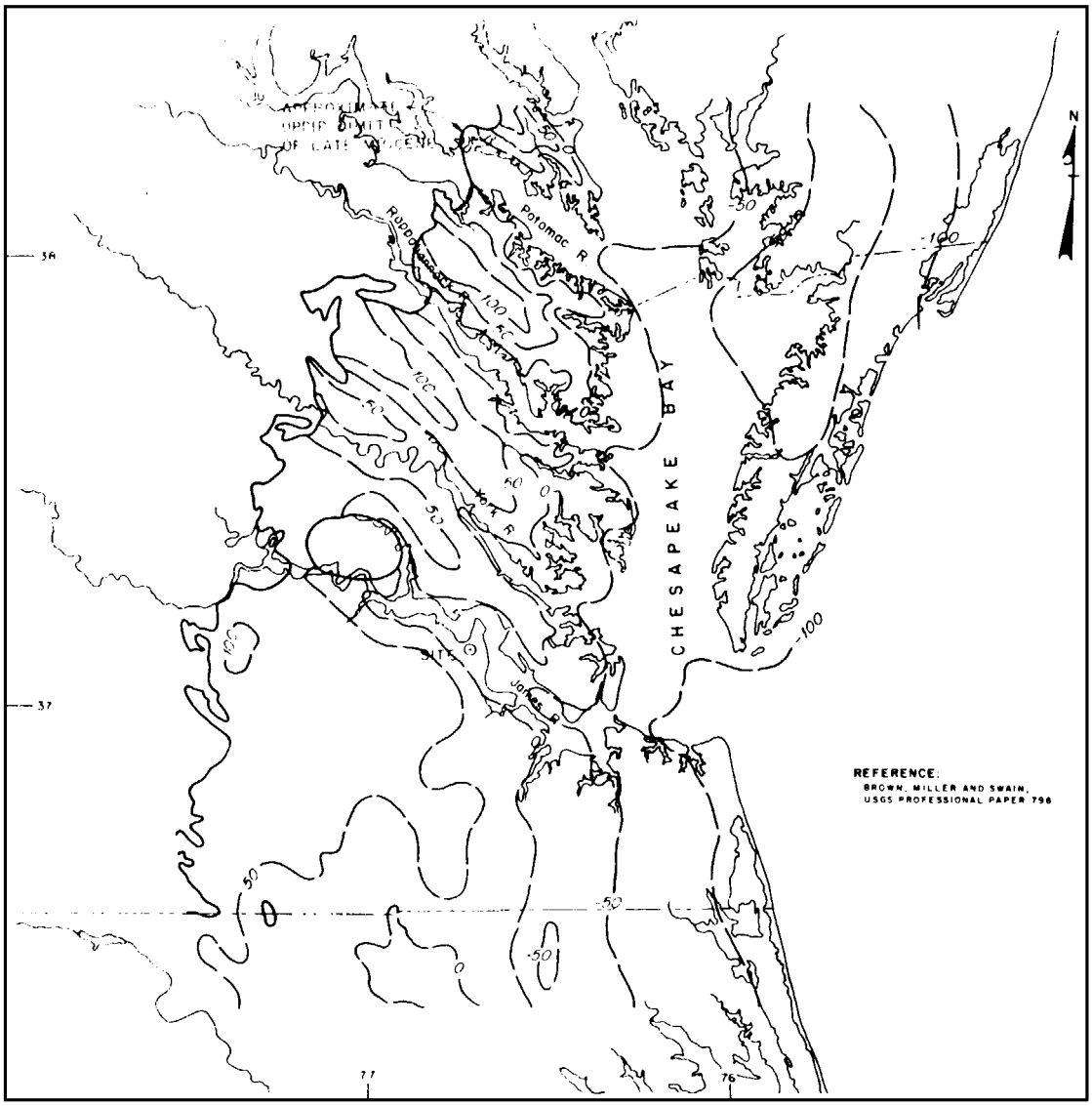


Figure 2A-18
STRUCTURAL CONTOURS; POST MIOCENE

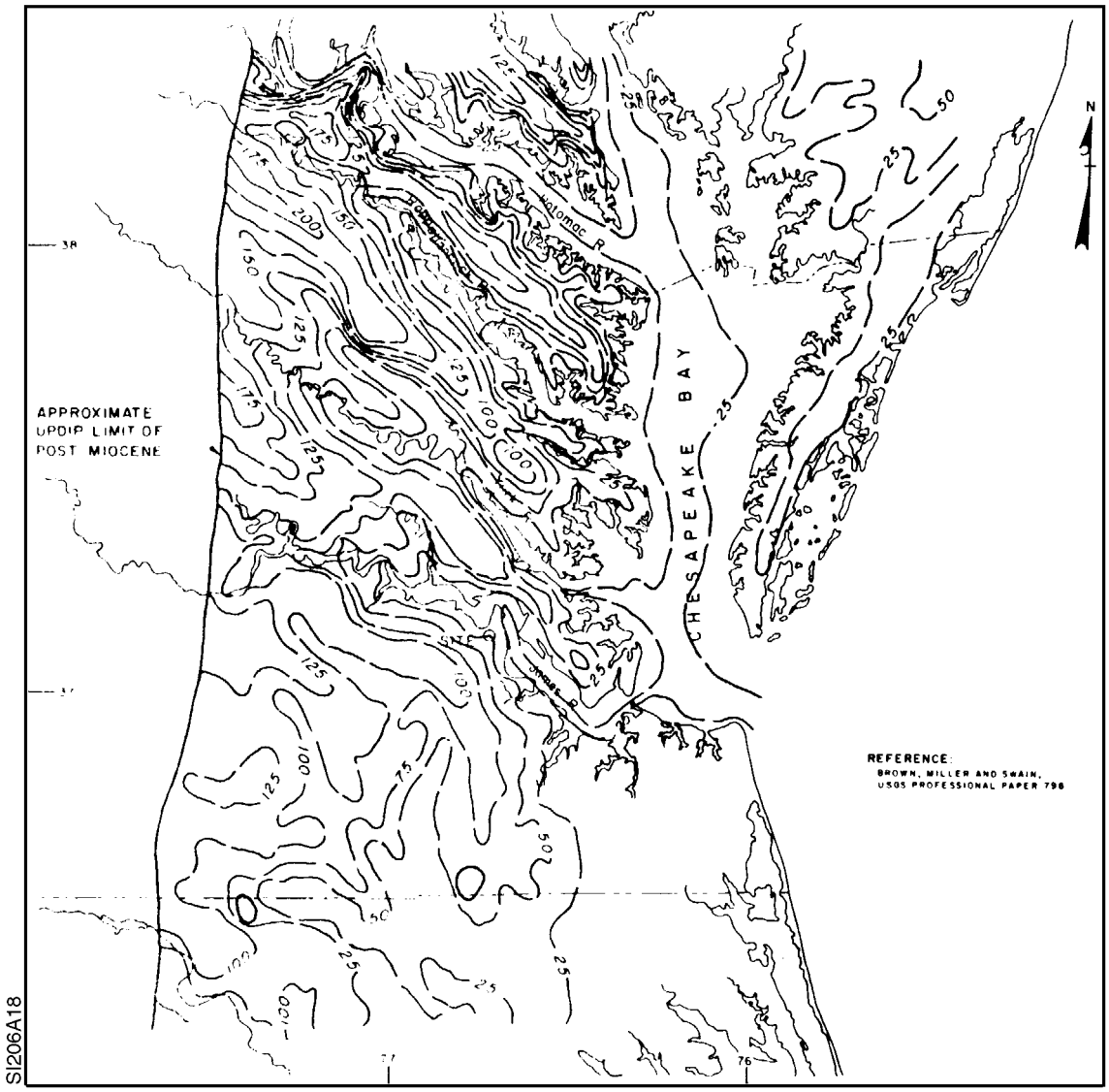


Figure 2A-19
GEOGRAPHICAL CROSS SECTION A-A' BACONS CASTLE TO YORKTOWN

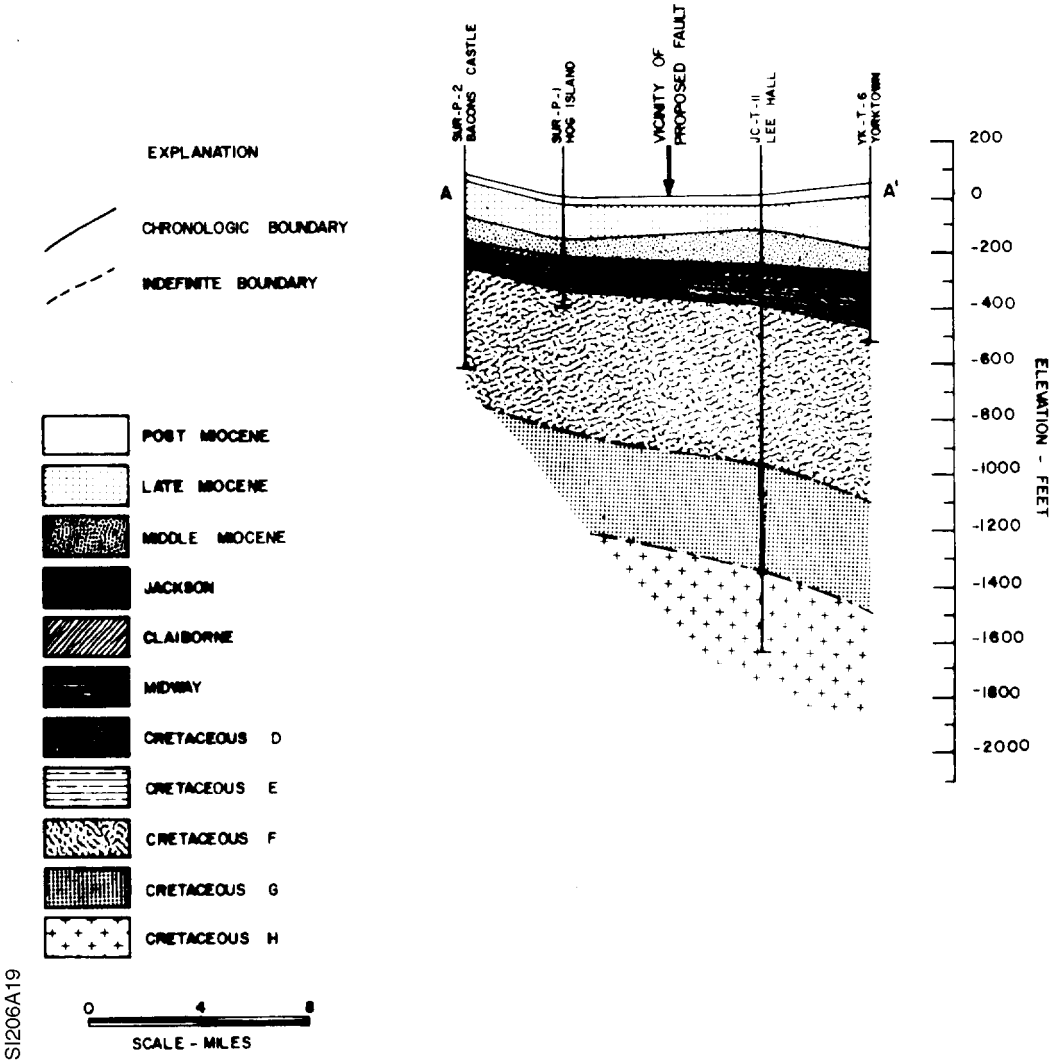


Figure 2A-20
MAP SHOWING OCCURRENCE OF CHLORIDE IN ARTESIAN WATER
IN THE VIRGINIA COASTAL PLAIN SOUTH OF POTOMAC RIVER

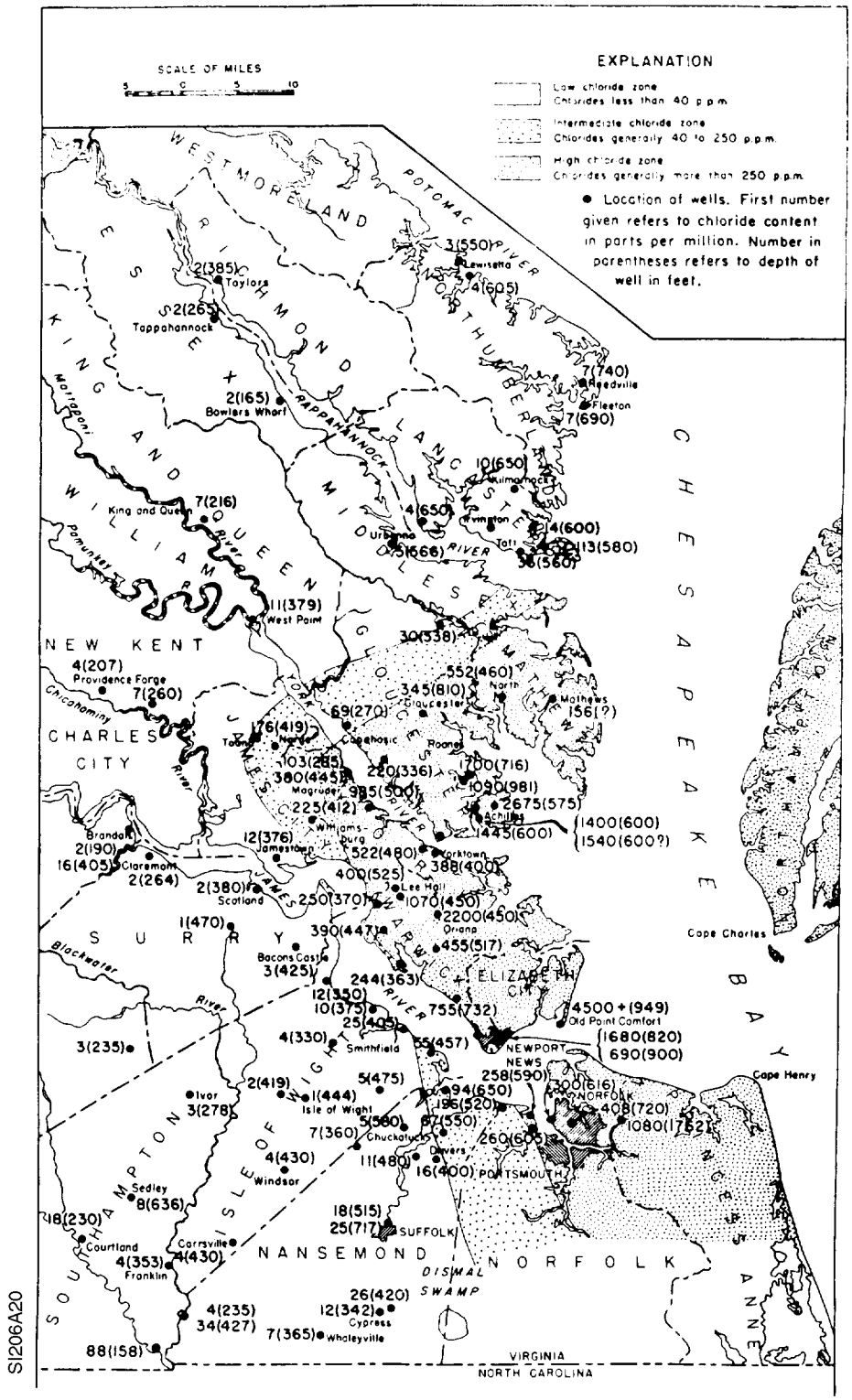


Figure 2A-21
CHLORIDE CONCENTRATION VS. DISTANCE SEMI-LOGARITHMIC PLOT

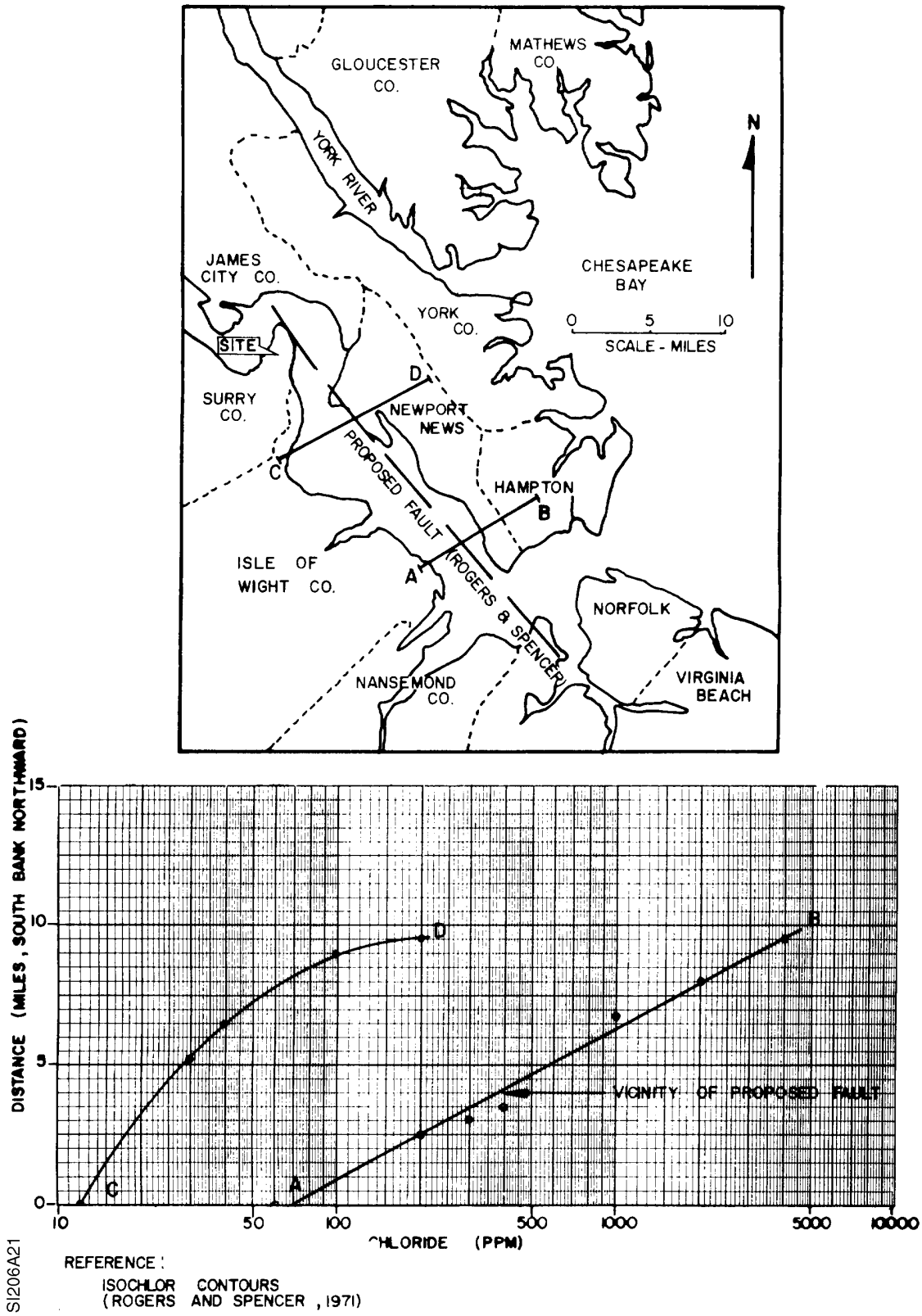


Figure 2A-22
POTENTIOMETRIC SURFACE PRINCIPAL AQUIFER SYSTEM CIRCA 1900

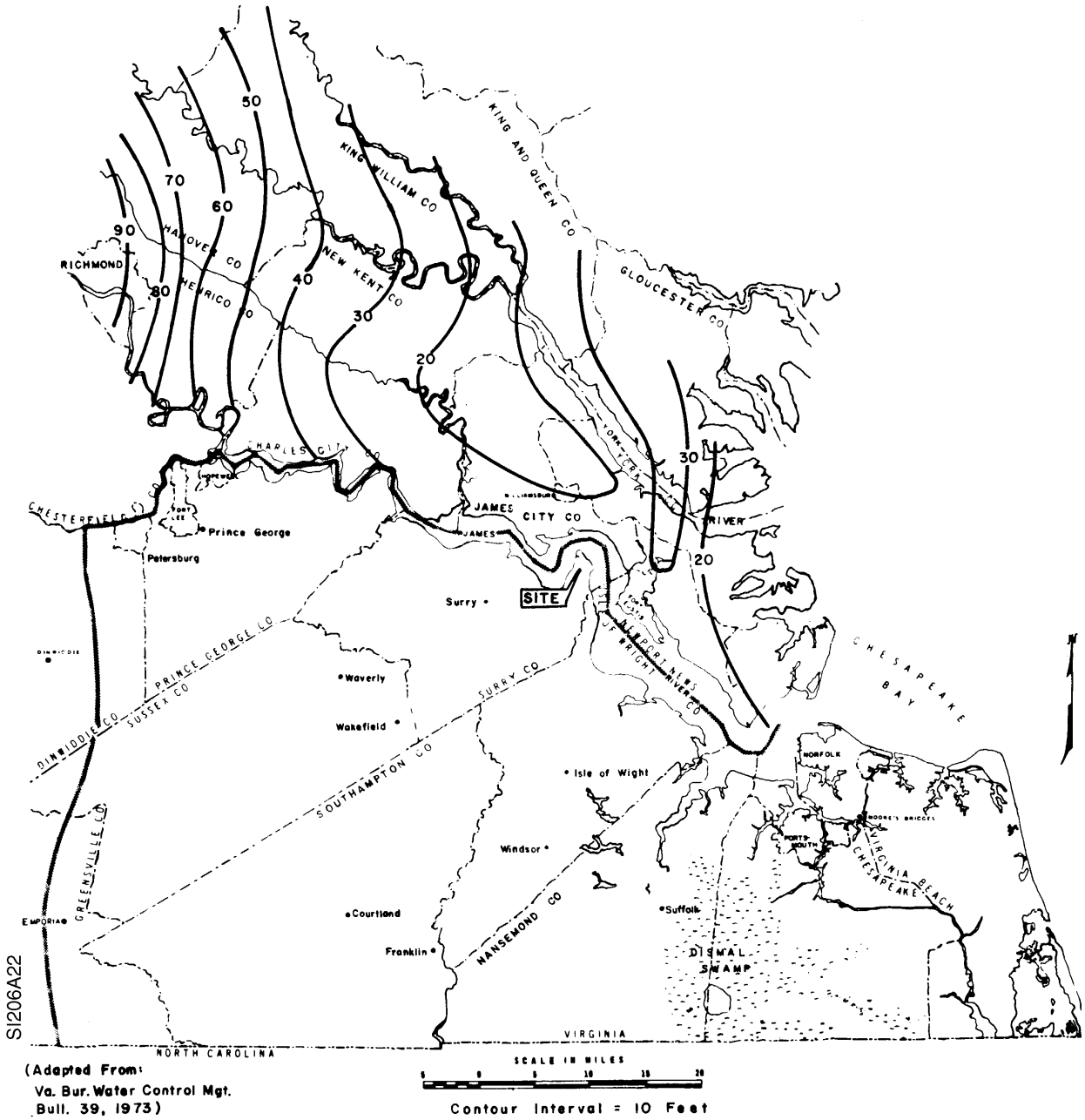


Figure 2A-23
POTENTIOMETRIC SURFACE IN PRINCIPAL AQUIFER, 1937-1939

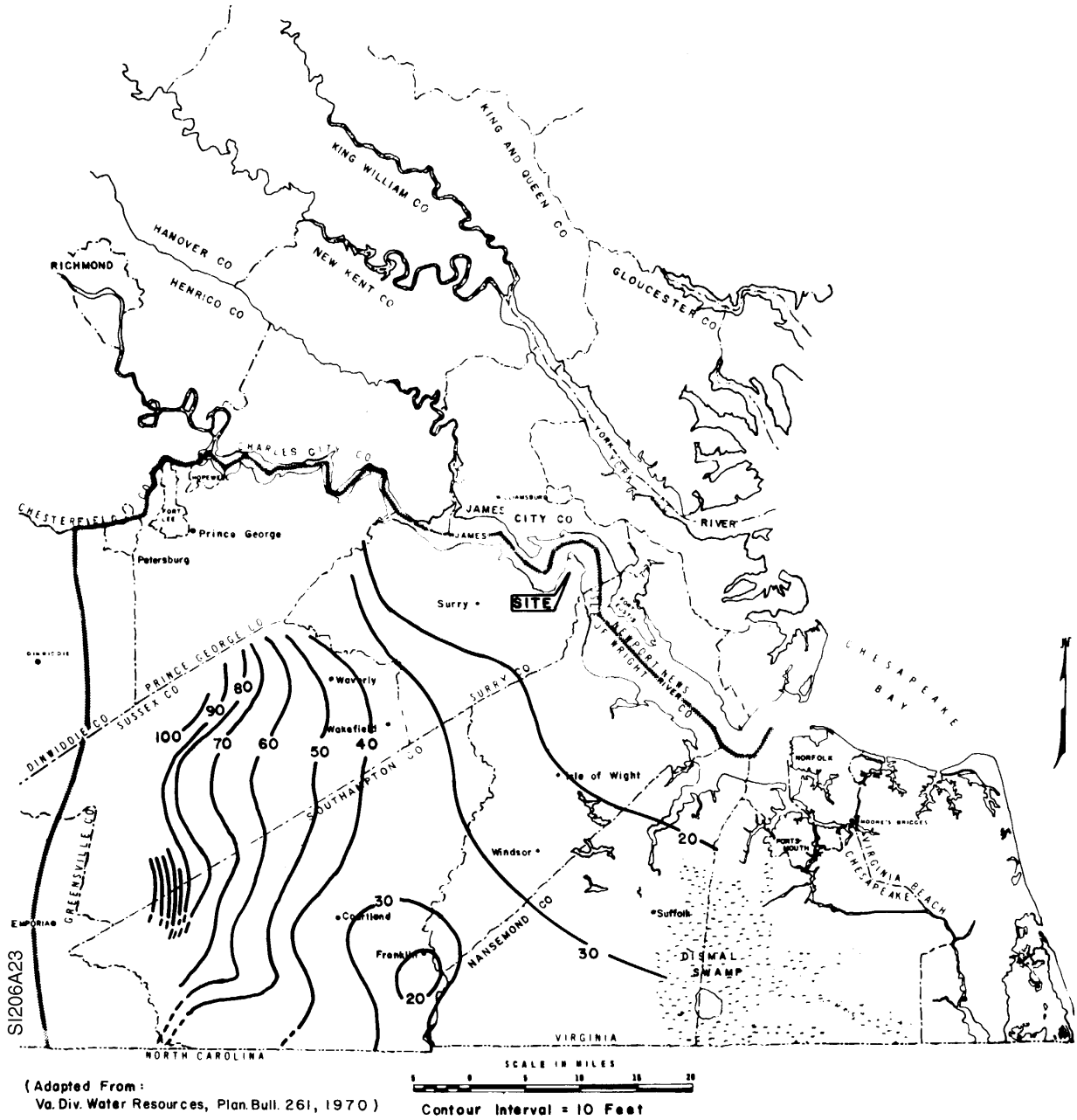


Figure 2A-24
POTENTIOMETRIC SURFACE PRINCIPAL AQUIFER SYSTEM 1945 TO 1949

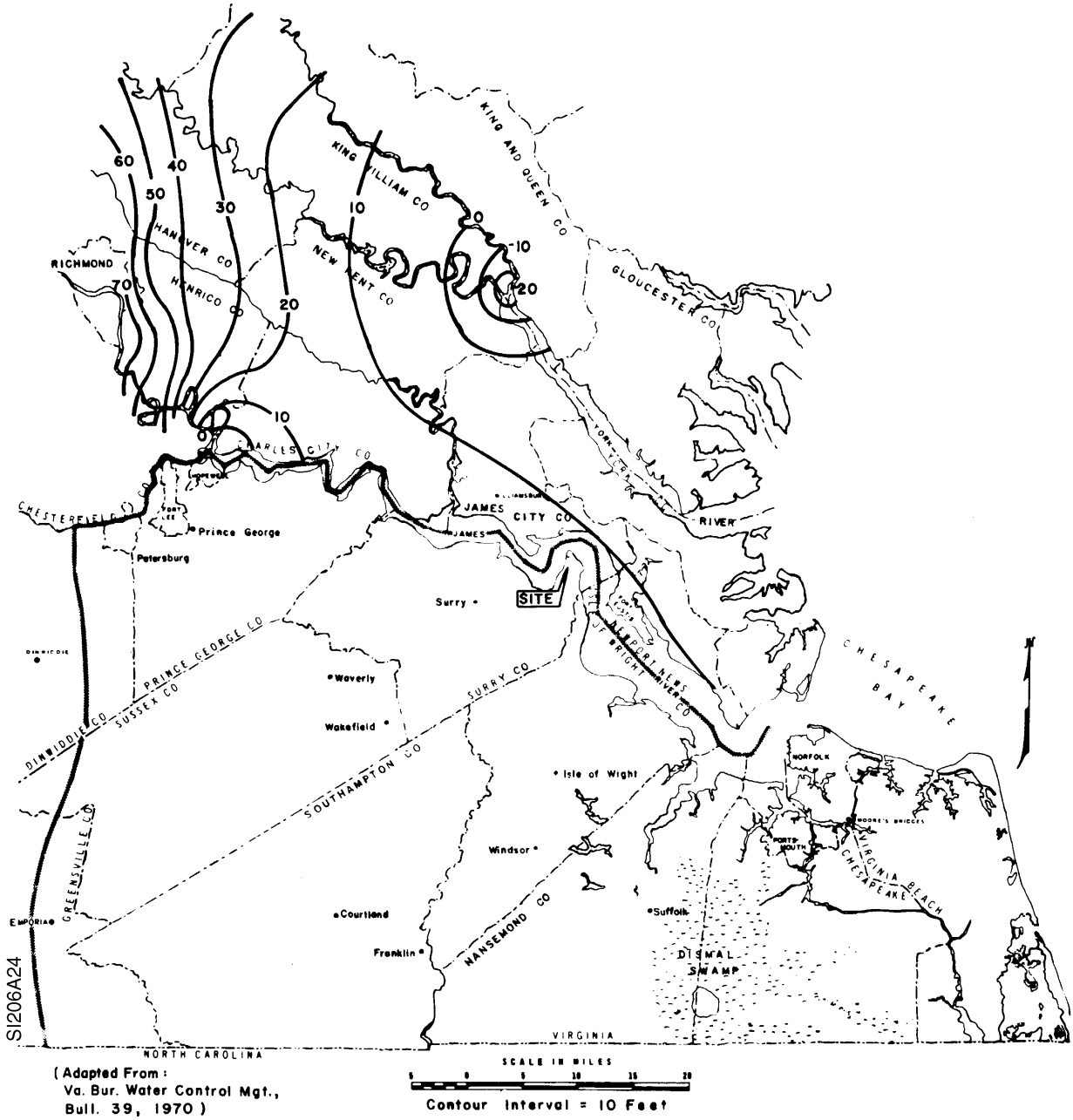


Figure 2A-25
POTENTIOMETRIC SURFACE IN PRINCIPAL AQUIFERS, 1966-1969

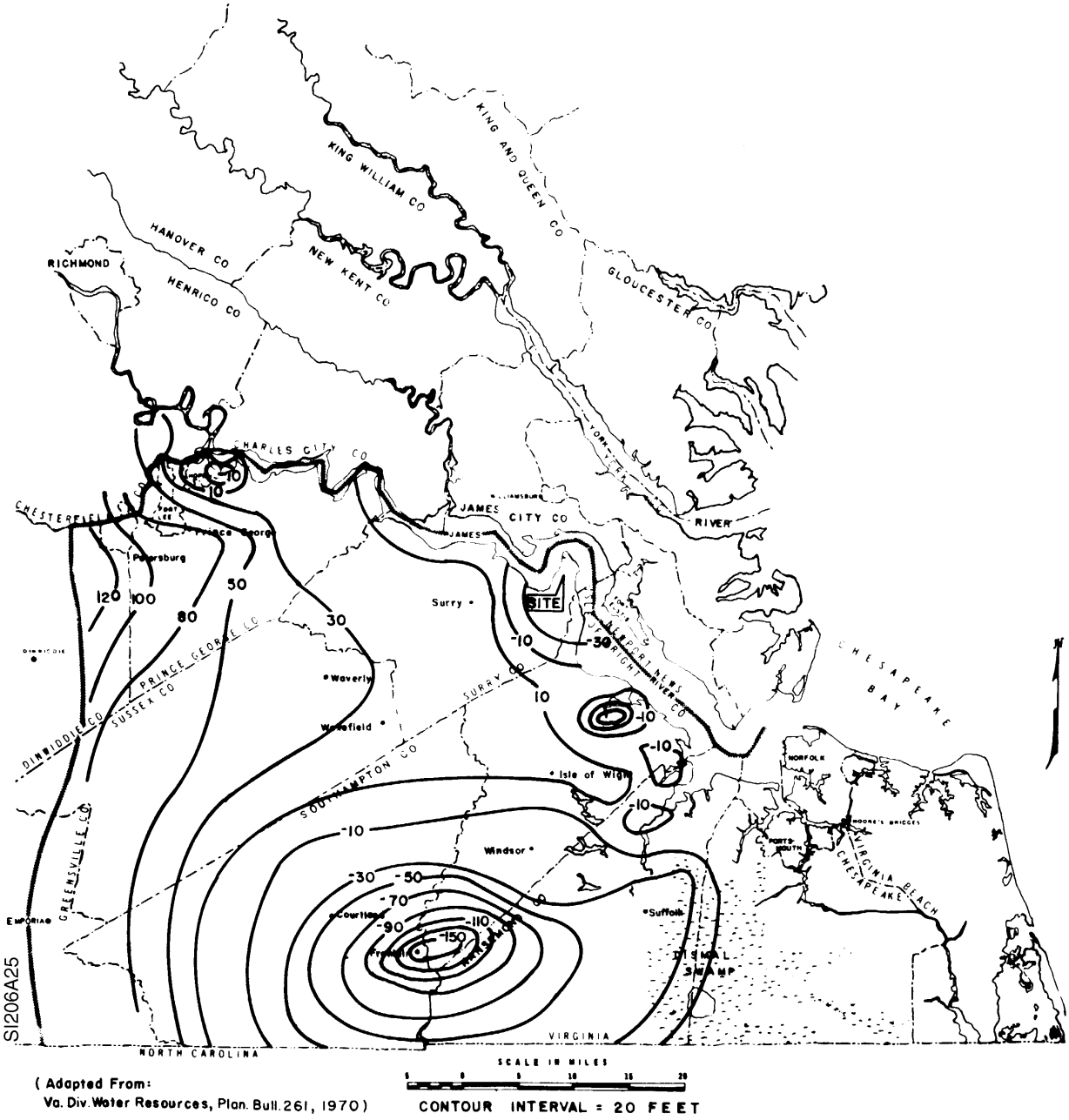
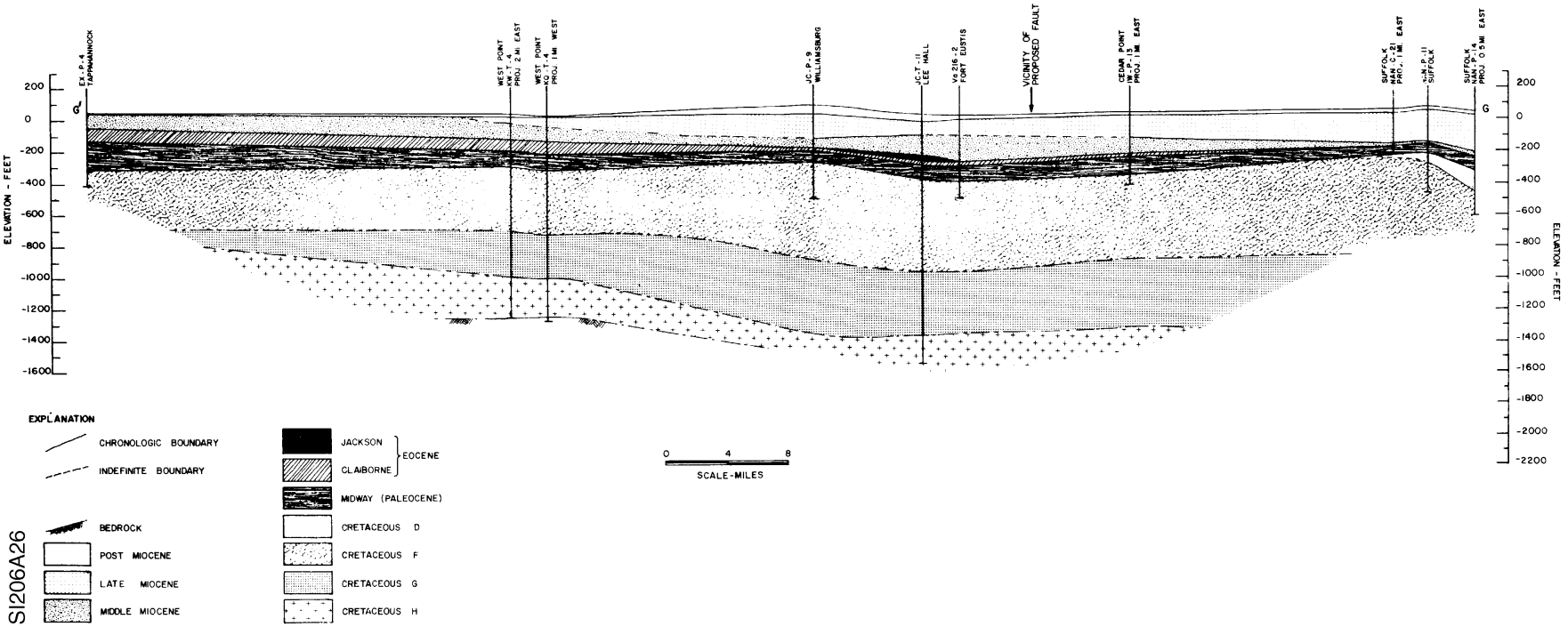


Figure 2A-26
GEOLOGICAL CROSS SECTION G-G' TAPPAHANNOCK TO SUFFOLK



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Appendix 2B
IN-SITU SEISMIC COMPRESSIONAL AND SHEAR WAVE VELOCITY MEASUREMENTS SURRY POWER STATION UNITS 3 AND 4

Presented herein is the excerpt from the Geotechnical Report for Surry Power Station Units 3 and 4 concerning the seismic velocity investigation and report from Weston Geophysical Engineers titled *In-Situ Seismic Compressional and Shear Wave Velocity Measurements.*

This data was obtained for Surry Power Station Units 3 and 4 located approximately 1/2 mile from the ISFSI site and is believed to be representative of the dynamic properties of the soil beneath the proposed installation.

Seismic Velocity Investigation

Ten borings were drilled and kept open for the detonating and monitoring devices of the seismic cross-hole investigation. The boreholes were cased to Elevation -150 with 3-l/2 in. o.d. flush joint casing. The borings were drilled within 1 inch of their planned location. Great care was taken to level and plumb the drill rigs, to ensure a vertical borehole. The appended report by Weston Geophysical Engineers, Inc. describes the seismic velocity investigation and presents the data.

IN-SITU SEISMIC COMPRESSIONAL AND SHEAR WAVE VELOCITY MEASUREMENTS SURRY POWER STATION UNITS 3 AND 4

Introduction

Seismic field measurements were performed at the location of the proposed Units 3 and 4, Surry Power Station of the Virginia Electric and Power Company, Surry, Virginia. Field work was conducted during the period of December 1972 through January 1973.

The purpose of this investigation was to measure both the in-situ “P” (compressional) wave and the “S” (shear) wave velocities of the geologic materials at the site. These velocities are used to compute values of Poisson’s Ratio, Young’s Modulus, Shear Modulus, and Bulk Modulus of these materials.

Field Procedures

Cross-hole velocity measurements were made using three orthogonal elements, containing one vertical and two horizontal geophones. Seismic energy was generated in one hole and detected by the geophones in four other holes with the seismic source and geophones at the same elevation level. This procedure was repeated using three combinations of shothole and detector hole as follows:

1. Shothole B-201
   Recording holes B-202, B-203, B-204, B-205
2. Shothole B-206
   Recording holes B-205, B-204, B-203, B-204
3. Shothole B-203
   Recording holes B-202, B-133S, B-137S, B-1357

Results

Figure 2B-1 shows the locations of the boreholes used for these measurements. The primary borehole array, Borings B-201 to B-206, is located along a line between the centers of the proposed Units 3 and 4. Shothole B-201 is at the center of the proposed Unit 3.

Table 2B-1 presents the results of this study from Elevation +5 to -140 feet. This table consists of the measured velocity values by elevation. Since there is some scatter on the travel-time curves plotted from the field data, these values are followed by a ± sign; this symbol indicates a range of ±50 ft/sec Also included are the elastic moduli values computed for the various velocity levels. Density values for these computations were provided by Stone & Webster Engineering Corporation.

Velocity values obtained from the three shothole-recording hole combinations were in excellent agreement with each other.

A limited amount of surface refraction data were obtained along the alignment between Units 3 and 4. The refraction data confirmed the “P” wave results of the cross-hole data above Elevation -50. It also indicated a near-surface material with a “P” wave velocity of 1500 ft/sec underlain by a thin layer of 2400 ft/sec “P” wave material.

Additional measurements using both cross-hole and uphole techniques were made at Surry Units 3 and 4. Two additional boreholes designated B-339 and B-340 were drilled as shot holes for the uphole and cross-hole surveys as shown on Figure 2B-2. Borehole B-340 is located at the eastern edge of Unit 4, as shown on the plan map of boreholes.

Cross-hole measurements were made using the following additional cross-hole patterns to supplement the original survey:

Shot Bole B-339 - Recording holes 201, 202, 204, and 205;

Shot Hole B-340 - Recording holes 202, 204, 205, and 206.

The cross-hole measurements using Shot Hole B-340, have been superimposed upon the travel-time plots of the original survey of January 1973 for comparison and show confirmation of the previous data as shown on Figure 2B-3.

An uphole survey was conducted in Boreholes B-339 and B-340. The location of surface detection arrays of vertical and horizontal geophones are shown on Figure 2B-2. Shots consisting of multiple cap arrays at 10-foot intervals were made using holes B-339 and B-340; these holes were uncased and drilling mud was used to keep them open. The travel-time plots for the uphole survey are shown on Figure 2B-3. Based on previous experience, an uphole survey rather than a down hole survey was conducted because of certain advantages in the control of energy generation, shot hole conditions and recording locations, including orientation of geophones. Seismic velocities measured in the uphole survey (Figure 2B-3) are the same as measured in the cross hole survey (Figure 2B-3).

Table 2B-1
SEISMIC VELOCITY AND DYNAMIC MODULE DATA

Elevation (feet)	"P" Wave Velocity (ft/sec)	"S" Wave Velocity (ft/sec)	Poisson's Ratio	Shear Modulus (psi)[a]	Young's Modulus (psi)[a]	Bulk Modulus (psi)[a]
+ 5 to 0	5200±	650±[b]	.492	1.09×10^4	3.26×10^4	68.57×10^4
0 to - 50	5600±	950±	.485	2.33×10^4	6.94×10^4	78.11×10^4
-50 to -90	5300±	950±	.483	2.33×10^4	6.93×10^4	69.64×10^4
-90 to -140	5500±	970±	.484	2.43×10^4	7.23×10^4	75.10×10^4

NOTES: ± Indicates range of ±50 ft/sec

a.Moduli calculation - based on a unit weight of 120 lb/ft^3.
b.Based on limited data.

Figure 2B-1
BORING LOCATION MAP
IN-SITU COMPRESSIONAL AND SHEAR VELOCITY MEASUREMENT

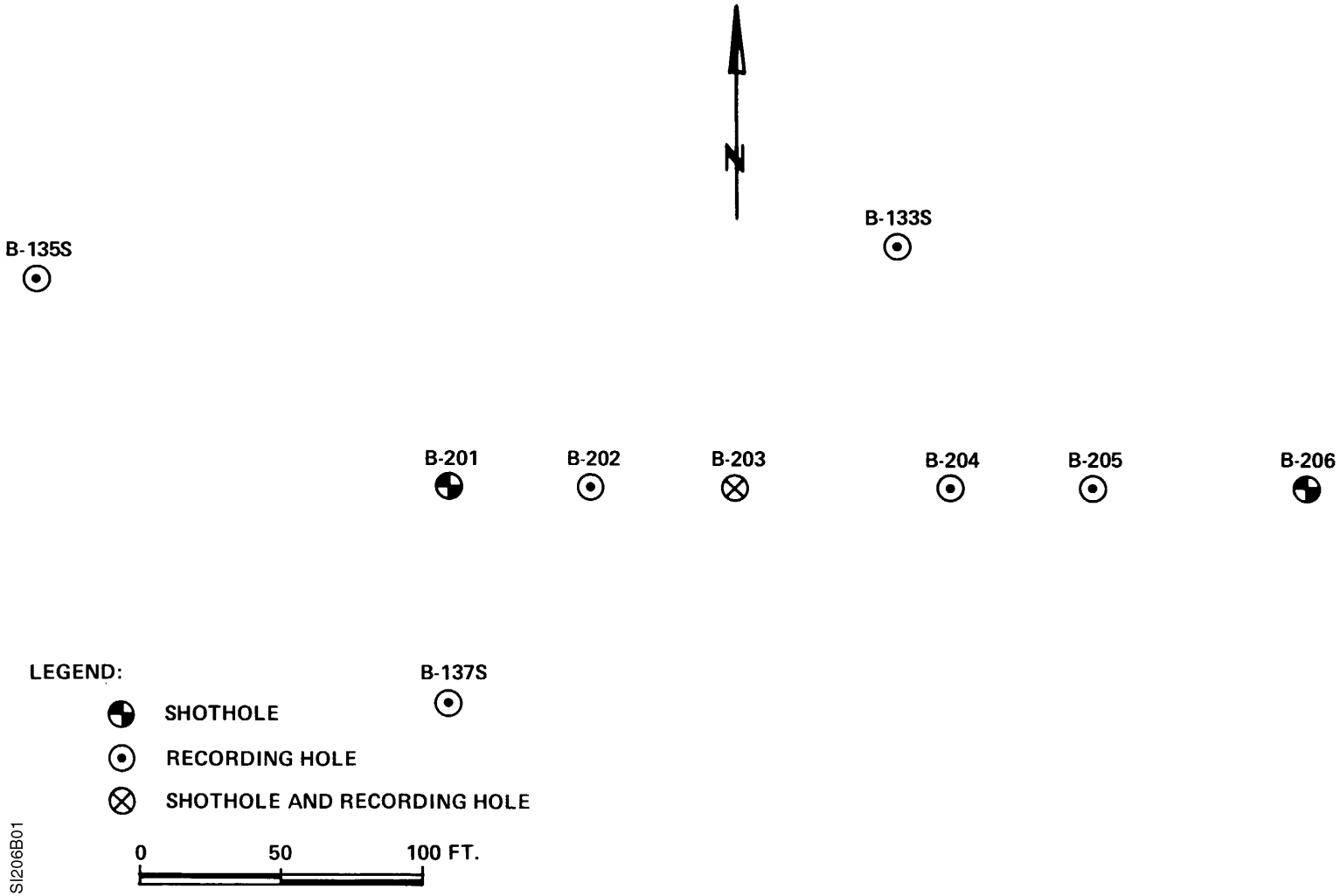

Figure 2B-2
SEISMIC UPHOLE LOCATIONS

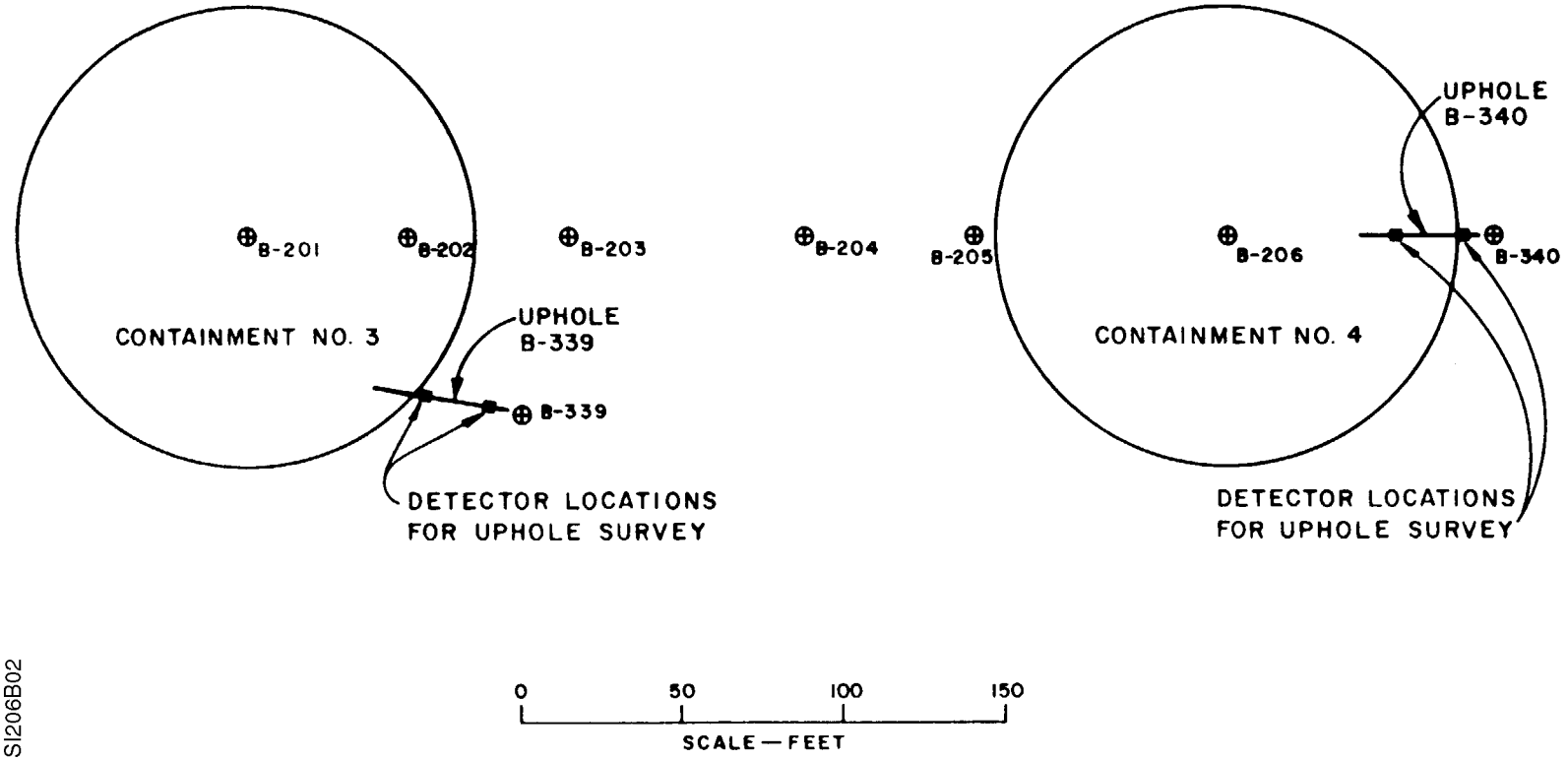

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Figure 2B-3 (SHEET 1 OF 5)
SEISMIC CROSSHOLE TIME DISTANCE PLOTS

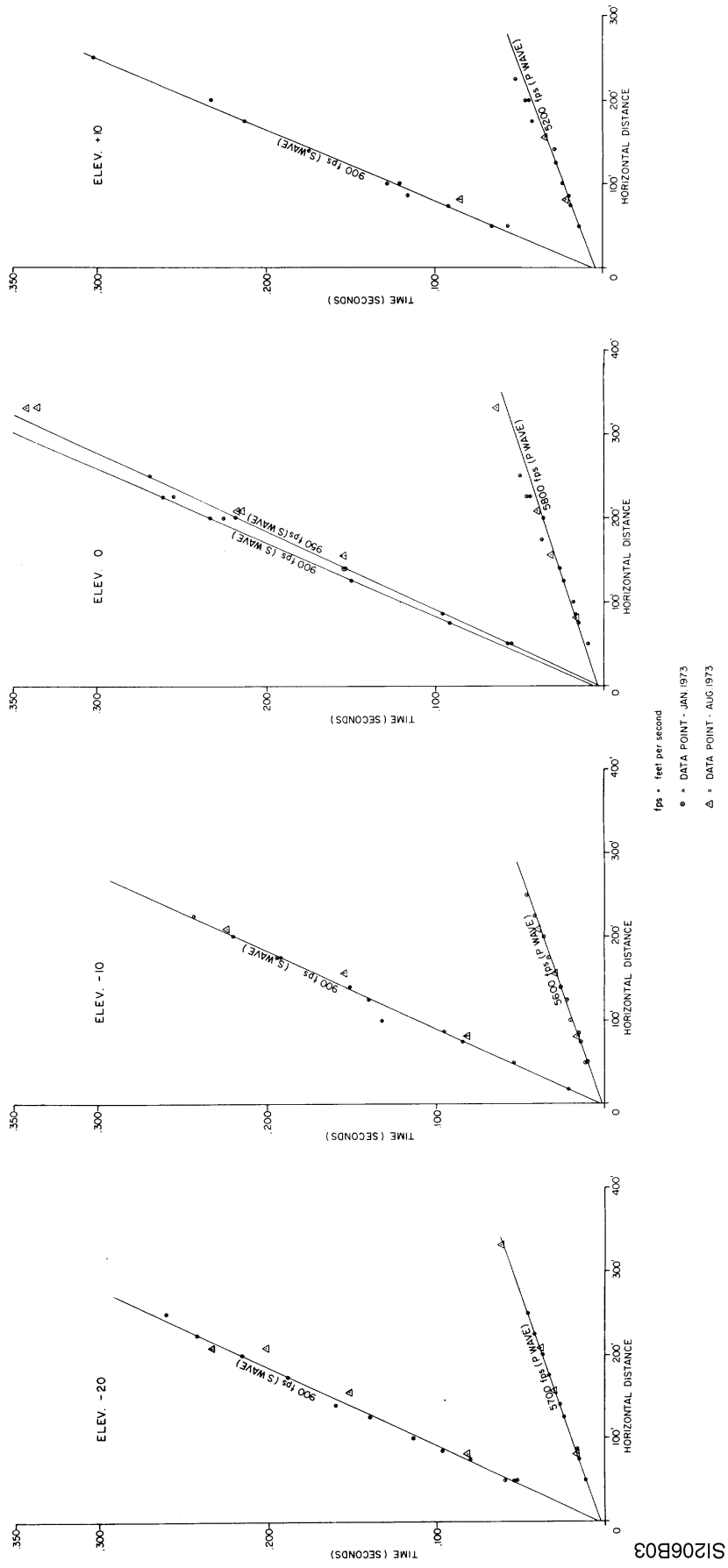

Figure 2B-3 (SHEET 2 OF 5)
SEISMIC CROSSHOLE TIME DISTANCE PLOTS

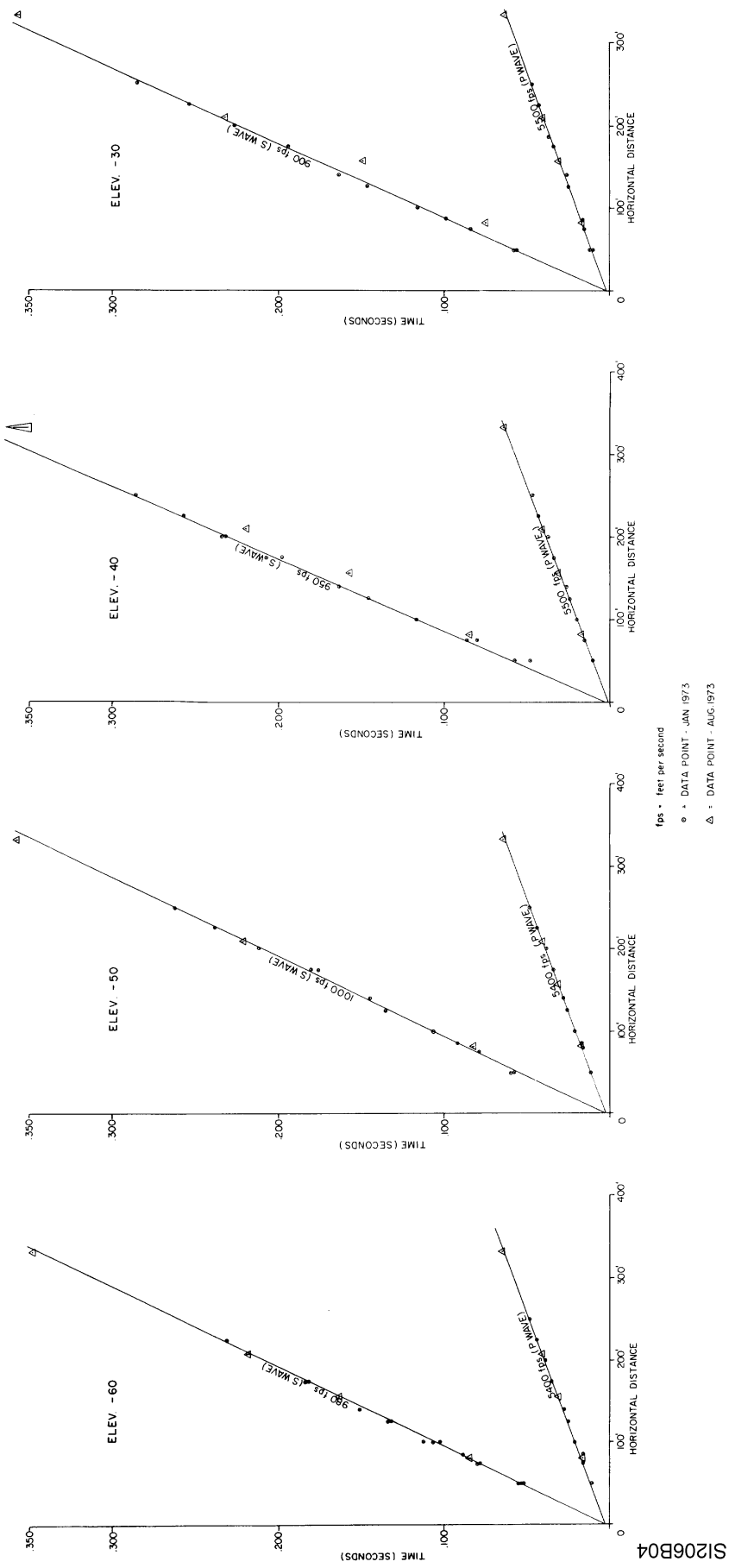

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Figure 2B-3 (SHEET 3 OF 5)
SEISMIC CROSSHOLE TIME DISTANCE PLOTS

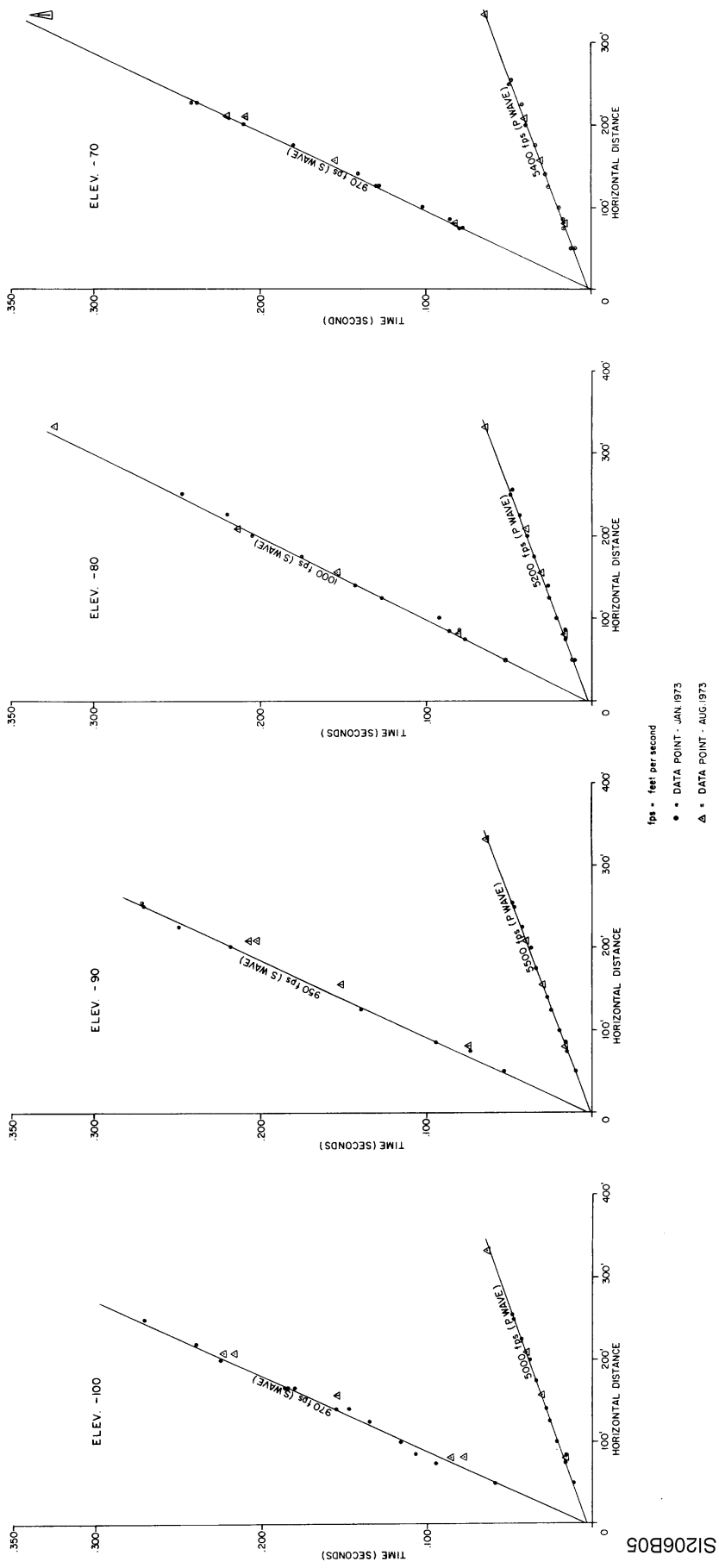

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Figure 2B-3 (SHEET 4 OF 5)
SEISMIC CROSSHOLE TIME DISTANCE PLOTS

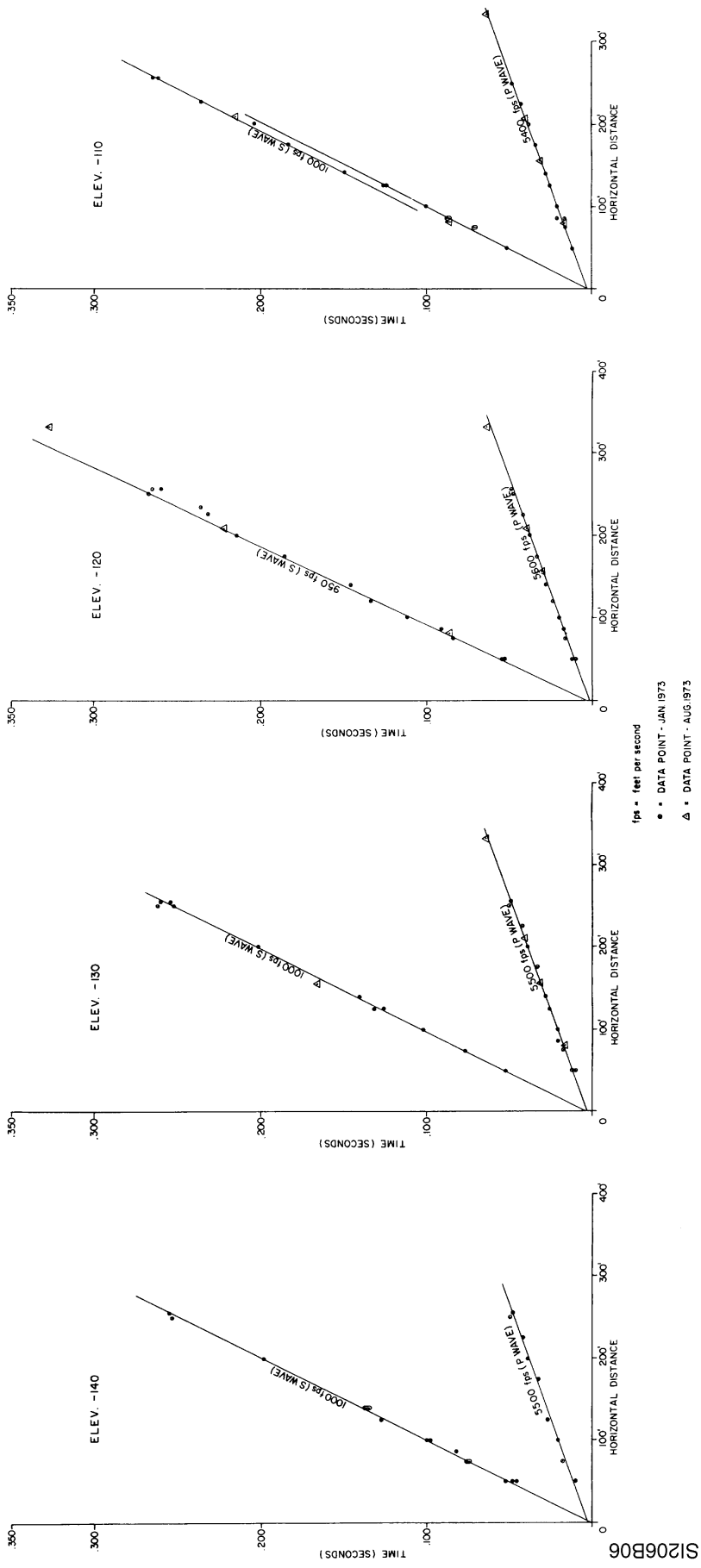

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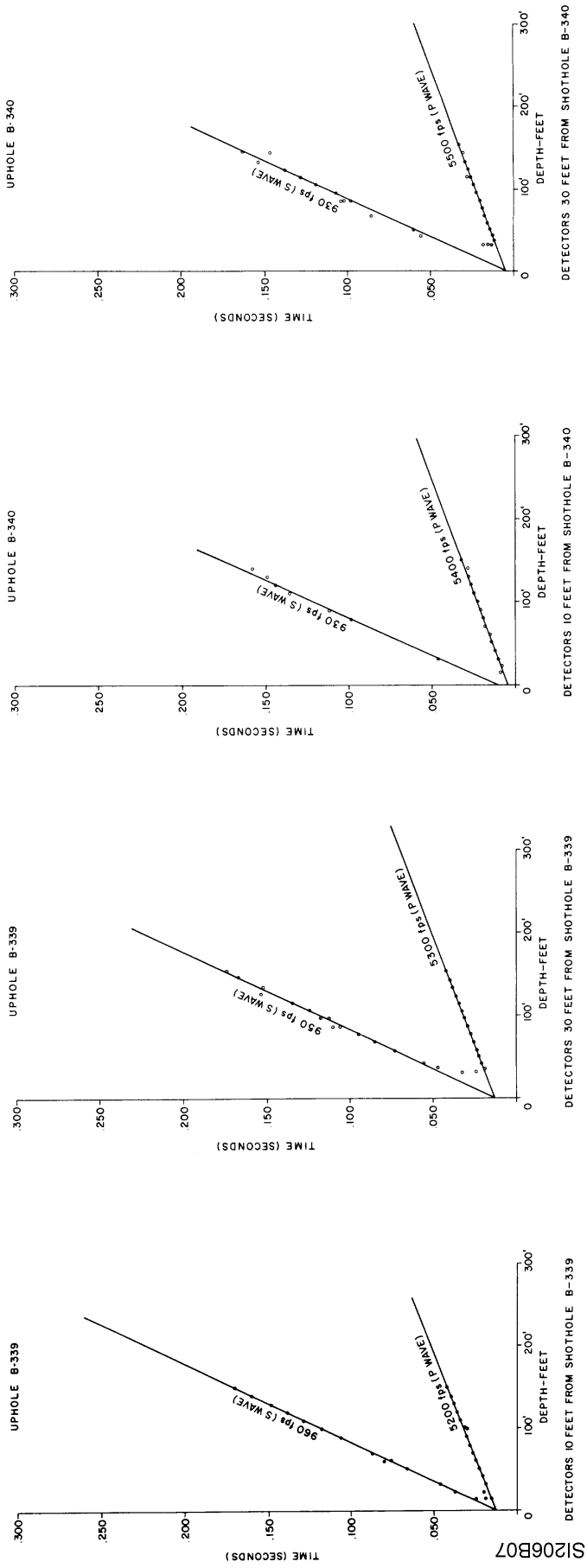
Figure 2B-3 (SHEET 5 OF 5)
SEISMIC CROSSHOLE TIME DISTANCE PLOTS



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Chapter 3
DESIGN CRITERIA

This chapter describes the design criteria to be met by the SSSCs to be used in the Surry ISFSI. Compliance with these criteria ensures that the Surry ISFSI complies with the requirements of 10 CFR[1] Part 72.

3.1 PURPOSE OF INSTALLATION

The purpose of the Surry ISFSI is to provide additional interim storage capacity for the spent fuel resulting from the operation of the two pressurized water reactors at the Surry Power Station.

3.1.1 Materials to Be Stored

The ISFSI is designed to accommodate a total of 84 SSSCs. The ISFSI is capable of accommodating 1764 fuel assemblies. Each fuel assembly has 0.46 MTU. The total spent fuel storage design capacity of the facility is 811.44 MTU.

The physical characteristics of the fuel and fuel insert components to be stored at the ISFSI are described in detail in Chapter 3 of the Surry Power Station Units 1 and 2 FSAR and are summarized in Table 3.1-1. An evaluation of the storage of insert components with the fuel placed in SSSCs is provided in Appendix A for each SSSC design.

Fuel used during the first years of Surry Power Station Units 1 and 2 operation had initial enrichments not exceeding 3.5 weight percent U-235 and discharge burnup not exceeding 35,000 MWD/MTU. The Surry Power Station has been authorized to operate with fuel with higher initial enrichment and higher burnup. This SAR and the referenced SSSC topical reports, however, address only the fuel enrichments up to the maximum analyzed for the SSSCs as referenced in Appendix A and the SSSC topical reports.

The average heat generation rate for each cask at the time of storage will be as specified in the SSSC topical reports or Appendix A and the ISFSI Technical Specifications.

3.1.1.1 Material Characteristics

The following fuel assembly characteristics constitute limiting parameters for storage of specific assemblies at the ISFSI:

a. Initial Fuel Enrichment

b. Fuel Burnup

c. Heat Generation

d. Spent Fuel Physical Configuration/Condition

1. Code of Federal Regulations, Title 10, *Energy*, January 1, 1982.

3.1.1.1.1 Allowable Limits

The allowable limits for each of these characteristics are discussed below.

3.1.1.1.1.1 *Initial Fuel Enrichment.* The initial fuel enrichment of any fuel that is stored in the ISFSI will be limited to the maximum enrichment specified in the SSSC topical reports or Appendix A and the ISFSI Technical Specifications.

3.1.1.1.1.2 *Fuel Burnup.* The fuel that is stored in the ISFSI will be limited to that specified in the SSSC topical reports or Appendix A and the ISFSI Technical Specifications.

3.1.1.1.1.3 *Heat Generation.* The heat generation rate by an individual fuel assembly is dependent on three factors: the initial fuel enrichment, the fuel burnup, and the amount of decay time after discharge. The maximum allowable heat generation rate and fuel temperature for a particular SSSC are specified in the SSSC topical reports or Appendix A and the Surry ISFSI Technical Specifications.

3.1.1.1.1.4 *Spent Fuel Physical Configuration/Condition.* Only spent fuel irradiated at Surry Power Station Units 1 and 2 with the physical configuration as listed in items 1, 2, and 3 of SAR Table 3.1-1 will be stored in the ISFSI. The fuel stored shall be intact (unconsolidated), shall not have gross cladding defects, and shall not have visible physical damage which would inhibit insertion or removal from the cask fuel basket.

3.1.1.1.2 Verification

The method of verification for each of these characteristics is discussed below.

3.1.1.1.2.1 *Initial Fuel Enrichment and Fuel Burnup.* Fuel management records shall be utilized to verify that the initial fuel enrichment and fuel burnup are within the above limits. Each fuel assembly is engraved with a unique identification number (based on ANSI/ANS 57.8) and a vendor identification, which is unique to the site for which the fuel assemblies were fabricated. This will allow visual confirmation of the identity of the fuel assemblies placed in the cask.

3.1.1.1.2.2 *Heat Generation.* The heat generation rate of a fuel assembly is based on three factors: initial fuel enrichment, burnup, and cooling time after discharge. Fuel management records will be used to obtain these three factors and an NRC approved code such as ORIGEN will be utilized to ensure that the heat generation is less than that specified in the SSSC topical reports and the Surry ISFSI Technical Specifications.

3.1.1.1.2.3 *Spent Fuel Physical Configuration/Condition.* Fuel management records will be reviewed to ensure that the assemblies to be put in the cask have not been previously identified as having gross cladding defects. The fuel assemblies shall also be visually inspected (e.g., using TV cameras) for physical damage which could potentially cause problems during insertion and/or removal from the storage cask.

3.1.2 General Operating Functions

The fuel assemblies will be stored unconsolidated and dry in sealed surface storage casks. The casks will rest on a reinforced concrete slab, and provide safe storage by ensuring a reliable decay heat path from the spent fuel to the environment and by providing appropriate shielding and containment of the fission product inventory.

Storage of spent fuel in SSSCs is a totally passive function, with no active systems required to function. Decay heat is removed via the cask surface to the environment by convective and radiant cooling.

The casks are to be handled with a lifting yoke, the fuel building cask handling crane, a transporter, or other appropriate equipment. The fuel building crane places the cask on the concrete pad in the crane enclosure. The cask is then picked up by the transporter which is pulled to the ISFSI by a haul vehicle. After the transporter has been maneuvered to locate the cask in its storage position, the cask is set down by the transporter.

The equipment in the fuel building is capable of handling casks and associated lifting equipment up to 125 tons fully loaded with the casks measuring no more than 16 feet in length with the top cover removed.

All the handling equipment to be used outside the fuel building will be sized to handle casks measuring up to the above specifications, as needed. This equipment will be designed according to appropriate commercial codes and standards, and will be operated, maintained, and inspected in accordance with the supplier’s recommendations. Documentation shall be maintained to substantiate conformance with all applicable standards.

Table 3.1-1
CHARACTERISTICS OF FUEL USED AT SURRY POWER STATION [a]

1. Fuel Assemblies	
a. Rod array	15 x 15
b. Rods per assembly	204 (21 fuel rods are omitted to provide passage for control rods, insert components, and in-core instrumentation)
c. Length, including insert component	162.2 in.
d. Rod pitch	0.563 in.
e. Overall dimensions	8.426 in. x 8.426 in.
f. Total weight, including insert component	1525 lb
g. Active fuel length	144 in.
2. Fuel Rods	
a. Outside diameter	0.422 in.
b. Clad thickness	0.0243 in.
c. Clad material	Zircaloy-4
3. Fuel Pellets	
a. Material	UO_2 Sintered
b. Length	0.6 in.
4. Fuel Condition for Storage in SSSCs	
a. Maximum initial enrichment	[b]
b. Maximum burnup of storage	[b]
c. Average heat generation for one cask at time of storage	[b]

a. From Surry Power Station Units 1 and 2 FSAR. All dimensions are for cold conditions.
b. Specified in the SSSC topical reports or Appendix A and the Surry ISFSI Technical Specifications.

3.2 STRUCTURAL AND MECHANICAL SAFETY CRITERIA

The safe storage of the spent fuel assemblies depends only on the capability of the SSSCs to fulfill their design functions. The SSSCs are self-contained, independent, passive systems, which do not rely on any other systems or components for their operation. Therefore, the SSSCs are the only components at the Surry ISFSI which are important to safety. The criteria used in the design of the SSSCs ensure that exposure of the SSSCs to credible site hazards will not impair their safety functions.

3.2.1 Tornado and Wind Loadings

3.2.1.1 **Applicable Design Parameters**

The SSSC manufacturers will be required to meet either the design basis tornado and extreme wind used for the Class 1 (safe shutdown) systems and structures of the Surry Power Station, as described in Section *2.2.2* of the Surry Power Station FSAR and Section 2.3.1.3.2 of this SAR or alternately, those prescribed by Regulatory Guide 1.76, *Design Basis Tornado for Nuclear Power Plants*, April 1976. The design basis tornado for the Surry Power Station has a rotational wind velocity of 300 mph, a translational velocity of 60 mph, and a pressure drop of 3 psi in 3 seconds.

The design basis extreme wind is 137 mph at 30 feet above ground and with a gustiness factor of 1.3, as described in Section 2.3.1.3.1 of this SAR.

The design basis tornado and wind loadings for the casks are provided in the SSSC topical reports.

Design basis extreme ambient temperatures for the SSSCs have been selected to be -20°F and 115°F. These temperatures exceed the extreme temperatures experienced at the Surry site (Section 2.3.2.1.1), thus providing an additional level of conservatism. Other design criteria for the Surry ISFSI include 0- to 100-percent humidity and direct exposure to sunlight.

The daily solar radiation at the Surry site is estimated to be less than 800 cal/cm^2 (50 kW hours). This is a conservative estimate based on 90 percent transmissivity at the summer solstice (Reference 1). On this basis, a very conservative design criterion of an added heat load of 5 kW over 10-hour periods is imposed on the SSSCs.

3.2.1.2 **Determination of Forces on Structures**

The description of the methods used to convert the tornado and wind loading into forces on the casks is addressed in the SSSC topical reports.

3.2.1.3 Ability of Structures to Perform Despite Failure of Structures Not Designed for Tornado Loads

The safety function of the SSSCs is not dependent on any other structures or systems. In addition, there are no structures in the vicinity of the ISFSI, which, if failed under tornado loads, could damage the SSSCs.

3.2.2 Water Level (Flood) Design

The design basis flood used for the ISFSI is the same as that used for Class 1 (safe shutdown) structures of the Surry Power Station, and is described in Section 2.4.2 of this SAR. The maximum flood level calculated to occur at the ISFSI is 28.2 feet above msl. This is postulated to occur during the probable maximum hurricane, and includes wave runup.

The design finished grade elevation of the ISFSI is approximately 35.0 feet above msl, leaving a margin of more than 6 feet above the maximum flood. Therefore, the ISFSI site is flood dry.

3.2.3 Seismic Design

Section 2.6.2 describes the vibratory ground motions experienced in the region of the Surry site and defines a design earthquake peak acceleration value of 0.07g for the ISFSI. As indicated in Section 2.6.2.3, an earthquake in excess of 0.05g may be expected to have a recurrence interval of about 500 years. In view of the totally passive function of the SSSCs, and their inherent strength, a ground earthquake of 0.07g is considered a conservative design criterion. See Appendix 3A. The SSSC topical reports describe the ability of the casks to withstand the design earthquake.

3.2.4 Snow and Ice Loadings

The rain and snow falls experienced at the Surry site are described in Section 2.3.1.2 of this SAR.

Snow and ice would melt soon after contacting the surface of the cask due to the decay heat generated by the stored fuel. These phenomena are not considered credible challenges to the SSSCs. Therefore, snow and ice loadings are not identified among the design criteria for the SSSCs.

3.2.5 Combined Load Criteria

The loads postulated as design criteria for the SSSCs have been described in this chapter.

Methods and assumptions made in analyzing the mechanical and structural behavior of the casks are described in the SSSC topical reports.

3.2.6 References

1. List, Robert J., *Smithsonian Meteorological Tables*, Sixth Revised Edition, 1951.

2. *Topical Safety Analysis Report for the CASTOR V/21 Cask Independent Spent Fuel Storage Installation (Dry Storage)*, GNSI, January 1985.

3.3 SAFETY PROTECTION SYSTEMS

3.3.1 General

The handling of the casks while they are being placed in the ISFSI requires that they be lifted by a transporter. Technical Specifications for the Surry ISFSI limit the height the SSSCs may be lifted while being transported to, and emplaced at, the ISFSI. The SSSCs are able to withstand a drop from these heights onto the ISFSI concrete slab without compromising their integrity and without resulting in physical damage to the fuel.

Because of the passive nature of the Surry ISFSI and the absence of support systems, no other items requiring special design consideration have been identified.

3.3.2 Protection by Multiple Confinement Barriers and Systems

3.3.2.1 Confinement Barriers and Systems

Confinement of radioactivity during the storage of spent fuel is achieved by (1) the uranium dioxide fuel pellet matrix, (2) the metallic tubes (cladding) in which the pellets are contained, and (3) the sealed cask in which the assemblies are stored.

The confinement function of the SSSCs is achieved by totally enclosing the spent fuel assemblies within a double-seal rigid metal vessel. The SSSCs are fabricated, delivered to the Surry site, loaded, sealed, and emplaced at the ISFSI in a manner that ensures their integrity, the capability to perform their safety functions, and compliance with all applicable rules and regulations.

The specific codes and standards to which the casks are fabricated, delivered to the site, and sealed are addressed in the SSSC topical reports. Compliance with applicable current nationally recognized codes and standards is expected. Codes and standards representing an acceptable level of design are:

a. American Welding Society (AWS) *The Structural Welding Code* (AWS Dl.l-1980)

b. American Iron and Steel Institute (AISI) *Steel Products Manual*

c. American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*, Section II

d. American Society of Testing and Materials (ASTM) Standards

As described in Chapter 11, the SSSC manufacturers will be required to maintain the necessary documentation to substantiate conformance with the specified codes and standards.

Construction materials are compatible with each other and with the expected radiation levels. In addition, the baskets or racks holding the fuel assemblies within the SSSCs are typical of those currently used in spent fuel pools throughout the industry, and are designed to protect the spent fuel assemblies from mechanical damage during insertion and removal operations and as a result of all credible events. Damage resulting from postulated accidents is limited to the extent that normal removal of the fuel assemblies is not precluded.

Once the casks are sealed, there are no credible events which could result in an unacceptable release of radioactive products to the environment. Similarly, there are no credible scenarios which could result in contamination of the outside surface of the SSSCs or in the generation of radioactive waste products.

3.3.2.2 **Ventilation—Offgas**

Natural air flow around the casks provides sufficient cooling. No forced ventilation is required. No radioactive releases during normal operation or accidents resulting in radioactive releases are considered credible. In addition, the gaseous releases postulated as the result of the hypothetical accidents described in Chapter 8 are of a very small magnitude. Therefore, no offgas system is required.

3.3.3 Protection by Equipment and Instrumentation Selection

3.3.3.1 **Equipment**

As discussed in Section 3.2, the SSSCs represent the only components of the ISFSI which are important to safety. Design criteria for the SSSCs are described in this section and summarized in Table 3.3-1.

3.3.3.2 **Instrumentation**

Due to the totally passive and inherently safe nature of the SSSCs, safety-related instrumentation is not necessary.

However, high quality commercial grade instrumentation will be provided to monitor the SSSCs functional performance. Instrumentation to survey and monitor cask parameters such as temperature and pressure will be furnished as recommended by the specific cask designs. Appropriate capabilities to check and recalibrate these monitors will also be provided. The casks are provided with temperature or pressure measuring systems as described in the SSSC topical reports.

3.3.4 Nuclear Criticality Safety

The criterion for ensuring that the fuel remains subcritical at all times is that the effective neutron multiplication factor (k_{eff}) be less than 0.95 (including any calculational uncertainties) for all normal and postulated accident conditions.

3.3.4.1 Control Methods for Prevention of Criticality

Methods to be used to ensure that subcriticality is maintained at all times in the casks are addressed in the SSSC topical reports or Appendix A.

3.3.4.2 Error Contingency Criteria

Error contingency criteria for the casks are presented in the SSSC topical reports or Appendix A.

3.3.4.3 Verification Analyses

The criteria for establishing verification of the models and programs used in the criticality calculations for the casks are presented in the SSSC topical reports or Appendix A.

3.3.5 Radiological Protection

Provisions for radiological protection by confinement barriers and systems are described in Section 3.3.2.1. No additional radiological protection design criteria are considered to be necessary.

3.3.5.1 Access Control

The Surry ISFSI does not require the continuous presence of operators or maintenance personnel. In addition, it is located within a fenced-in area shared only with a low level waste (LLW) storage facility and concrete pad for storage of contaminated material, which are not continuously manned. Access to the fenced-in area is limited to personnel needed during operations at the ISFSI or the LLW storage facility, e.g., periodic inspections of these facilities, emplacement of SSSCs, and security checks. These activities are controlled by station Health Physics and Security procedures.

3.3.5.2 Shielding

The SSSCs provide sufficient shielding to allow handling of the loaded casks with as low as reasonably achievable (ALARA) doses to the operators and to comply with the radiation limits in 10 CFR Part 72. For a description of the specific shielding provided by the casks, see the SSSC topical reports or Appendix A. For specific dose estimates, see Chapter 7 of this SAR.

3.3.5.3 Radiological Alarm Systems

There are no credible events which could result in unacceptable releases of radioactive products or unacceptable increases in direct radiation. In addition, the releases postulated as the result of the hypothetical accidents described in Chapter 8 are of a very small magnitude.

Therefore, radiological alarm systems are not necessary. However, as described in Sections 3.3.3.2, 4.3.7, and 5.4.1, other type nonsafety-grade monitors are provided with suitable alarms. Procedures to be followed when these alarms are activated will be specified in the Surry ISFSI operating procedures and are described in Section 4.3.7 of this SAR.

3.3.6 Fire and Explosion Protection

A backup diesel generator and its associated fuel tank are located within the ISFSI security fence. To prevent a postulated fire associated with a leaking fuel tank from propagating to the ISFSI, a collection trench is provided for the diesel fuel tank. There are no other significant combustible sources within the ISFSI security fence.

As indicated in Section 2.2.3.1, overpressure of less than 1 psi can be conservatively postulated to occur at the Surry ISFSI as a result of accidents involving explosive materials which are stored or transported near the site. Therefore, the SSSCs are designed to withstand a 1 psi external overpressure without any impairment of their safety functions. In addition, Section 2.2.3.2.1 indicates that an accidental release of fuel oil from the onsite fuel oil storage facility could result in an increase in the ambient temperature of about 8°F. As indicated in Section 3.2.1.1, the thermal analyses of the SSSCs assume an ambient temperature which exceeds the maximum temperature experienced at the site by about 10°F, and the maximum insolation during the summer solstice. These criteria provide sufficient margin to encompass the 8°F increase in ambient temperature that may be expected from the postulated oil fire.

3.3.7 Materials Handling and Storage

3.3.7.1 Spent Fuel Handling and Storage

The handling of spent fuel within the Surry Power Station is addressed as part of the facility license under 10 CFR Part 50. This includes the handling of the SSSCs within the spent fuel building and the loading of the casks with irradiated assemblies. Fuel that may be damaged to the extent of losing its cooling geometry or reasonable cladding integrity will be kept at the spent fuel pool and not considered for storage at the ISFSI.

Handling of the sealed casks outside of the power station in the process of emplacing them at the ISFSI will be done according to procedures that ensure that their safety functions and the power station capability for safe shutdown are not impaired. These operations are described in Chapters 5 and 9.

3.3.7.2 Radioactive Waste Treatment

The Surry ISFSI does not generate radioactive waste. However, cask loading and decontamination, while in the fuel and decontamination building, may generate very small amounts of waste. This waste is disposed of in accordance with the radioactive waste procedures described in Chapter 6, and is part of the 10 CFR Part 50 licensed activities.

3.3.7.3 **Waste Storage Facilities**

Waste storage facilities are neither required nor provided for the Surry ISFSI.

3.3.8 Industrial and Chemical Safety

No hazardous chemical are involved in the operation of the Surry ISFSI. Ion exchange resins are not used at the ISFSI, and no operations involving resins are anticipated.

Handling of the storage casks is the only operation which may be viewed as presenting a situation important to plant personnel safety, although equivalent loads are lifted and transported frequently during other industrial operations. Adherence to the ISFSI procedures will ensure that risks incurred during the handling of the SSSCs are minimized.

Table 3.3-1
DESIGN CRITERIA FOR DRY SEALED SURFACE STORAGE CASKS

The casks must meet the following criteria, assuming that the casks are loaded with the fuel described in Table 3.1-1.

1.	Maximum weight with yoke	125 tons
2.	Maximum length	16 feet with covers removed
3.	Criticality with single active or credible passive failure	k_{eff} <.95
4.	Capable of being lifted by mobile crane or lifting rig	
5.	Capable of being stored and transported in vertical or horizontal position	
6.	Adequate provisions to monitor performance of cask	
7.	Maximum surface dose	200 mrem/hr [a.]
8.	Ambient temperature	-20°F to 115°F
9.	Direct exposure to sunlight	5 kW over 10-hr periods
10.	Ambient humidity	0 to 100%
11.	Tornado winds	300 mph rotational velocity, 60 mph translational velocity; or per Regulatory Guide 1.76, April 1974
12.	Tornado pressure drop	3 psi in 3 seconds
13.	Maximum winds (V_{30})	105 mph
14.	Gustiness factor	1.3
15.	Explosive peak overpressure	1 psi
16.	Design Earthquake peak acceleration	0.07g
17.	Withstand drop onto concrete slab without compromising cask integrity and without physical damage to fuel or loss of subcriticality	
18.	Capable of tipping over and rolling without exceeding expected damage for the cask drop onto concrete slab.	
19.	Designed, fabricated, delivered to site, and sealed according to recognized commercial codes and standards	
20.	Construction materials to be compatible with each other and with expected radiation levels	
21.	All surfaces contacting fuel assemblies to be free of burrs, sharp corners, edges, and weld beads that could mar or damage the fuel assembly surface or injure personnel	
22.	Permanent identification of each fuel assembly storage location to be provided	
23.	Leak tightness to be maintained under all operating conditions and credible events	
24.	Leak tightness to be maintained following cask drop onto ISFSI pad, Design Earthquake, and other postulated site hazards	

a. Doses for particular casks may vary, but dose due to total array of casks at the ISFSI must be enveloped by the analyses of Chapter 7 of this SAR.

Table 3.3-1 (continued)
DESIGN CRITERIA FOR DRY SEALED SURFACE STORAGE CASKS

25. All cutting and welding required for the handling of the casks not to result in damage to the fuel assemblies
26. All surfaces (external) wetted by fuel pool water to be epoxy coated to facilitate decontamination. This includes lifting yoke.

3.4 CLASSIFICATION OF STRUCTURE COMPONENTS AND SYSTEMS

3.4.1 General

The SSSCs are the only components of the Surry ISFSI which are important to safety. None of the other systems and structures comprising the Surry ISFSI (concrete slabs, fence, monitors, wiring, and lights) perform a safety function. The handling mechanisms (rigs, impact limiters, and transporter) are not considered important to safety because the SSSCs are designed to withstand their failure without jeopardizing the health and safety of the public.

The specific portions of the casks that are important to safety and a definition of the specific safety function are provided in the SSSC topical reports.

3.5 DECOMMISSIONING CONSIDERATIONS

3.5.1 General

No radioactive releases during normal operation or accidents resulting in radioactive releases are considered credible. Therefore, no means exist for the contamination of the outside surface of the casks, the concrete slabs, or any other part of the ISFSI. Even the accidents analyzed in Chapter 8 are postulated to result only in radioactive gaseous releases which will not contribute to the contamination of any component of the ISFSI. Thus, there is no need for any additional design criteria to explicitly facilitate decommissioning of the Surry ISFSI.

Steps for decommissioning the casks are provided in the SSSC topical reports.

Appendix 3A
STRUCTURAL CONSIDERATIONS FOR THE ISFSI CONCRETE SLAB

3A.0 INTRODUCTION

The primary purpose of the concrete slab is to provide a well defined and level support surface for the casks. It also serves as an aid in preventing tip over of the casks in the event of a seismic occurrence in that it provides a hard and stable surface upon which the casks are supported. Section 3A.2.5 of this appendix provides a demonstration that the material stored in the cask creates no added hazard to public health and safety due to tip over. Therefore, the support slabs of the ISFSI have no function important to safety. As the ISFSI and the casks are of a totally passive design, there are no safe shutdown functions required for safety and the term Seismic Category I is not applicable. Analysis has been conducted to demonstrate that the slabs, fully loaded with casks, will withstand a design earthquake with no adverse effects either to the slab or to the casks. Further, the analysis has shown that the casks remain upright during and after the seismic event.

3A.1 ANALYSIS FOR DESIGN EARTHQUAKE

3A.1.1 Design Criteria

An analysis of the slab and casks was conducted for the design seismic event with the following design criteria:

1. Consistent with the results of Section 2.6 of the ISFSI SAR, the design earthquake shall have a peak free field acceleration of 0.07g.
2. The design spectrum shall be in accordance with Regulatory Guide 1.60, *Design Response Spectra for Seismic Design of Nuclear Power Plants,* Revision 1, December 1973.
3. Consistent with similar seismic analyses, which were conducted for Surry Power Station Units 1 and 2 as reported in its FSAR, the free field motion shall be applied at the ground surface.
4. Based on these input parameters, a dynamic analysis of the slab and casks shall be conducted to quantify the effects of the design earthquake both in regard to the slab and casks, but more importantly to evaluate the potential for cask tip over.

3A.1.2 Implementation of Criteria—Method of Analysis

A time-history analysis was conducted for the slab fully loaded with casks in accordance with the mathematical model shown in Figure 3A-1. The slab was modeled as a rigid mass connected to an equivalent vertical and two orthogonal horizontal soil springs and associated dampers. Since the casks are rigid with respect to earthquake exciting frequencies and no mechanism for dynamic interaction between casks is present, this combined inertia effect is represented by a single rigid mass added to the mass of the slab. Auxiliary analyses were conducted to evaluate cask rocking and the potential for tip over.

3A.1.2.1 **Design Time History**

Three statistically-independent synthetic time-history records shown in Figure 3A-2 were used to represent the vertical and two orthogonal horizontal time-history records. Figures 3A-3, 3A-4, and 3A-5 compare response spectra developed from these time history records with that specified by Regulatory Guide 1.60 normalized, i.e., adjusted upward for a l.0g earthquake for various damping ratios. As indicated in the figures, each individual time history provides a response that is equal to or exceeds the Regulatory Guide 1.60 spectra at all frequencies. These three time histories were used to simultaneously excite the slab and casks. Although the duration of the design earthquake is expected to be much less, the time history records extend for 24 seconds.

3A.1.2.2 **Soil-Structure Interaction**

Soil-structure interaction is accounted for by elastic half space concepts, in accordance with the procedures outlined in Reference 1. To account for possible variations in soil, two analyses were conducted, using lower and upper bound soil properties that represent possible variations in representative properties of the composite soil.

Shear Modulus, G_s	13.7×10^5 psf (lower bound)
Shear Modulus, G_s	27.0×10^5 psf (upper bound)
Soil Density, γ_s	115 psf
Poisson's Ratio, μ	0.49

To provide additional conservatism, the computed radiation damping values were reduced to 75 percent of the values computed by Reference 1. Soil material damping was taken as 3 percent critical and added to the radiation damping.

3A.1.2.3 **Computer Code**

The analysis was conducted using the BSAP computer code (Reference 2), which is a linear analysis finite element program which has been reviewed previously by the NRC staff.

Overturning of the casks was evaluated by comparing the maximum kinetic energy of the casks (E_s) to the potential energy (E_o) required to cause overturning. The factor of safety against overturning is the ratio of potential energy to maximum kinetic energy, or:

$$\text{F.S.} = \frac{E_o}{E_s}$$

where $E_s = l/2\ m_c\ (V^2_H + V^2_V)$

m_c is the mass of the cask and V_H and V_V are, respectively, the maximum values of the resultant horizontal and vertical velocities. This introduces a conservatism into the analysis, since at any given instant the sum of these velocity components are less than the maximum values.

3A.1.3 Results of Analysis

As indicated in the previous section, two dynamic analyses of the slab and casks were conducted to represent lower and upper bound limits of the composite soil. Natural frequencies of the slab loaded with 28 125-ton casks are as follows:

	Lower Bound Soil Properties	Upper Bound Soil Properties
N-S direction, Hz	5.51	7.74
E-W direction, Hz	5.25	7.38
Vertical direction, Hz	6.98	9.78

A peak g level of 0.093g was obtained on the slab for the lower bound soil properties. However, the variation in soil properties had little effect on the response since a maximum g level of 0.088 was obtained for the upper bound soil properties. This results in a maximum amplification of the slab with respect to the free field motion of approximately 1.33.

Since the natural frequencies of the fully loaded slab are associated with those expected to provide peak and near-peak response, as indicated by the results associated with variation of soil properties, the response of a slab less than fully loaded with casks and/or with lighter casks would be expected to be no greater and probably less than that presented.

Evaluation of cask tip over based on the results of the dynamic analysis and using the energy approach discussed in the previous section indicates that the factor of safety against tip over is at least 240 for the design earthquake. The kinetic energy developed in the casks represents no more than l/240 of that necessary to cause tip over.

Seismically induced settlement, discussed in SAR Section 2.6, is of no consequence either to slab integrity or to cask tip over.

3A.2 ADDITIONAL CONSIDERATIONS AND ANALYSIS

3A.2.1 Criteria

Analysis has been presented to demonstrate that adequate margins of safety are provided to ensure that cask tip over is not a viable consideration during the design seismic event. Additional analysis is presented in Section 3A.2.5 which ignores the above conclusions, but provides added assurance regarding the safety of the casks during a seismic event by evaluating the effects of a postulated tip over. It concludes that no adverse safety concerns exist if tip over occurs.

Further evidence regarding the extreme conservative design of these slabs and casks is obtained by evaluating the effects of an event even more severe than the design earthquake. The purpose of this additional analysis is to identify margins which exist above and beyond those necessary for the design earthquake.

To simulate the occurrence of substantial settlement, the following characteristics were considered:

1. Total uniform slab settlement of 14 inches. Although soil settlement may be induced by a seismic event, due to the time required for excess pore water pressure in the soil to dissipate, the actual settling of the ground would take place after the shaking has stopped. Therefore, it is not necessary to consider settlement or differential settlement in conjunction with a seismic event.

2. Accompanying the uniform settlement is a differential uniform settlement at the rate of 7 inches in 20 feet which is random in orientation and may occur in multiple directions.

3. Additionally, it has been assumed that the slab can sustain a loss of contact with the soil for a span of 15 feet at multiple locations randomly selected.

   These do not represent values determined by soil stability analysis but rather represent extreme assumptions much more severe than the design event selected only to demonstrate the additional safety margins which exist in the slab/cask system if influenced by a seismic event.

To evaluate the effect of settlement on the slab and casks, the following criteria were established:

1. As a result of the severe differential settlement conditions specified above, the concrete compressive strength shall be taken as equal to or less than the minimum specified design concrete strength of the slab.

   Reinforcing steel strain shall be no greater than 50 percent of the minimum specified ultimate strain. Results shall also show that the slab does not separate vertically due to shear loading.

2. The slab shall be considered acceptable for bridging a span of 15 feet if the concrete stresses remain below the minimum specified compressive stress and the reinforcing steel stresses do not exceed minimum specified yield stress.

3A.2.2 Method of Analysis

As previously discussed, the most critical effect of the dynamic response due to a seismic event is the potential for overturning. Considering the margins of safety associated with the overturning of a cask for the design earthquake and realizing that the kinetic energy will increase approximately with the square of the excitation level, it is evident that excitation levels in excess of ten times the design earthquake level are required to cause overturning of the casks. Thus, cask tip over due to dynamic events has substantial margins above the design earthquake excitation level. For this reason, further dynamic analysis of the slab loaded with casks need not be considered.

The effect of extreme seismic induced soil settlement may contain four possible separate components:

1. Uniform downward settlement
2. Uniform differential settlement
3. Differential settlement which is random in orientation and occurs in multiple directions
4. Loss of contact over a large area of the support surface

Uniform downward settlement causes no adverse effect on either the slab or the cask. The only effect such settlement has is to lower the final elevation of the slab/cask system. Likewise, uniform differential settlement of the slab causes no reduction in the structural integrity of the slab. It does, however, increase the chances of cask tip over. However, since the height of the cask center of gravity is approximately equal to its width, the differential settlement must cause the slab to be tilted in excess of 23° from the horizontal before this possibility is realized.

Multiple oriented differential settlement, if it is excessive, has the potential to cause permanent distress to the slab. Although such distress does not necessarily affect the functional requirements of the slab, as discussed previously, it is an issue that can be addressed to provide assurance that the slab remains continuous, and, therefore, maintains a sufficiently level and well defined resting place for the casks.

To evaluate the performance of the slab under these extreme conditions, two mathematical models of the slab were generated, representing two worst cases of randomly oriented settlement conditions. (See Figure 3A-6). The model represents the slab by two-dimensional elasto-plastic beam sections supported on a bed of special spring elements, which represents the elastic properties of the soil. The magnitude of the moments at the elastic limit of the beams was determined in accordance with the ultimate strength design methods included in ACI 318-83. The limit was assumed to occur when the tension reinforcing steel reaches its yield strain limit. As a result, the slab section was designed to be underreinforced and, therefore, yielding of the reinforcing steel will occur before crushing of the concrete. This ensures ductile behavior.

Maximum differential settlement was assumed to emanate from an arbitrary reference point on the slab in opposite directions such that the reference point either becomes a high point (see Figure 3A-6) or a low point as in Figure3A-6. This was accomplished by using special soil spring elements that have the capability of providing initial gaps at appropriate locations under the slab. Note that in Figure 3A-6 a slope equal to twice the maximum anticipated differential settlement is imposed on one side of the slab. This approach was necessary to initiate the mathematical solution and is valid in representing equal maximum settlement downward and away from an arbitrary reference point on the slab. Downward loading of the casks (along with the dead load of the slab) was enforced in accordance with the imposed spacing of the casks, but was oriented such as to represent a worse loading condition.

The analyses were conducted using the ANSYS computer code (Reference 3), which is a nonlinear finite element code that has been previously utilized in structural analysis of nuclear power plant structures.

The effect of loss of contact with the soil was considered by eliminating support under the slab for an infinitely long strip having a width of 15 feet. A study determined that the controlling location and orientation of this strip is most severe if it is either placed at the end of the slab, causing it to be cantilevered, or placed in the longitudinal direction of the slab such that either side of the slab is unsupported for a width of 15 feet. All other possible orientations produce less severe effects on the structure. Structural integrity of the slab was evaluated manually in accordance with ACI 318-83.

3A.2.3 Results

Maximum strain in the reinforcing steel occurs for the case where the arbitrary reference is the high point on the slab (Figure 3A-6). The computed strain is no more than 0.016 or 46 percent of the allowable. Shear capacity of the slab is computed to be no more than 36.5 percent of the ultimate capacity.

Utilizing a 3-foot-deep slab reinforced with No. 11 rebar at 12 O.C. each way, top and bottom, the reinforcing steel is stressed to approximately 85 percent of allowable due to loss of soil support. The allowable stress is 90 percent of yield stress of the reinforcing steel.

3A.2.4 Criteria to Evaluate Acceptability of the Concrete Slab Following a Design Earthquake

In the unlikely event that the design earthquake were to occur at the site, assessment of potential damage would address the following three concerns:

1. Structural integrity of the concrete slab
2. Stability of the casks as it is affected by potential differential settlement
3. Stability of the foundation material

Although the system can be exposed to much more severe seismic conditions without jeopardizing the overall stability of the casks, continued use of the slab after a design earthquake will be based on meeting such criteria.

Meeting these criteria ensures the slab will remain within its elastic limit and that foundation stability is maintained.

Structural integrity of the slab is influenced by the strain in the reinforcing steel since the slab is underreinforced. This strain can be evaluated by the change in curvature of the slab caused by the seismic event.

Differential settlement which would cause instability of the casks is not a controlling concern. Based on the geometry of the cask, the slab could experience a differential settlement at the rate of 105 inches over 20 feet before cask instability would occur.

Stability of the foundation materials can be ensured if differential settlement is within limits to maintain the structural integrity of the concrete slab.

Utilizing the mathematical models shown in Figure 3A-6 to evaluate the slab, it has been determined that a vertical relative displacement caused by a seismic event of 1/2 inch between any two points on the slab 14 feet apart can be tolerated before slab replacement or a detailed structural evaluation is required. If the relative settlement of the slab is within these limits, the slab may be safely used with assurance that integrity will be maintained during a future design seismic event. These relative displacement limits are based on postulated differential settlement of 3 inches in 20 feet occurring in opposite directions from an arbitrary reference point on the slab.

3A.2.5 Cask Tip-Over Accidents

As previously discussed in Section 3A.1.3, adequate margins of safety exist to ensure against cask tip-over resulting from the ISFSI design earthquake.

The cask tip-over analyses are described in the SSSC topical reports and include an evaluation of the following concerns:

1. Criticality must be within acceptable limits.
2. Cask integrity must be maintained (no loss of confinement).
3. Any damage must be limited so as not to preclude the removal of fuel assemblies (i.e., basket integrity must be maintained).

3A.2.6 Conclusions

Based on the results of the site specific investigations and analyses for the Surry ISFSI, the following conclusions can be made:

1. Based on the criteria established in 10 CFR 72.66(b) and using a building code approach for determining the seismic design level, a conservative value of 0.07g was determined for the design earthquake.
2. The soil stability analysis under static loading indicated that the factor of safety against a bearing failure is greater than 3.0.
3. The minimum factor of safety against the potential of liquefaction using the simplified procedure is 1.5.
4. The analyses that were performed for the concrete slab indicated the slab would remain continuous and without loss of integrity during the design earthquake. Additional analyses indicated the concrete slab could withstand, without loss of integrity, uniform downward

settlement of 14 inches, differential settlement of 7 inches in 20 feet, or loss of soil contact for a span of 15 feet.

5. Analyses performed regarding the potential for cask tip over indicated a factor of safety to be over 240 under design earthquake conditions. Therefore, it can be concluded that the cask will not tip over during a design seismic event.

3A.3 References

1. Whitman, R. V., Richard, E. F., *Design Procedure for Dynamically Loaded Foundations,* Journal of the Soil Mechanics and Foundation Division Proceedings of the ASCE, 1967, pp. 169 to 193.
2. *BSAP, Bechtel Structural Analysis Program,* CE800, Version E13-47.
3. *ANSYS Program,* CE798, Rev. 3, Update 67H.

Figure 3A-1
BSAP MODEL OF SLAB, CASKS AND SOIL SPRINGS

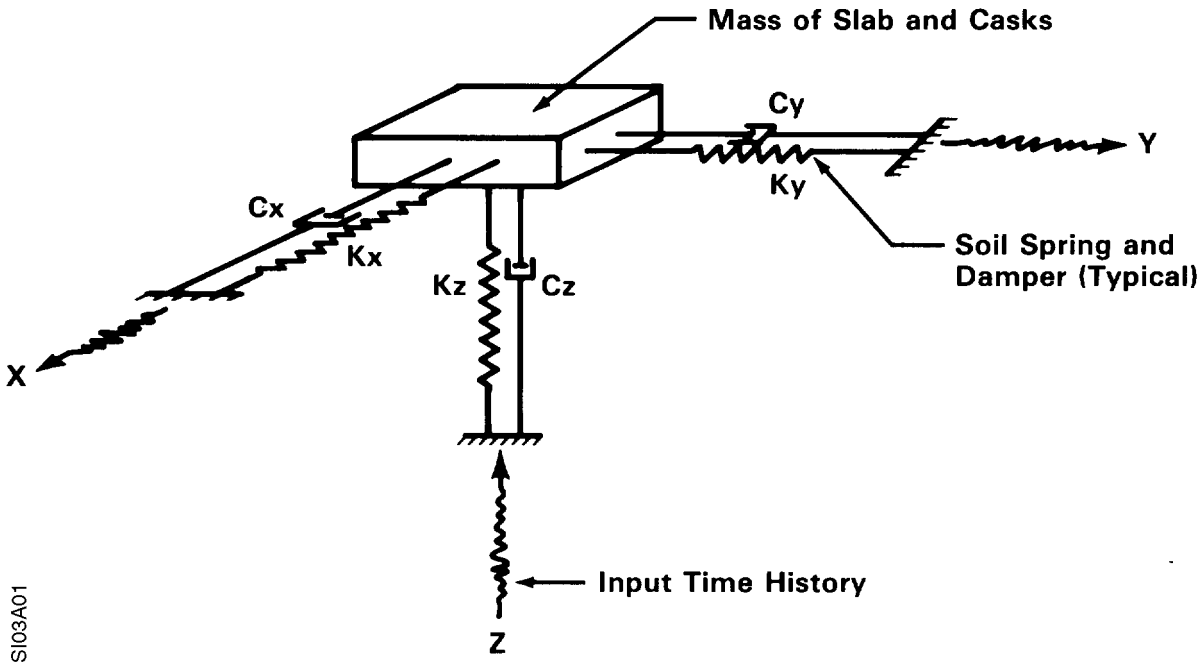


Figure 3A-2
SYNTHETIC TIME HISTORY MOTION OF THE DESIGN EARTHQUAKE

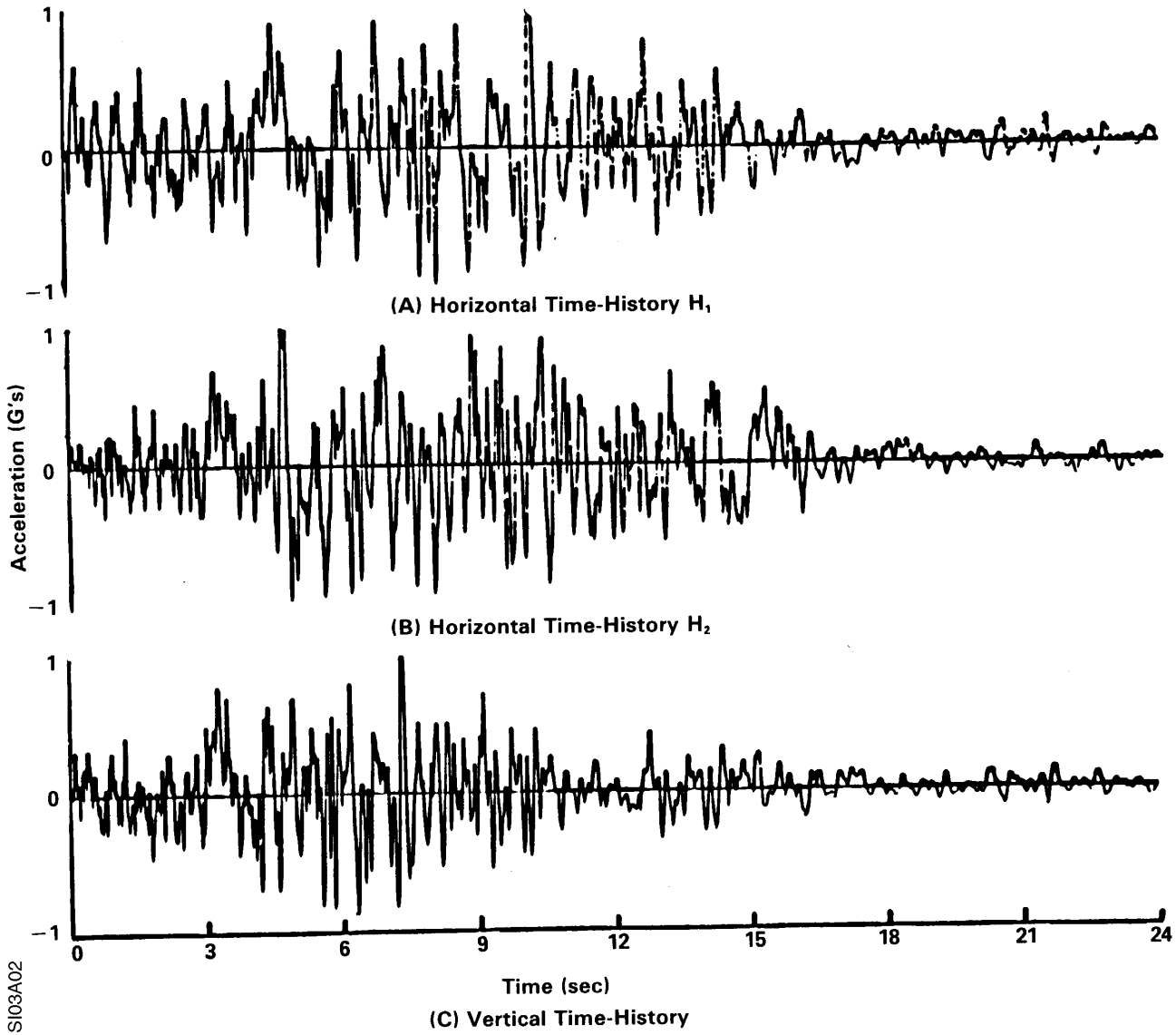


Figure 3A-3
COMPARISON OF THE ACCELERATION RESPONSE SPECTRA OF HORIZONTAL TIME HISTORY H_1 WITH THE HORIZONTAL DESIGN SPECTRA FOR 2 PERCENT, 5 PERCENT, AND 10 PERCENT CRITICAL DAMPING

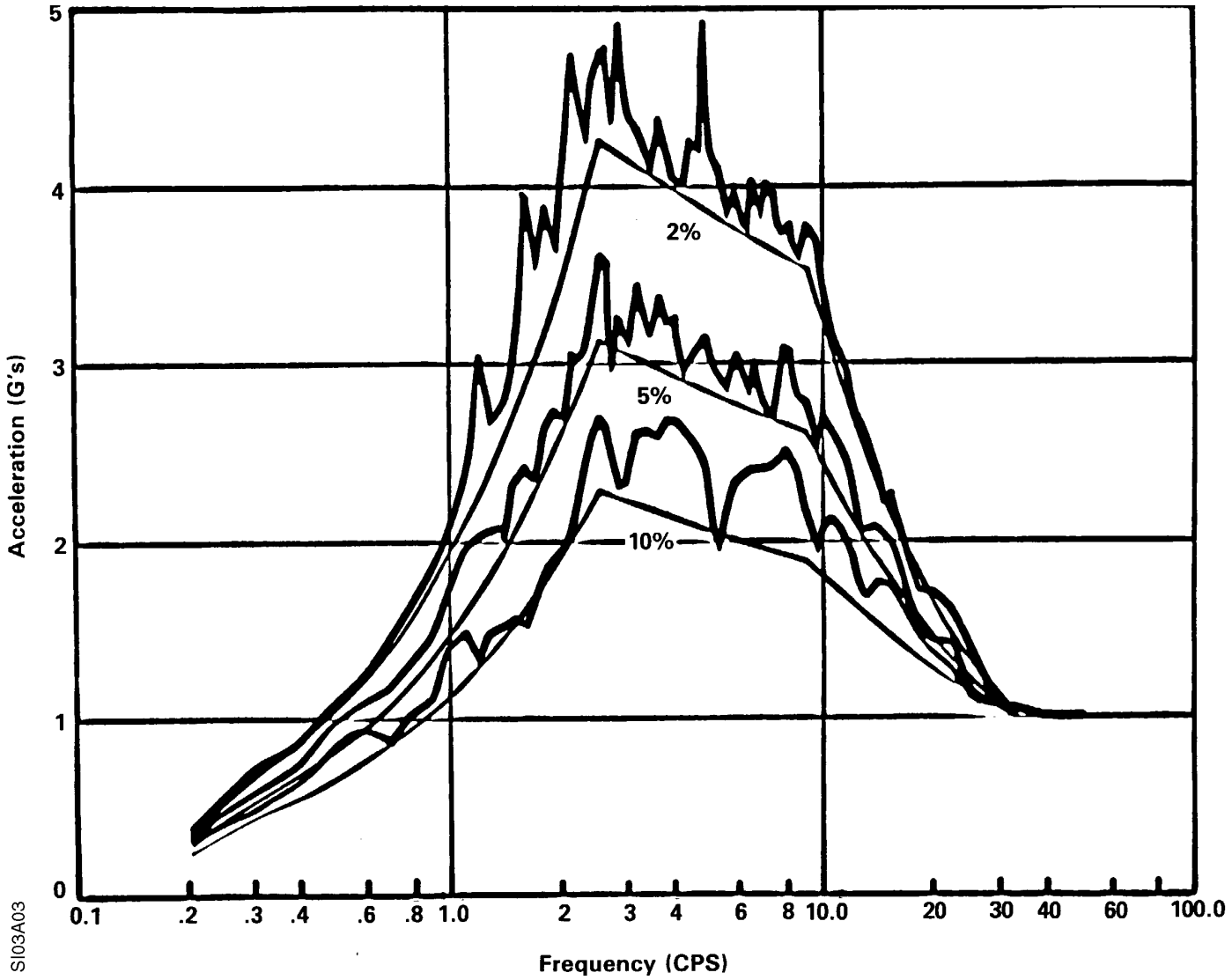


Figure 3A-4
COMPARISON OF THE ACCELERATION RESPONSE SPECTRA OF HORIZONTAL TIME HISTORY H_2 WITH THE HORIZONTAL DESIGN SPECTRA FOR 2 PERCENT, 5 PERCENT, AND 10 PERCENT CRITICAL DAMPING

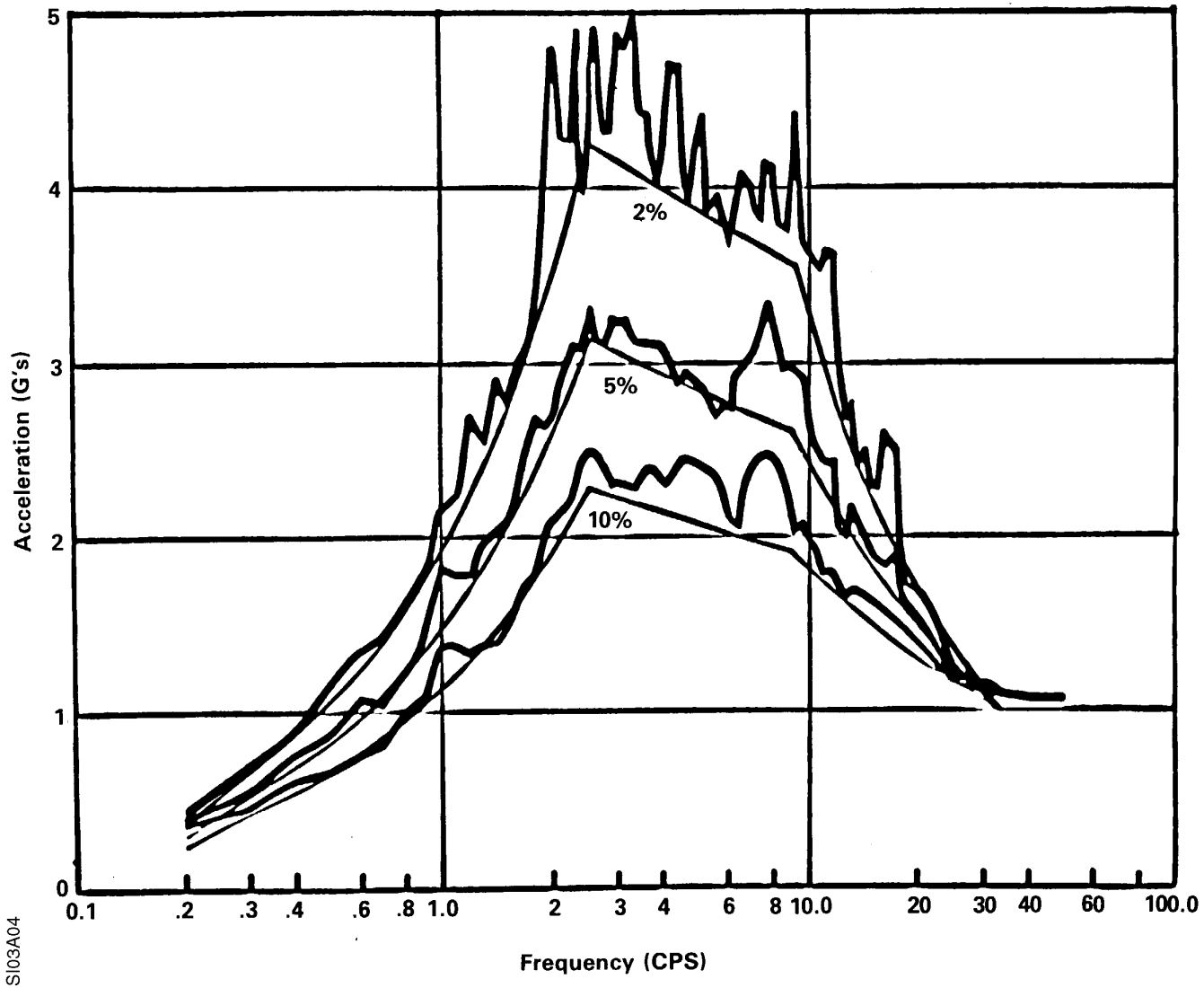


Figure 3A-5
COMPARISON OF THE ACCELERATION RESPONSE SPECTRA OF THE VERTICAL TIME HISTORY WITH THE VERTICAL DESIGN SPECTRA FOR 2 PERCENT, 5 PERCENT, AND 10 PERCENT CRITICAL DAMPING

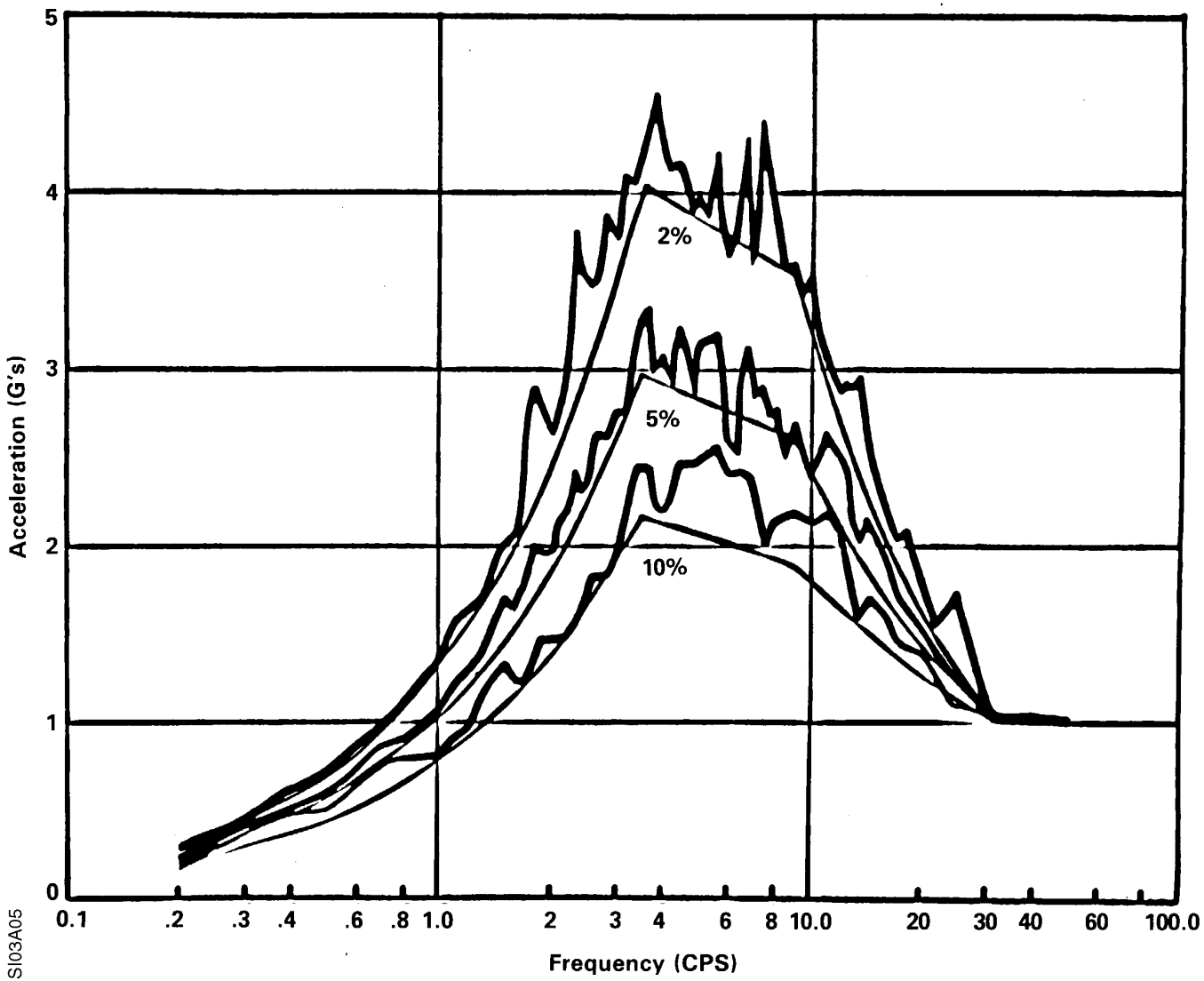


Figure 3A-6 (SHEET 1 OF 2)
ANSYS MODEL OF SLAB, CASKS AND SOIL SPRINGS

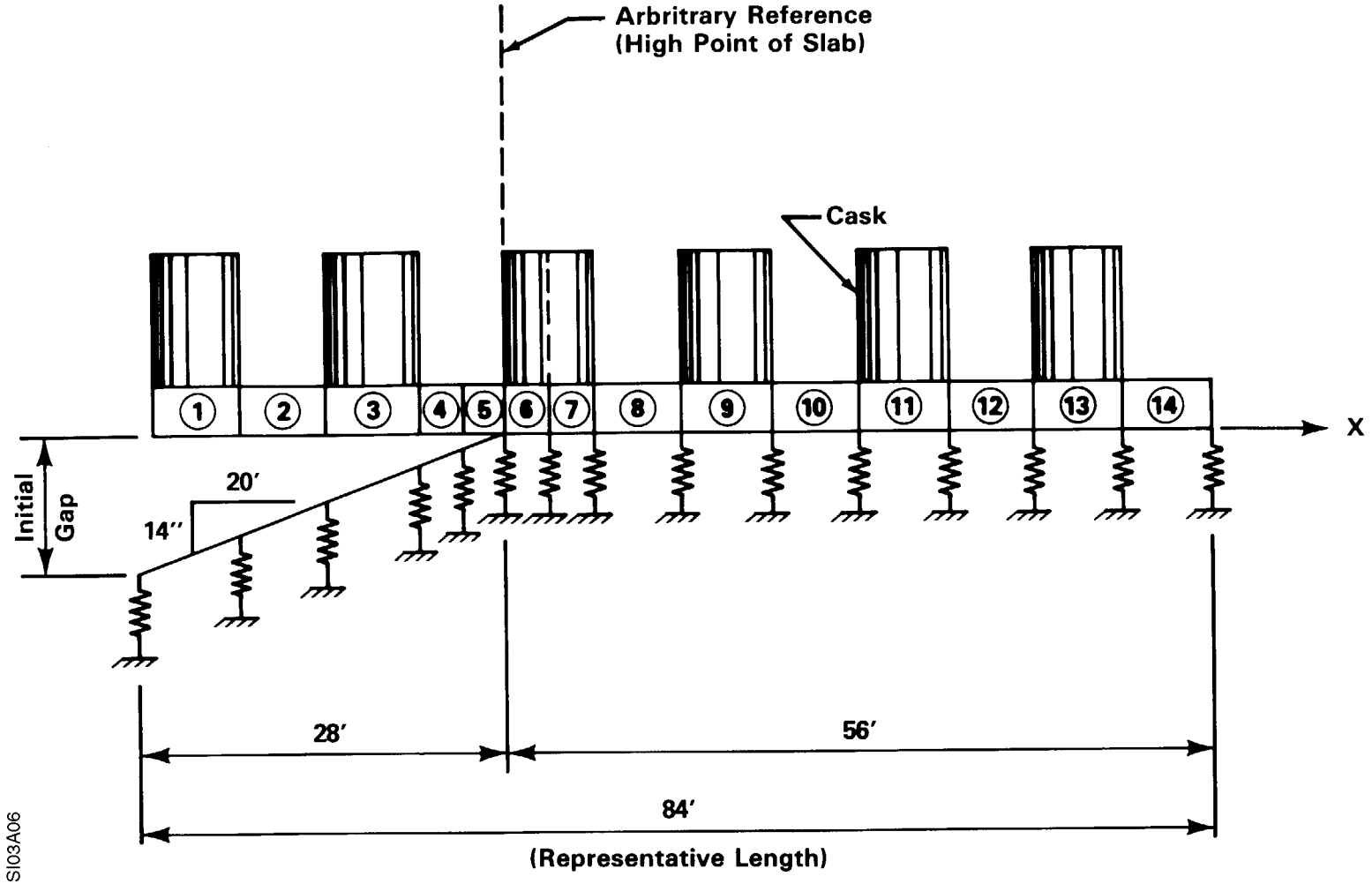
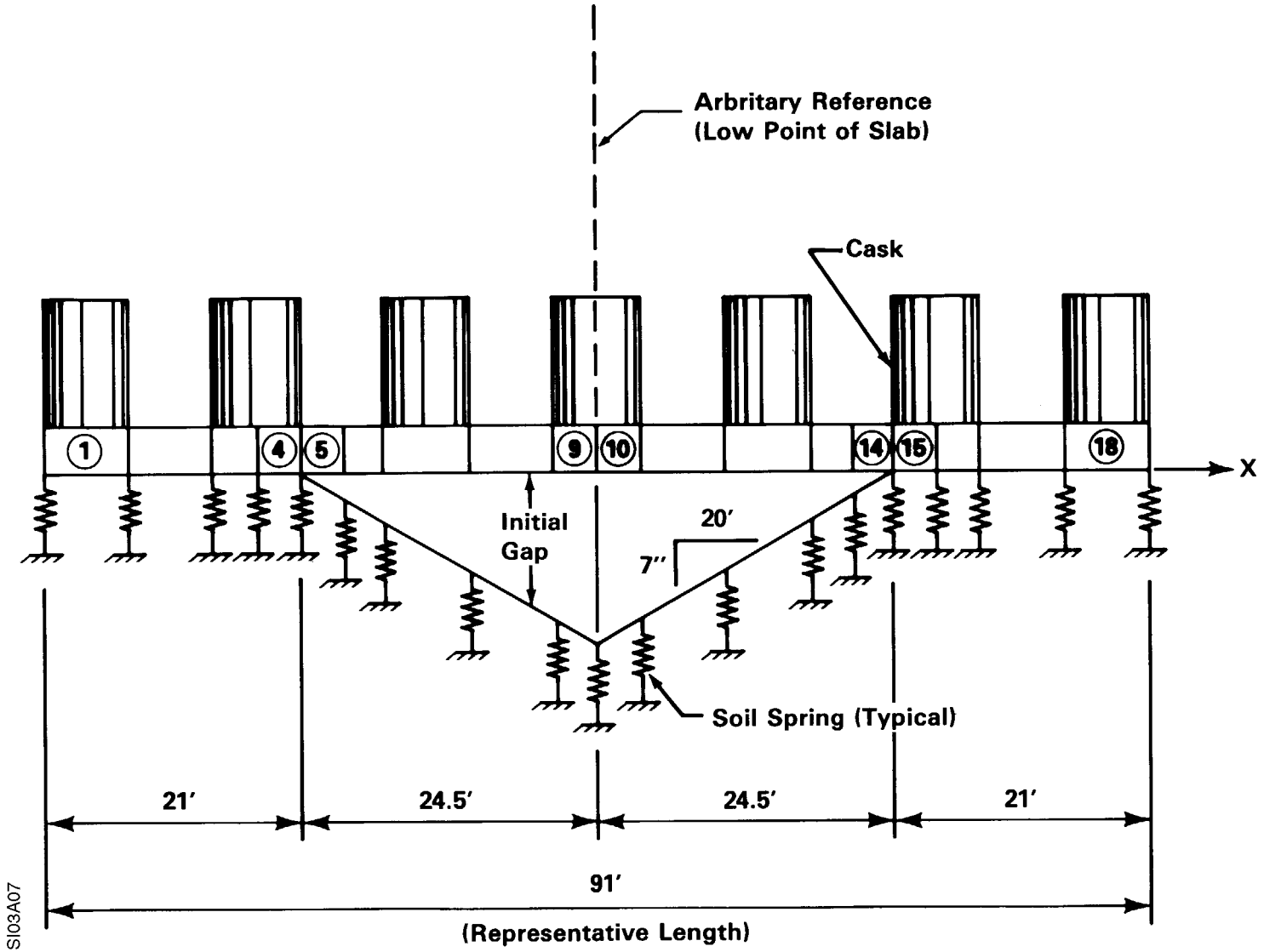


Figure 3A-6 (SHEET 2 OF 2)
ANSYS MODEL OF SLAB, CASKS AND SOIL SPRINGS



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Chapter 4
INSTALLATION DESIGN

This chapter provides descriptive information on the Surry ISFSI structures, systems and components. It also provides the bases for the design criteria presented in Chapter 3.

4.1 SUMMARY DESCRIPTION

4.1.1 Location and Layout of Installation

The Surry ISFSI is located within the Surry site, as described in Section 2.1.1.

The only components with a safety function are the SSSCs. The SSSCs are stored on three nonsafety-related concrete slabs, 230-by-32-feet, to be built one at a time, as needed, within the fenced-in area shared with the low level waste (LLW) storage installation. Each slab is designed to accommodate approximately 28 casks, each approximately 8 feet in diameter and weighing no more than 125 tons, with approximately 8 feet surface to surface distance when stored in the vertical position. The exact number of casks will depend on the specific characteristics of the particular SSSCs used.

The Surry ISFSI fenced-in area is approximately 800-by-800 feet with an entrance on the south side. An inner security fence is also provided around each slab.

The layout is shown on Figure 4.1-1.

4.1.2 Principal Features

4.1.2.1 **Site Boundary**

A description of the area owned and controlled by Virginia Power is provided in Section 2.1 and is shown on Figure 2.1-1.

4.1.2.2 **Controlled Area**

As described in Section 2.1, the controlled area for the Surry ISFSI is the same as for the Surry Power Station.

4.1.2.3 **Emergency Planning Zone**

The Emergency Planning Zone (EPZ) for the Surry ISFSI is the same EPZ as for the Surry Power Station, and is shown on Figure 4.1-2.

4.1.2.4 **Site Utility Supplies and Systems**

The only utility associated with the Surry ISFSI is electrical power for lights, communications, and monitoring instrumentation as shown on Figure 4.1-3. The source of this power is described in Section 4.3.2.

4.1.2.5 **Storage Facilities**

There are no holding ponds, chemical or gas storage vessels, or other open-air tankage within the ISFSI fenced-in area.

Hazardous materials stored at, or near, the Surry site are described in Section 2.2.

4.1.2.6 **Stack**

There are no stacks at the Surry ISFSI.

Figure 4.1-1
GENERAL SITE LAYOUT

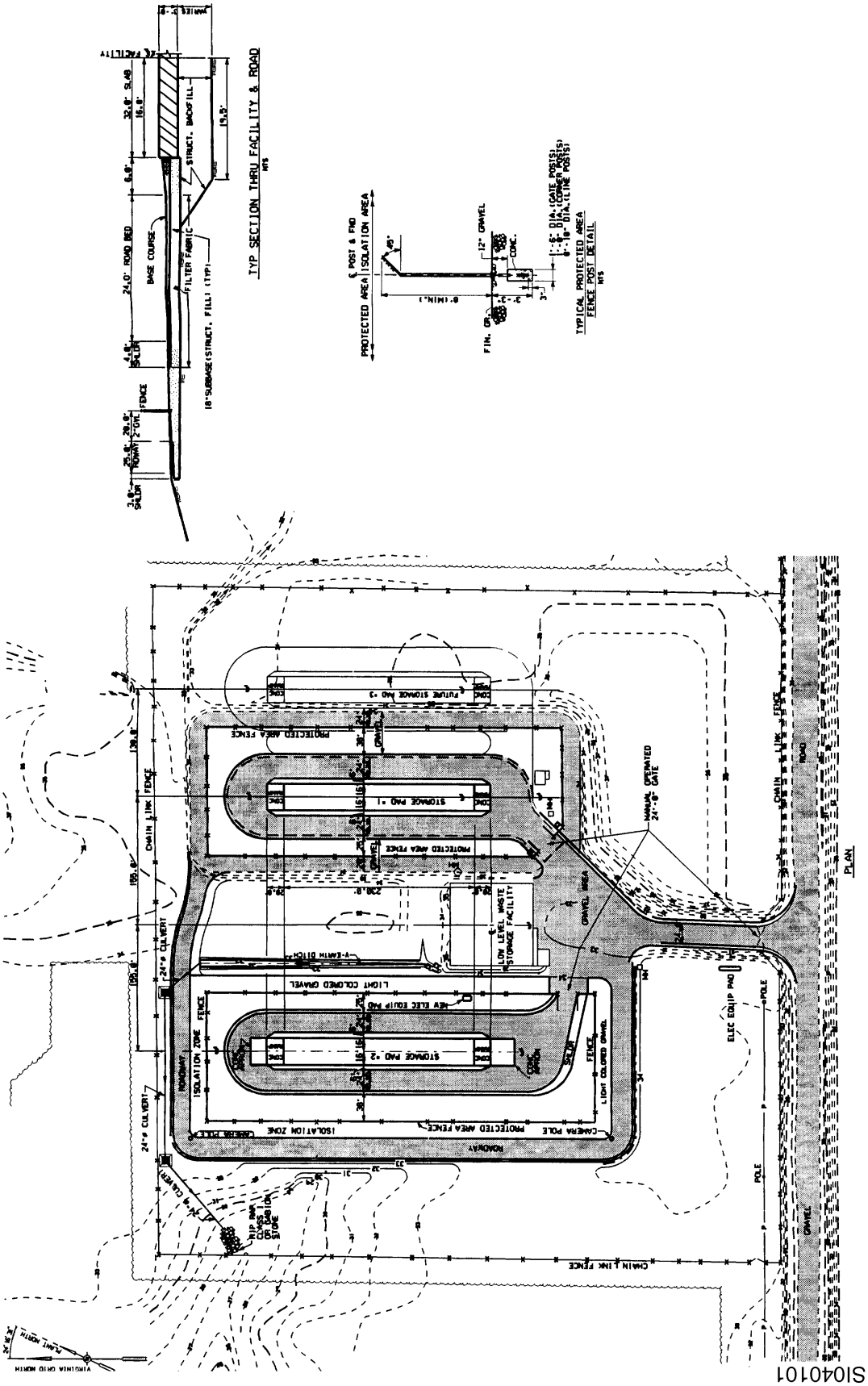


Figure 4.1-2
EMERGENCY PLANNING ZONE

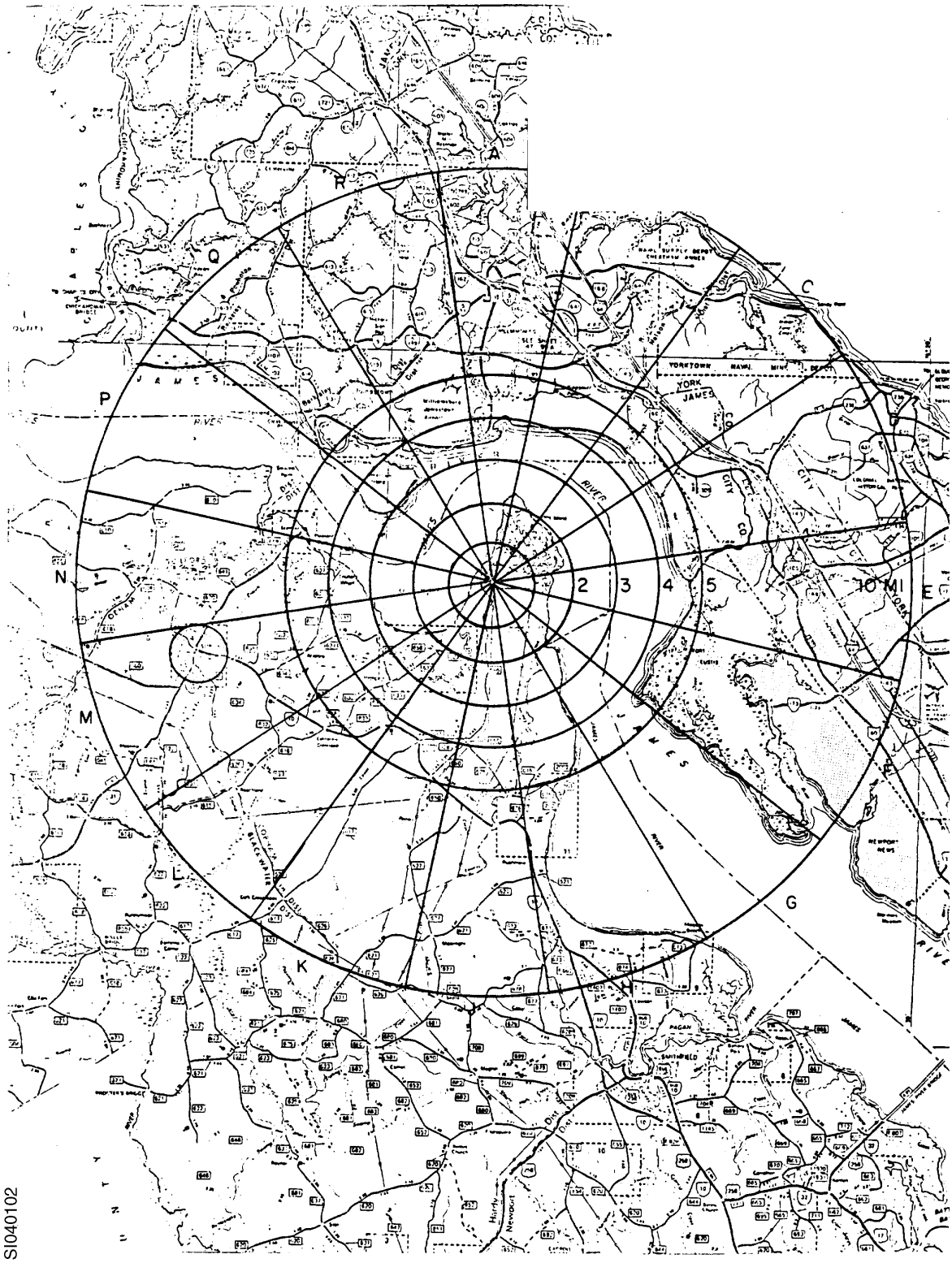
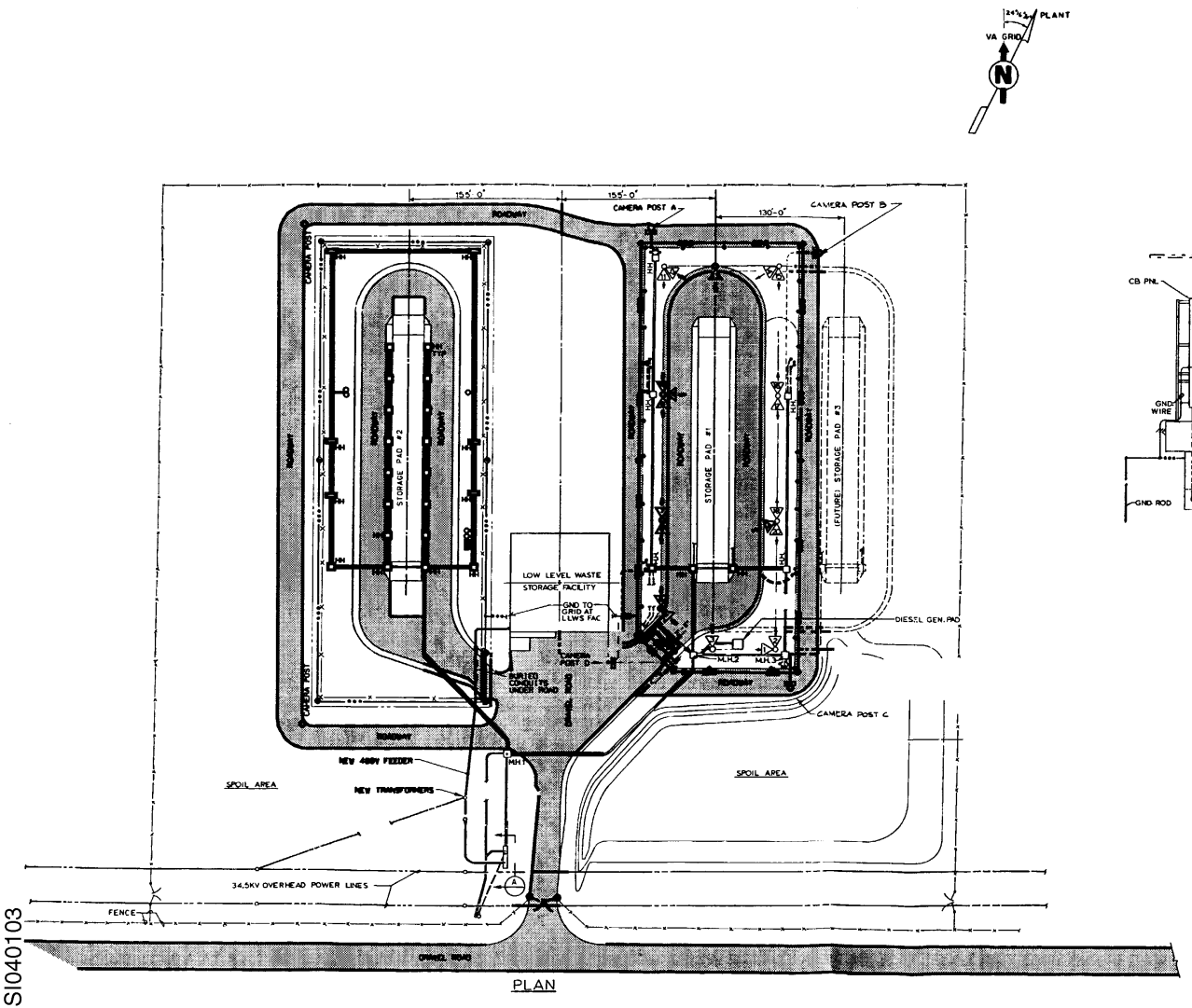
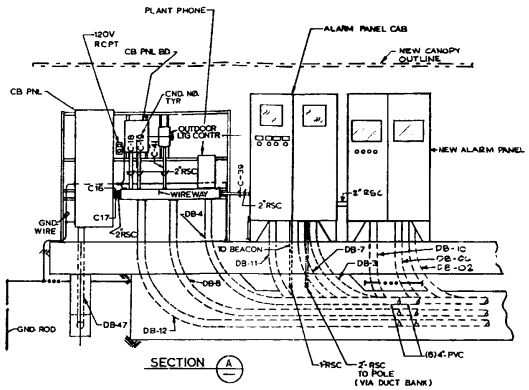


Figure 4.1-3
ISFSI ELECTRICAL EQUIPMENT LOCATION





LEGEND

2	LUMINAIRE, MID FLOODLIGHT 1000W INDICATE ASSIGNED NO. TO LUMINAIRE
○	INDICATES SPARE CONDUIT IN DUCT BANKS.
Φ	INDICATES CONDUITS WITH ASSIGNED CABLES. (SEE DWG. FE-82E.)
T	BOOST TRANSFORMER
CB PNL BD	CIRCUIT BREAKER PANEL BOARD
RCPT	RECEPTACLE
CND	CONDUIT
RSC	RIGID STEEL CONDUIT
PVC	POLYVINYL CHLORIDE
GND	GROUND

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4.2 STORAGE STRUCTURES

The design criteria for the SSSCs are described in Chapter 3 of this SAR. These criteria are based on potential site hazards, limiting conditions for operation, and postulated accidents which the SSSCs must be able to withstand. Compliance with the specified design criteria will ensure that the requirements of 10 CFR Part 72 are satisfied.

4.2.1 Structural Specifications

The operational areas of the Surry ISFSI are the three concrete slabs and the areas immediately around them. The slabs provide a uniform level surface for storing the SSSCs. The compacted areas around the slabs allow movement and positioning of the handling equipment.

These slabs will be built in accordance with the BOCA Basic Building Code (Reference 1) and applicable American Concrete Institute codes and standards (References 2 & 3), and will be approximately 3.0-foot-thick reinforced concrete with design compressive strength of 3000 psi at 28 days. The three concrete slabs will be built within the fenced-in area adjacent to where the low level waste storage building is located. An elevation and engineering drawing of the slabs is shown on Figure 4.2-1.

The area surrounding the slabs will be compacted to properly support the haul vehicle and transporter needed for the handling of the SSSCs.

4.2.2 Installation Layout

4.2.2.1 Building Plans

The overall layout of the Surry ISFSI is described in Section 4.1.1, and is shown on Figure 4.1-1. The SSSCs are the only component of the Surry ISFSI vital to the fulfillment of its safety function. All other structures and components are of a support nature and do not perform safety functions.

The most important of these support systems are the concrete slabs, which provide a uniform level surface, slightly above grade elevation, for the SSSCs. These are described in Section 4.2.1.

4.2.2.2 Building Sections

There are no building sections as such. However, engineering drawings showing section and details of the concrete base mat are presented on Figure 4.2-1.

4.2.2.3 Confinement Features

Confinement of radioactivity is accomplished solely by the SSSCs and is not dependent upon the particular layout of the installation. Therefore, other than the SSSCs themselves, no confinement features are provided at the ISFSI. Analyses of the casks' ability to perform their confinement function are provided in the SSSC topical reports.

4.2.3 Individual Unit Description

The bases and engineering design specifications for the SSSCs are described in the SSSC topical reports. These reports also provide assurance that the applicable design criteria described in Chapter 3 are met.

In turn, compliance with the design criteria ensures that the General Design Criteria in Subpart F of 10 CFR Part 72 are satisfied. This is illustrated in Table 4.2-1 which shows a correspondence between each of the General Design Criteria and the design criteria of specifications that the SSSCs must meet as identified in Chapter 3.

4.2.3.1 Functions

Descriptions of the fuel loading, cask preparation, and cask placement operations are provided in Chapter 5.

Performance objectives during fuel loading are to transfer the selected fuel assemblies from their storage location to the SSSC without damaging the fuel. All operations within and outside the fuel building will be conducted in a manner that does not jeopardize the safe operation of the Surry Power Station, does not present a hazard to the stored fuel, and does not result in releases of radioactive gases in excess of the guidelines in 10 CFR Part 100.

Performance objectives for the post-loading activities are to ensure that the casks can fulfill all of their design functions, and in particular that the casks will confine the radioactive products under all credible conditions.

Cask transfer and emplacement operations will be performed according to procedures which will ensure that the design criteria are not exceeded, and that the safety of the Surry Power Station is not impaired.

4.2.3.2 Components

A description of the components used for loading, preparing, and handling the SSSCs is provided in Chapter 5.

4.2.3.3 Design Bases and Safety Assurance

The ability of the SSSCs to perform their design function is demonstrated in the SSSC topical reports or Appendix A .

Loading and handling of the casks will be done according to the applicable procedures.

As described in Chapter 8, the design and operation of the Surry ISFSI ensure that a single failure does not result in the release of significant radioactive material.

The interactions between the ISFSI and the Surry Power Station are primarily those concerning the loading and handling of the casks in the fuel handling and decontamination buildings. These are discussed in Chapter 5.

Radiation protection of operating personnel is addressed in Chapter 7.

Nuclear criticality safety for the SSSCs is addressed in the SSSC topical reports or Appendix A.

4.2.4 References

1. *BOCA Basic Building Code,* Building Officials and Code Administrations International, Inc., 1981.
2. *Building Code Requirements for Reinforced Concrete,* American Concrete Institute, ACI 318-77, and 1980 Supplement and Commentary.
3. *Manual of Standard Practice for Detailing Reinforced Concrete Structures,* American Concrete Institute, ACI 315-74.

Table 4.2-1
COMPLIANCE WITH GENERAL DESIGN CRITERIA
(SUBPART F, 10 CFR PART 72)

§72.122	(a)	Quality standards	The design criteria require that the SSSCs be designed, fabricated, delivered to the site, and sealed according to recognized commercial codes and standards and in accordance with Vepco's QA program for safety-related equipment
	(b)	Protection against environmental conditions and natural phenomena	Extreme environmental conditions are defined in Chapter 2. The design criteria require that the SSSCs be designed to withstand the Design Earthquake, high ambient temperature and humidity, exposure to sunlight, and extreme winds.
	(c)	Protection against fire and explosions	No large fire within the Surry ISFSI is considered credible. The design criteria require that SSSCs be designed to withstand extreme ambient temperatures and peak overpressure resulting from postulated nearby explosions.
	(d)	Sharing of structures, systems, and components	The ISFSI activities will be done without jeopardizing the safe shutdown capability of the Surry Power Station Units 1 and 2.
	(e)	Proximity of sites	The design and operation of the Surry ISFSI result in minimal additions of risk to the health and safety of the public.
	(f)	Testing and maintenance of systems and component	The SSSCs require minimum maintenance. The design criteria require that the SSSCs be capable of being inspected and monitored.
	(g)	Emergency capability	Scenarios requiring emergency actions are neither considered credible, nor postulated to occur. Nevertheless, all emergency facilities at the Surry Power Station would be available if needed
	(h)	Confinement barriers and systems	The design of the SSSCs will ensure that the stored fuel is maintained in a safe condition. No paths for radioactive releases are considered credible. Therefore, no ventilation or offgas systems are needed.

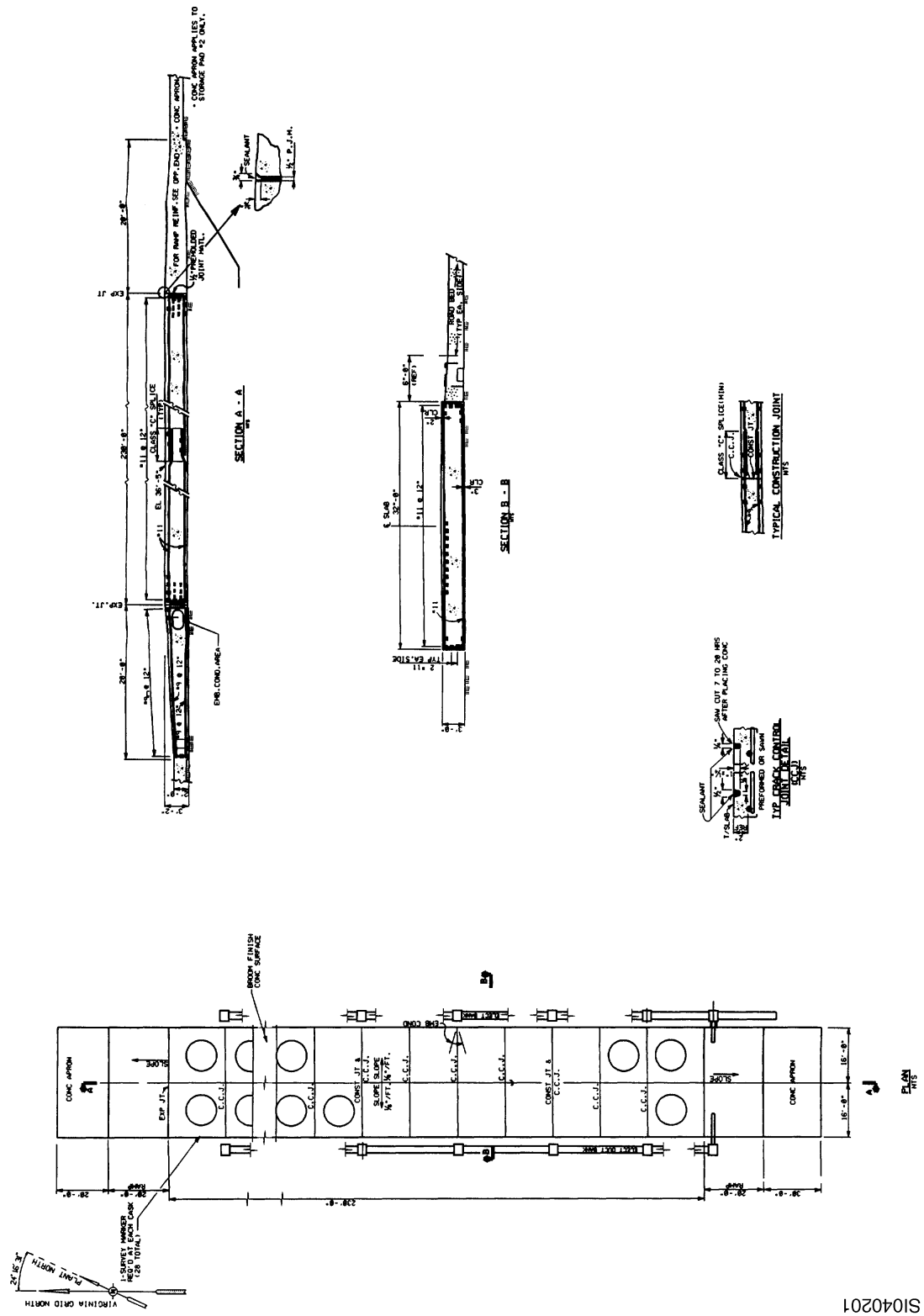
Table 4.2-1 (continued)
COMPLIANCE WITH GENERAL DESIGN CRITERIA
(SUBPART F, 10 CFR PART 72)

	(i)	Instrumentation and control systems	No instrumentation or control systems are needed for the SSSCs to perform their safety functions. Nevertheless, some monitors and alarms will be provided.
	(j)	Control room or control areas	The Surry ISFSI is a passive installation, with no need for operator actions. Thus, no control room is needed.
	(k)	Utility services	The SSSCs are the only safety-related components at the Surry ISFSI. There are no utility or emergency systems required to perform any safety functions at the Surry ISFSI.
§72.124	(a)	Design for criticality safety	The design criteria require that the SSSCs be designed to maintain subcriticality at all times, assuming a single active or credible passive failure.
	(b)	Methods of criticality control	Different SSSC designs may use different methods of criticality control. However, all designs use conservative analyses and specified error contingency criteria.
§72.126	(a)	Exposure control	Operations at the Surry ISFSI will be done according to ALARA procedures. Minimal maintenance operations are needed following SSSC emplacement at the ISFSI. SSSC loading, sealing, decontamination, and preparation are done at the fuel and decontamination buildings according to health physics procedures in effect for the Surry Power Station.
	(b)	Radiological alarm systems	No radioactive releases are considered credible at the Surry ISFSI. No safety-related alarm systems are needed.
	(c)	Effluent and direct radiation monitoring	Operation of the Surry ISFSI does not result in radioactive contamination of any effluents. No safety-related monitors are needed. Direct radiation monitors will be installed around the ISFSI.

Table 4.2-1 (continued)
COMPLIANCE WITH GENERAL DESIGN CRITERIA
(SUBPART F, 10 CFR PART 72)

	(d)	Effluent control	No radioactive releases are considered credible at the Surry ISFSI.
§72.128	(a)	Spent fuel and radioactive waste storage and handling systems	The design criteria require that the SSSCs have adequate provisions to monitor the SSSC performance, provide sufficient shielding to lower surface doses to below prescribed levels, maintain leak tightness under all operating and credible conditions, and maintain fuel in a safe condition. Only minimal amounts of radioactive waste are generated in the decontamination of the casks.
	(b)	Waste treatment	Radioactive wastes generated in the decontamination of the SSSCs are processed by the Surry Power Station waste processing systems.
§72.130		Decommissioning	Operation of the Surry ISFSI does not result in contamination of the outside surface of the SSSCs or any other ISFSI components. Therefore, there is no need for provisions to facilitate decommissioning.

Figure 4.2-1
CONCRETE BASE MAP



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4.3 AUXILIARY SYSTEMS

The Surry ISFSI does not rely upon auxiliary systems for the performance of its safety functions. No safety-related auxiliary systems are required, and none are provided.

4.3.1 Ventilation and Offgas Systems

Ventilation and offgas systems are not required for the Surry ISFSI and none are provided.

Ventilation is not needed because the ISFSI design features the SSSC array in an open arrangement which allows cooling to take place by natural heat convection. Hence, no forced ventilation is needed.

Offgas systems are not required because the casks are double sealed, and there are no credible scenarios that could result in radioactive releases.

4.3.1.1 Major Components and Operating Characteristics

This subsection does not apply to the Surry ISFSI for reasons stated in Section 4.3.1.

4.3.2 Electrical Systems

Electric power is not required to support functions of the Surry ISFSI important to safety. A discussion of power for security equipment is provided in the Security Program (Reference 1).

Nonsafety-related electric power is supplied to the ISFSI for purposes of lighting, general utility, and instrumentation with which cask seal integrity is monitored. Cask temperature may also be monitored, depending on specific cask design. These functions are supportive in nature, and are not needed for effective SSSC function.

4.3.2.1 Major Components and Operating Characteristics

The source of electric power is obtained from a 34.5/0.48 kV transformer which also feeds the low level waste storage facility. The 34.5 kV line is normally fed from an offsite power source, but can be manually transferred to the station switchyard. The low level waste storage facility transformer provides power to ISFSI loads through a separate feeder and disconnect and distribution panel which are located near the ISFSI local annunciator. This distribution panel will provide feed to loads for all three pads. Service power for lighting and welding receptacles is 480V, 60 Hz, single or three phase.

4.3.2.2 Safety Considerations and Controls

Since only the casks are important to safety and since the casks do not require electric power to perform their functions, loss of electricity will not jeopardize the safety of the facility.

The ISFSI is a passive installation. There are no operations to control, no motorized fans, dampers, louvers, or valves, and no electrically operated cranes or lifts. Electricity is required only for monitoring equipment and convenience lighting. A power loss will result in no more than

a temporary loss of data. This is not considered of major significance because there are no conditions under which the parameters monitored will change abruptly.

4.3.3 Air Supply Systems

Since there are no airborne contaminants associated with the ISFSI, neither compressed air nor breathing air supply systems are required or provided.

4.3.3.1 Compressed Air

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.3.

4.3.3.2 Breathing Air

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.3.

4.3.4 Steam Supply and Distribution System

Steam is not required at the Surry ISFSI, and none is provided, because the SSSCs do not require steam for heat, motive power, or any other reasons. No other feature of the ISFSI requires steam.

4.3.4.1 Major Components and Operating Characteristics

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.4.

4.3.4.2 Safety Considerations and Controls

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.4.

4.3.5 Water Supply System

Water is not required at the Surry ISFSI, and none is provided because the SSSCs do not require a continuous water supply for cooling, makeup, cleaning, or any other reason.

Potable water is not required because the ISFSI is only manned on an infrequent basis by a small number of people during cask handling operations and inspections.

Cask washdown is not done while the casks are stored at the ISFSI.

Decontamination of the casks takes place at the Surry Power Station decontamination building prior to their transfer to the ISFSI.

Fire suppression water is not required because no large credible fire exists.

4.3.5.1 Major Components and Operating Characteristics

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.5.

4.3.5.2 **Safety Considerations and Controls**

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.5.

4.3.6 Sewage Treatment System

Neither sanitary nor chemical sewage is produced at the Surry ISFSI. During the infrequent periods of manning for cask transfer operation, portable sanitary facilities may be provided in the vicinity of but not directly in the ISFSI. Chemical wastes, such as small amounts of ethylene glycol (antifreeze) or drips of lubricating fluid from transport vehicles could be cleaned up manually and disposed of at appropriate facilities of the Surry Power Station. No permanent sewage treatment system is required or provided.

4.3.6.1 **Sanitary Sewage**

This section does not apply to the Surry ISFSI for reasons stated in 4.3.6.

4.3.6.2 **Chemical Sewage**

This section does not apply to the Surry ISFSI for reasons stated in 4.3.6.

4.3.7 Communication and Alarm Systems

4.3.7.1 **Major Components and Operating Characteristics**

The ISFSI is not manned on a continuous basis. Some SSSCs will be provided with a pressure sensing device to monitor their seal tightness. Some casks may also be monitored for temperature. This instrumentation is not required for safe operation of the ISFSI and therefore will not be safety related.

The monitoring devices will actuate a pressure or temperature switch, as applicable, at a preset alarm level. Specific recommendations for monitoring the casks are provided in SSSC topical reports. Each of the cask alarms (maximum of two per cask) will initiate an annunciator lamp in the local annunciator at the ISFSI. The alarm point will indicate the specific cask and parameter in question and will remain lit until reset.

In addition, the initiation of any alarm will energize a flashing light visible to personnel doing Surry site monitoring.

4.3.7.2 **Safety Considerations and Controls**

Degradation of an SSSC primary seal is considered extremely unlikely. Nevertheless, in the event that this were to occur, the pressure sensor would activate an alarm.

Upon identification of the affected SSSC, a series of actions identified in the ISFSI procedures will be taken. Depending on the exact circumstances, these may include monitoring the cask pressure with a time recorder in order to ascertain whether the failure is a progressing one, and checking for possible instrumentation failure. If a failure of a seal is ascertained,

arrangements will be made to fix the cask in place, to transfer the cask to the fuel building for repair work, if necessary, or any other action recommended by the manufacturer and included in the Surry ISFSI operating procedures.

It should be remembered that the hypothesized seal failure addressed in this section would not result in radioactive releases because of the double-seal nature of the SSSCs.

The ISFSI operating procedures will be prepared to provide step-by-step actions to be taken for all kinds of alarms. These will be prepared according to the specific SSSC manufacturers' designs and recommendations.

4.3.8 Fire Protection System

As described in Section 8.2.5, no fires other than small electrical fires are considered credible at the Surry ISFSI, and separation has been provided for security-related equipment.

Therefore, the Surry ISFSI does not include a fire protection system, other than portable fire extinguishers which will be available within the ISFSI. In addition, the fire fighting equipment and personnel present at the Surry Power Station would be available if needed.

4.3.8.1 Design Bases

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.8.

4.3.8.2 System Description

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.8.

4.3.8.3 System Evaluation

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.8.

4.3.8.4 Inspection and Testing Requirements

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.8.

4.3.8.5 Personnel Qualification and Traininq

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.8.

4.3.9 Maintenance Systems

Major maintenance operations are not required at the Surry ISFSI. Cask design features have been included to minimize or eliminate maintenance. The SSSCs are either coated with a polymer protection or are made of corrosion-resistant material such as stainless steel. Other equipment, instrumentation, etc., will be specified and selected to withstand the effects of the environment at the site. Specific maintenance recommendations for the casks are provided in the SSSC topical reports.

The Surry ISFSI does not include active components such as remotely operated equipment or hot cells, nor is an active ventilation system required or provided.

Fuel stored in the Surry ISFSI will be in its original unconsolidated form. Handling of the fuel and cask loading will be done with systems and equipment that are presently in use for this or equivalent purposes in the Surry fuel building. Since cask loading does not present unique or new handling procedures, extraordinary equipment contamination is not expected. Hence, the need for disposal of contaminated equipment is not expected.

4.3.9.1 Major Components and Operating Characteristics

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.9.

4.3.9.2 Safety Consideration and Controls

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.9.

4.3.10 Cold Chemical Systems

No chemical operations are required for the Surry ISFSI, and no chemical storage, handling, process, or other system involving chemical reactions are planned or provided.

Cask designs featuring liquid neutron shields typically use a mixture of water and ethylene glycol (a common antifreeze) in the shield volume. Ethylene glycol is not a hazardous chemical when used for the purpose stated.

New casks may be shipped under an internal nitrogen (or other inert gas) blanket and may employ desiccants such as silica-gel. These materials are not hazardous when used for this purpose.

4.3.11 Air Sampling Systems

Air sampling systems are not required at the Surry ISFSI as discussed in Section 3.3.2.1.

4.3.11.1 Major Components and Operating Characteristics

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.11.

4.3.11.2 Safety Considerations and Controls

This section does not apply to the Surry ISFSI for reasons stated in Section 4.3.11.

4.3.12 Reference

1. North Anna Power Station Units 1 and 2, Surry Power Station Units 1 and 2, and Independent Spent Fuel Storage Installations Physical Security Plan.

4.4 DECONTAMINATION SYSTEMS

There are no credible mechanisms which could result in contamination of the outside surface of the SSSCs, other ISFSI components, or operating personnel, after the casks leave the fuel building. Therefore, the Surry ISFSI does not include provisions for decontamination.

Decontamination of the casks after they have been loaded is done within the decontamination building of the Surry Power Station, as described in Chapters 5 and 6.

4.4.1 Equipment Decontamination

This section does not apply to the Surry ISFSI for reasons stated in Section 4.4.

4.4.1.1 Major Components and Operating Characteristics

This section does not apply to the Surry ISFSI for reasons stated in Section 4.4.

4.4.1.2 Safety Considerations and Controls

This section does not apply to the Surry ISFSI for reasons stated in Section 4.4.

4.4.2 Personnel Decontamination

This section does not apply to the Surry ISFSI for reasons stated in Section 4.4.

4.5 SHIPPING CASK REPAIR AND MAINTENANCE

Incidental mechanical operations involving the storage casks include receiving of the new casks from the supplier, their temporary (empty) storage, and transfer to the fuel building. During these operations, the casks will be inspected in detail and abnormalities corrected. The facilities and machine shops of the Surry Power Station will be made available in the event repair operations become necessary.

No repair operations are anticipated once the casks are placed into storage. Periodic maintenance is not required beyond instrument adjustments and other similar evolutions of a minor nature, such as touching up defects in outer decontamination coatings. These can all be performed within the ISFSI area, without need to move the SSSCs.

4.6 CATHODIC PROTECTION

In general, cathodic protection is not required for the SSSCs since the surrounding medium for the SSSC is air which is a poor electrolyte. Hence, protection from electrolytic decomposition of the SSSCs is not required. See the SSSC topical reports for discussions of provisions for cathodic protection systems.

4.7 FUEL HANDLING OPERATION SYSTEMS

There are no fuel handling facilities exclusively dedicated to the Surry ISFSI. Loading, preparation, decontamination, and testing of the SSSCs take place within the fuel and

decontamination buildings of the Surry Power Station. These operations are described in detail in Chapter 5.

4.7.1 Structural Specifications

This section does not apply to the Surry ISFSI for reasons stated in Section 4.7.

4.7.2 Installation Layout

This section does not apply to the Surry ISFSI for reasons stated in Section 4.7.

4.7.3 Individual Unit Description

This section does not apply to the Surry ISFSI for reasons stated in Section 4.7.

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Chapter 5
OPERATIONS SYSTEMS

This chapter describes the operations associated with the Surry ISFSI. As indicated in previous chapters, the Surry ISFSI is a totally passive installation, requiring no actions or maintenance for its proper functioning. The operations described in this chapter relate to the loading and preparation of the SSSCs and their transfer to the ISFSI.

5.1 OPERATIONS DESCRIPTION

5.1.1 Narrative Description

The loading and preparation of the SSSCs take place within the Surry Power Station fuel and decontamination buildings. These operations are essentially those which are followed for the loading of fuel into shipping casks, as described in Section 9.12 of the Surry Power Station FSAR.

A Technical Specification change request (Reference 1) to the Surry Power Station Units 1 and 2 operating license addressed the handling of the SSSCs within the fuel and decontamination buildings. As concluded in the NRC's Safety Evaluation (Reference 2), these operations are conducted in a manner that ensures that the capability to safely operate the power station is not jeopardized. Specifically, the consequences of a postulated cask drop have been evaluated and have been determined to meet the guidelines of NUREG-0612, Section 5.1 (Reference 3).

Following loading and decontamination, the SSSCs are moved to the crane enclosure where they are picked up by the transporter that transfers them to the ISFSI. The path followed by the transporter from the decontamination building to the ISFSI is shown on Figure 5.1-1. This figure also shows the location of all nearby systems and structures needed for the safe shutdown of the power station. Drop of an SSSC while in transit to the ISFSI will not result in damage to any of these systems and structures, nor in radioactive releases in excess of the guidelines in 10 CFR Part 100.

The transfer path shown on Figure 5.1-1 is a compacted gravel road capable of holding the transporter and SSSC. Other heavy equipment, including the replaced steam generators, has been moved along this road. The road is maintained clear of obstacles.

As indicated in Section 3.3.1, the design criteria require that the SSSCs maintain their integrity, preclude physical damage to the fuel, and ensure subcriticality following a cask drop onto ISFSI pad. Operating procedures will limit the lifting heights once the casks are placed onto the transporter.

Therefore, none of the operations needed to emplace the SSSCs at the Surry ISFSI will result in unacceptable damage to the Surry Power Station Units 1 and 2, or to the stored spent fuel.

5.1.2 Flowsheets

Table 5.1-1 shows a typical sequence of operations performed before the SSSCs are placed on their storage position at the ISFSI. Operations more specific to a particular vendor's casks are outlined in the vendor's SSSC topical report.

These operations are performed in accordance with procedures addressing health physics and handling of the SSSCs. They also fulfill the surveillance requirements specified in Chapter 10.

Wastes resulting from the decontamination process are handled by the Surry Power Station radioactive waste disposal systems, as described in Section 6.3.2.1.

Descriptions of equipment used in these operations are provided in Section 5.2.

5.1.3 Identification of Subjects for Safety Analysis

5.1.3.1 Criticality Prevention

The design criteria specified in Section 3.3.4 require that spent fuel stored at the Surry ISFSI be maintained subcritical at all times. The specific means by which the casks comply with this criterion are described in the SSSC topical reports or Appendix A.

5.1.3.2 Chemical Safety

Section 2.2 describes the hazardous chemicals stored at, or transported in the vicinity of, the Surry site and their potential effects on the safety of the ISFSI. As a result of these hazards, a design criterion regarding overpressure protection has been placed on the SSSCs.

The Surry ISFSI does not require operator actions for its safe operation and is not continuously manned. Therefore, the presence of chemicals in the vicinity of the Surry ISFSI does not result in an undue risk to the safe storage of spent fuel.

5.1.3.3 Operation Shutdown Modes

The Surry ISFSI is a totally passive installation with no actions needed for the fulfillment of its safety functions. Thus, this section is not applicable.

5.1.3.4 Instrumentation

Due to the totally passive and inherently safe nature of the SSSCs, there is no need for any instrumentation to perform safety functions. Nevertheless, it may be desirable to monitor the performance of some or all of the SSSCs. Accordingly, the design criteria described in Section 3.3.3.2 require that the SSSCs have adequate provisions for the installation, testing, and calibration of monitors.

The parameters to be monitored will be selected based on recommendations made by the SSSC manufacturers, experience gained with specific SSSC designs, and other engineering and

health physics considerations. Instrumentation provisions for the casks are described in the SSSC topical reports.

Although these instruments are not safety related, commitments for their installation, inspection, and calibration and replacement, if needed, are proposed in Section 10.9.

Actions to be taken when monitored parameters exceed preset levels are described in Section 4.3.7.

5.1.3.5 **Maintenance Techniques**

Because of their passive nature, the SSSCs require little, if any, maintenance over the lifetime of the ISFSI. No major maintenance tasks are required. Typical maintenance tasks would involve occasional replacement and recalibration of monitoring instrumentation and recoating of some casks with corrosion-inhibiting coatings. No special maintenance techniques are necessary.

Specific maintenance recommendations for the casks are provided in the SSSC topical reports.

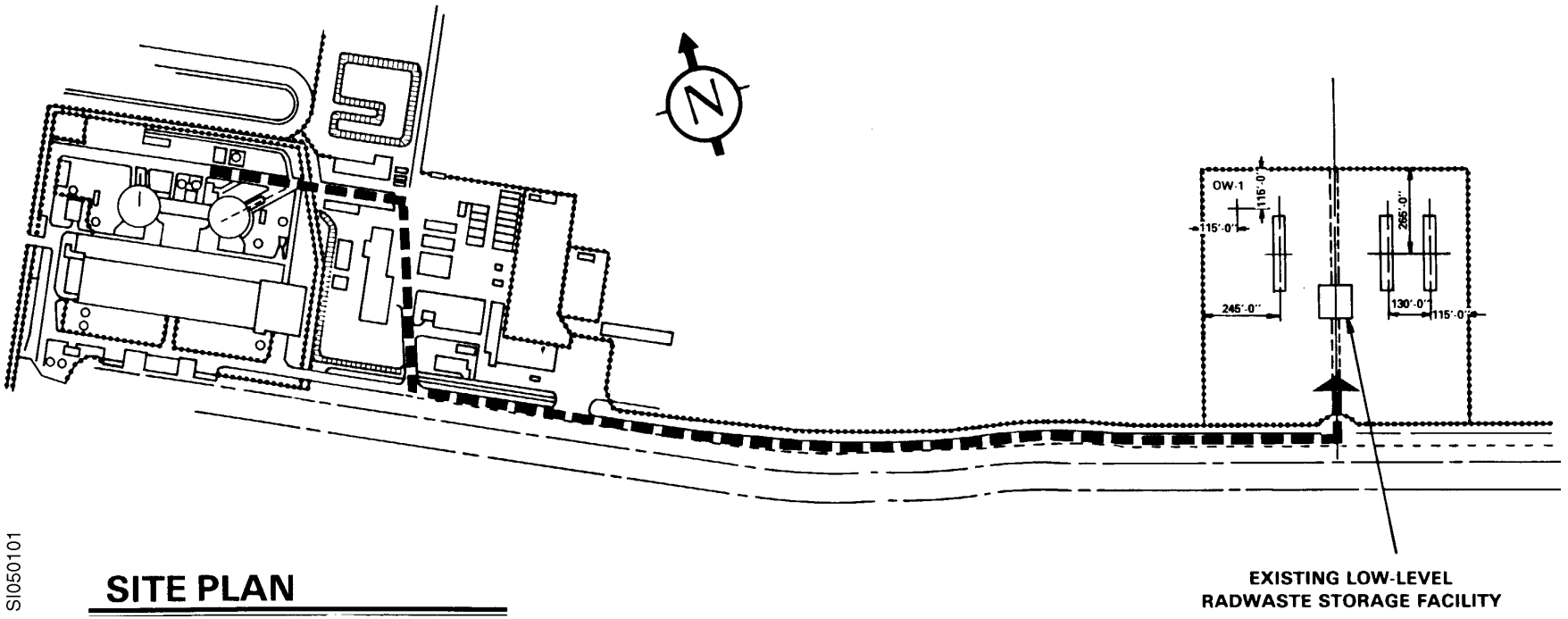
5.1.4 References

1. Letter No. 543 from R. H. Leesburg to Harold Denton, *Amendment to Operating Licenses DPR 32 and 37, Surry Power Station Units 1 and 2, Proposed Technical Specification Changes*, September 23, 1982.
2. NRC Safety Evaluation, Amendment Nos. 84 and 85 (Serial No. 131) to Facility Operating License Nos. DPR-32 and DPR-37, March 4, 1983.
3. NUREG-0612, *Control of Heavy Loads at Nuclear Power Plants*, July 1980.

Table 5.1-1
TYPICAL SEQUENCE OF OPERATIONS

1. Unload empty SSSC outside decontamination building using fuel cask trolley.
2. Move SSSC inside decontamination building.
3. Perform visual inspection of seals.
4. Move SSSC to fuel building.
5. Lower SSSC into the spent fuel pool cask loading area.
6. Load SSSC with preselected spent fuel assemblies using spent fuel handling crane.
7. Reconfirm inventory of fuel assemblies loaded into SSSC.
8. Place primary lid on SSSC.
9. Dewater cask.
10. Lift SSSC out of spent fuel pool.
11. Wash down exterior.
12. Move SSSC to decontamination building.
13. Decontaminate outside surface of SSSC.
14. Secure primary lid or place secondary lid, as applicable.
15. Dry cask and contents.
16. Perform radiation measurements.
17. Install thermocouples or other instrumentation, as applicable.
18. Pressurize SSSC and test seals (If applicable, place secondary lid, pressurize, and test seals).
19. Move cask to crane enclosure.
20. Load SSSC on transporter.
21. Transfer to ISFSI.
22. Perform radiation measurements.
23. Connect appropriate instrumentation.

Figure 5.1-1
TRANSFER PATH



5.2 FUEL HANDLING SYSTEMS

5.2.1 Spent Fuel Receipt, Handling, and Transfer

The equipment associated with the receipt, handling, and transfer of the SSSCs (and its associated spent fuel) is described below:

1. The casks are handled in the fuel building by the fuel cask trolley crane. The crane runs on fixed rails and has a capacity of 125 tons. The rails span the east end of the spent fuel pool where the cask loading area is located and pass over the decontamination building to the roadway where the cask will be loaded onto the cask transporter.
2. The fuel handling crane is used to load the spent fuel assemblies into the cask.
3. The fuel cask trolley crane transfers the sealed casks from the fuel pool to the decontamination building and to the crane enclosure.
4. A cask transporter will be used to transfer the SSSC from the crane enclosure to the ISFSI. This transporter is an A-frame design which carries the cask in a vertical orientation. It is about 14 feet wide, 21 feet long, and 25 feet high, and it weighs approximately 56,000 pounds. It has a tow bar pivot and four steerable wheels as well as four fixed wheels with foam filled pneumatic tires to ensure maximum stability, maneuverability, and even-load distribution. A haul vehicle will be used to pull the transporter and cask.
5. The transporter is equipped with hydraulic lift cylinders which will be used to place the casks into storage at the ISFSI. A similar procedure would be used in reverse when the cask is shipped off site for final disposition.

The cask is cooled by convective and radiant heat transfer, and as described in Chapter 4, no forced cooling is required or provided.

Provisions for maintaining the fuel assemblies in a subcritical array are described in Section 5.1.3.1.

Provisions for shielding the fuel assemblies are described in Sections 4.2 and 7.3.

5.2.1.1 **Functional Description**

A functional description of the systems used to load and transport the storage casks is given in Section 5.2.1. A flow diagram of this process is shown in Table 5.1-1. No defective fuel needing special handling provisions will be placed in the storage casks.

5.2.1.2 **Safety Features**

Handling of fuel is done according to procedures in effect for the Surry Power Station, as summarized in Section 5.2.1. The proper use of this equipment limits the possibility of mishandling the fuel.

The fuel handling crane handles the spent fuel under the protective cover of the spent fuel pool water. The effects of any mishandling of the fuel, such as a fuel handling accident, is discussed in Section 8.2.6.

The cask transporter is used on a graded road (shown on Figure 5.1-1) which limits the possibility of dropping the cask. The transporter is also equipped with hydraulic lift links and a hydraulically actuated restraint system to help prevent the cask from dropping. Even if the cask should drop from the transporter, it could only drop the maximum lift height allowed by the Technical Specifications. This drop would not damage the cask nor its contents, and would not result in any radioactive releases.

5.2.2 Spent Fuel Storage

All handling of the fuel and the SSSCs within the fuel and decontamination buildings is done according to the procedures in effect at the Surry Power Station.

After the loading is completed, a final verification of the fuel assemblies loaded into the cask will be performed. The primary lid will then be put into place, and the SSSC lifted out of the spent fuel pool to be dewatered.

The cask trolley crane then moves the casks to the decontamination building where they are dried. Here the secondary lid, if applicable, is placed and the casks are sealed and decontaminated. The cask trolley crane then moves the casks out of the decontamination building and places them in the crane enclosure for pickup by the transporter.

The transporter is pulled to the cask storage location by a haul vehicle. The transporter then unloads the cask and places it in its storage position.

Once the cask is in its storage position, the cask monitoring instrumentation is connected. This is described in Sections 5.1.3.4 and 5.4.1.

5.2.2.1 Safety Features

The safety of the Surry ISFSI resides mainly in the multiple-barrier confinement function provided by the SSSCs and the lack of active components needed for their safety functions. In addition, the design criteria specified in Chapter 3 ensure that these safety functions are not jeopardized by possible hazardous conditions to which the SSSCs may be exposed; e.g., natural phenomema, or by postulated accidents.

The casks are designed to withstand potential conditions experienced during normal or off-normal handling as described in Sections 3.3 and 5.2. Operating procedures, where necessary, will ensure that the casks are handled within these limits. The transporter equipment, utilized in the handling of casks, was selected based on adequacy for the operations to be performed and was verified in writing to be in compliance with all applicable codes and standards prior to cask handling operations. This was established by prior engineering review of the entire movement and documented in formal procedures. Adequate supervision, engineering, and health physics

coverage will be provided to ensure that the equipment is used properly and that prewritten operating procedures are followed. These procedures will include:

1. Location and stable position on the transporter (number, type, location, and strength requirements of attachments)
2. Maximum speed of the transporter
3. Required plant support groups to be present during the move
4. Organization chart of responsible parties
5. Defined haul path
6. Allowable environment limits (high wind, etc.)
7. Maximum height above surface(s) which may be employed during all cask motions
8. Reference to proper positioning, lowering, and leveling procedures through load release
9. Check lists required for all milestone points throughout move
10. An emergency list of requirements for a dropped cask will be developed, including those described in Section 8.2.10.

These would be applicable for movement from the plant to the ISFSI, for movements of casks(s) within the ISFSI, or return trips from the ISFSI to the plant. During transport, it is not envisioned necessary but would be acceptable to stop the transporter and/or rest the cask on the ground for a short time (e.g., a day). These contingencies and associated actions such as temporary security, health physic coverage, cleaning, etc. will be included in the procedures. Therefore, no physical devices are required for the handling equipment to limit impact loads or lifts.

5.3 OTHER OPERATING SYSTEMS

5.3.1 Operating System

The SSSC is the only operating system pertinent to this section.

5.3.1.1 Functional Description

A functional description of the SSSC is provided in Section 1.3.

5.3.1.2 Major Components

The SSSCs are the only safety-related components at the Surry ISFSI.

5.3.1.3 Design Description

The Surry ISFSI uses sealed and shielded casks to hold the PWR spent fuel assemblies. The cask designs are described in Appendix A.

The ALARA aspects of the Surry ISFSI operation are discussed in Chapter 7.

5.3.1.4 Safety Criteria and Ensurance

The Surry ISFSI, constructed, operated, and maintained as described in this SAR, is a safe and secure method for interim storage of spent fuel.

Design criteria which the SSSCs must meet are specified in Chapter 3. Compliance with these criteria ensure that operation of the Surry ISFSI will be in accordance with all the applicable safety requirements in 10 CFR Part 72. As shown in Chapters 7 and 8, its operation and response to credible events and postulated hypothetical accidents will not result in unacceptable risks to the health and safety of the public.

5.3.1.5 Operating Limits

Proposed operating limits for the Surry ISFSI are described in Chapter 10. Compliance with these limits will ensure that the design criteria specified in Chapter 3 and the safety assessments in this SAR are met.

5.3.2 Component/Equipment Spares

The cask monitoring instrumentation will be inspected and tested periodically in accordance with the commitments in Chapter 10 to ensure their proper operation. Replacement instrumentation will be available in accordance with historical requirements of the type of components used.

5.4 OPERATION SUPPORT SYSTEMS

There are no chemical systems used to monitor or control any of the ISFSI functions.

5.4.1 Instrumentation and Control Systems

There are no instrumentation and control systems necessary for the safe operation of the Surry ISFSI. Nonsafety instrumentation and alarms are described in Sections 4.3.7 and 5.1.3.4.

5.4.2 System and Component Spares

As indicated in previous sections, there is no safety-related instrumentation at the Surry ISFSI.

Failure of any of the monitoring equipment provided does not have any effects on cask integrity or the safe storage of the fuel.

5.5 CONTROL ROOM AND/OR CONTROL AREAS

Local panels at the ISFSI site provide annunciator alarm which would indicate the specific parameter and cask in question. Provisions have been made to allow for two alarms per cask.

The Surry ISFSI does not require continuous surveillance or operator actions, even during postulated accidents. Therefore, a control room is not considered necessary.

Coordination and supervision of emplacement operations take place in the area surrounding the SSSC, on the handling mechanism, and on any other equipment in use. Appropriate portable communications and radiation monitoring equipment will be used at those times.

5.6 ANALYTICAL SAMPLING

Neither radioactive releases during normal operation nor events resulting in radioactive releases are considered credible. Therefore, no means exist for the contamination of the outside surface of the casks.

Chapter 6
WASTE CONFINEMENT AND MANAGEMENT

6.1 WASTE SOURCES

No radioactive wastes are generated during the storage of spent fuel in a dry cask. However, since there may be some surface contamination deposited on the casks during fuel loading in the spent fuel pool, this contamination would have to be removed prior to placing the casks in storage. This contamination would consist of impurities typically found in the spent fuel pool water.

To remove this contamination, the cask will be washed down with water over the spent fuel pool before moving it to the decontamination building. Any residual contamination will be removed in the decontamination building in a manner similar to the design processes for smaller casks used for shipping fuel. The resulting contaminated water will be piped to the existing liquid waste disposal system and processed as described in Section 6.3.

The liquid waste generated is estimated to be less than 100 gallons per cask. Since the existing system is sized to process more than 8 million gallons of letdown annually from the primary system, it is seen that this is a negligible increase in the volume of waste processed by the Surry Power Station.

The liquid wastes from the Surry Power Station are either processed and discharged or dewatered and shipped for offsite disposal in high integrity containers. The contribution to these wastes from the cask decontamination process is expected to be negligible. The solid waste such as scrubbing towels from decontamination is estimated to fill less than two 55-gallon drums per cask.

6.2 OFFGAS TREATMENT AND VENTILATION

As discussed in Section 4.3.1, ventilation and offgas treatment systems are not required for the Surry ISFSI, and none are provided. Hence, there is no radioactive waste from items such as filters or scrubbers which would need to be treated.

However, as described in Sections 9.13 and 9.14 of the Surry Power Station FSAR, ventilation systems are provided for the fuel handling and decontamination buildings where cask loading and decontamination processes take place. Ventilation air from these buildings may be exhausted through filter banks consisting of roughing, particulate, and charcoal filters in series. Since the loading and decontamination of the SSSCs entail operations similar to the operations for which these ventilation systems were designed, these operations produce no new types of radwaste. Hence, these filters, when replaced, will continue to be handled using the procedures discussed in Section 11.2.4.1.2 of the Surry Power Station FSAR.

6.3 LIQUID WASTE TREATMENT AND RETENTION

As stated in Section 6.1, no liquid waste is generated while the casks are in storage; however, some liquid waste is generated during the cask decontamination process. This waste consists of water contaminated with fission and activation products typically found in the existing spent fuel pool. It is of the same composition and quality as the waste for which the existing Surry Power Station liquid waste disposal system is designed, and is generated in a manner similar to that planned for when the existing system was designed. Hence, this waste will be treated by the existing system as described in Section 11.2.3 of the Surry Power Station FSAR.

6.3.1 Design Objectives

As stated in Section 11.2.2 of the Surry Power Station FSAR, the waste disposal system is designed to satisfy the discharge requirements of 10 CFR Part 20 and 10 CFR Part 100 so as not to endanger the health of station operating personnel.

To ensure that processes associated with waste disposal meet the above design objectives, sampling, analysis, and monitoring of the liquid waste disposal system is done. Shielding is provided to reduce radiation levels, and area radiation monitoring equipment, health physics facilities, environmental programs, and administrative controls are provided for surveillance and control of radiation and exposure levels.

6.3.2 Equipment and System Description

The equipment and systems used to handle and process the contaminated water from the cask decontamination process are part of the decontamination building and the liquid waste disposal system and are summarized in the following sections.

6.3.2.1 Decontamination Building

The decontamination building abuts the east end of the fuel building’s north wall. The 125-ton cask handling trolley transfers the cask from the fuel building to the decontamination building. Once inside the decontamination building, the cask is lowered onto the pad where decontamination takes place. Decontamination is performed using the same equipment and processes already provided in the decontamination building for the similar, but smaller, shipping casks for which the building and equipment were designed, as shown in Section 9.14.2 of the Surry Power Station FSAR. Typically, this would involve washing down the casks with water and scrubbing as necessary. A contaminated solution holdup tank is provided to receive spillage from equipment, runoff from cleaning operations, and for the disposal of cleaning solutions. This tank has a pump for transferring liquid to the liquid waste disposal system.

6.3.2.2 **Liquid Waste Disposal System**

The liquid waste disposal system is used to process the contaminated water generated as a result of the cask decontamination process. As described in Section 11.2.3 of the Surry Power Station FSAR, the liquid waste disposal system may use the following processes:

1. Filtration of the waste to remove particulate matter.
2. Demineralization, to remove dissolved material.
3. Dilution, to reduce the concentration of the radioactive constituents of the waste.
4. Decay, to reduce the activity levels of the isotopes.

Since the existing system was designed to handle the wastes due to contamination of similar, although smaller, spent fuel casks, no additional processes are necessary to handle the SSSCs.

6.3.3 Operating Procedures

The cask decontamination process involves the following procedures:

1. Lower cask into position in the decontamination building.
2. Decontaminate as explained in Section 6.3.2.1.
3. Take a swipe sample of the exterior cask surface to check for contamination.
4. Count swipe sample.
5. If swipe sample shows contamination above level specified in applicable procedures, decontaminate.
6. Take a second swipe sample and count.
7. Repeat above process until specified contamination limits are met.

According to current health physics procedures for the Surry Power Station, no further decontamination is needed when the count rate of the swipe sample is less than or equal to 1,000 dis/min/100 cm^2. Requiring the casks to be decontaminated to this initial level provides assurance that, over the lifetime of the cask in storage, the contamination levels of 49 CFR 173.443 will not be exceeded.

As described in Section 9.14.3.1 of the Surry Power Station FSAR, in the event of an off-normal condition, such as leakage from piping or equipment, all areas of the decontamination building are provided with sumps to which fluids will drain. The sumps discharge to the liquid waste disposal system.

Airborne particulate matter is retained within the building because of the slightly subatmospheric pressure and is discharged in a controlled manner through the monitored ventilation vent.

6.3.4 Characteristics, Concentrations, and Volumes of Solidified Wastes

The design of the Surry Power Station assumed that there would be frequent processing and offsite shipment of spent fuel using casks similar to, although smaller than, the SSSCs. Since the surface area of an SSSC is smaller than the combined surface area of the number of smaller casks needed to transport the same amount of fuel, it is expected that the wastes generated during the cask SSSC decontamination process would be significantly smaller than the amount for which the station was designed and licensed and would not alter the physical, chemical, and thermal characteristics of the waste now being processed.

6.3.5 Packaging

The packaging of solid wastes generated by decontamination of the SSSCs will be the same as currently done at the Surry Power Station. As described in Section 11.2.4 of the Surry Power Station FSAR, the solid waste disposal system provides holdup, packaging, and storage facilities for the eventual offsite shipment and ultimate disposal of radioactive waste material.

6.3.6 Storage Facilities

Since the SSSCs wastes are processed in the same manner as other Surry Power Station wastes, no special storage facilities are required. Current wastes generated are stored in the yard storage area, low-level waste storage facility or sea van storage pad until they are transferred to a licensed disposal contractor or to a common carrier for delivery to a licensed disposal contractor. These are all done in accordance with existing Surry Power Station radwaste procedures.

6.4 SOLID WASTES

As discussed in Section 6.1, no solid wastes are generated during the storage of spent fuel in a dry cask. This is because the SSSCs perform a totally passive storage function, with all contamination being retained within the SSSCs. Maintenance activities on the cask would not generate solid waste because the casks are decontaminated prior to placement in the ISFSI, hence, eliminating the only source of contamination; no maintenance is required for the interior of the casks.

However, some solid waste would be generated during the cask loading and decontamination processes described in Section 6.3.

Solid wastes such as spent resins are generated as a result of the processing of contaminated water generated during cask decontamination. However, the cask decontamination process does not add a significant amount of contaminated water to the liquid waste disposal system and, therefore, will not create much solid waste.

The processing of solid waste generated from operation of the Surry Power Station Units 1 and 2 is described in Section 11.2.4 of the Surry Power Station FSAR. The small increment in solid wastes resulting from the cask decontamination process will be handled in the same manner.

In addition to the solid waste from the liquid radwaste processing, there would be minor amounts of waste generated from the disposal of items such as the scrubbing towels used during the decontamination process, if done. Since the plant was built assuming there would be frequent offsite shipment of similar but smaller casks, this waste is well within the design and licensing basis of the existing system.

6.4.1 Design Objectives

As stated in Section 11.2.2 of the Surry Power Station FSAR, the waste disposal system is designed to satisfy the discharge requirements of 10 CFR Part 20 and 10 CFR Part 100, and so as not to endanger the health of Surry Power Station operating personnel.

6.4.2 Equipment and System Description

The Surry Power Station solid waste disposal system is described in Section 11.2.4 of the Surry Power Station FSAR.

6.4.3 Characteristics, Concentrations, and Volumes of Solid Wastes

See Section 6.3.4.

6.4.4 Packaging

See Section 6.3.5.

6.4.5 Storage Facilities

See Section 6.3.6.

6.5 RADIOLOGICAL IMPACT OF NORMAL OPERATIONS—SUMMARY

During normal operation, the ISFSI does not produce any radioactive wastes. The casks are sealed and will not release any of their radioactive contents.

As described in Sections 6.1, 6.2, 6.3, and 6.4, radioactive wastes are only generated during cask decontamination. These wastes comprise a small fraction of the total amount of radioactive wastes generated at the Surry Power Station Units 1 and 2 and are part of the original design and licensing basis of the plant. As such, their contribution to the total dose received by the nearest area resident, while minimal, has already been accounted for in the Surry Power Station Operating Licenses.

For a description of the Surry Power Station waste disposal design bases, see Chapter 11 of the Surry Power Station FSAR.

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Chapter 7
RADIATION PROTECTION

7.1 ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES ARE AS LOW AS REASONABLY ACHIEVABLE (ALARA)

7.1.1 Policy Considerations and Organization

A radiological protection program will be implemented at the Surry ISFSI in accordance with the requirements of 10 CFR 72.126. The program will be based on policies in existence at the Surry Power Station, which are described below.

The management policies, organizational structure, and program criteria for maintaining exposures ALARA at the Surry ISFSI are the same as for the Surry Power Station, and are collectively referred to as the Virginia Power ALARA Program. The Virginia Power ALARA Program is an important part of the Surry Power Station radiation protection program. The basic principles of the Virginia Power ALARA Program are described in Virginia Power administrative procedures and are implemented by health physics technical procedures.

The Surry Power Station ALARA program complies with 10 CFR 20.1101, Radiation Protection Programs, and is consistent with the guidance of Regulatory Guide 8.8 (June 1978), *Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable.* The station ALARA program includes the following aspects:

- Specific individuals are assigned responsibility for, and authority to implement the station ALARA program consistent with Virginia Power policy. These individuals include the station ALARA coordinator and department ALARA coordinators.
- A Station ALARA Committee has been established with the responsibility for overall coordination of the station ALARA program and for advising the station management on matters relating to ALARA. A member of station management chairs the Committee.
- Pre-job measures are required to implement the station ALARA philosophy. These include ALARA evaluations of proposed work, pre-job meetings, and tiered levels of review based on projected expended person-rem.
- Monitoring and control of ongoing work is accomplished by the establishment of an exposure tracking system, ALARA hold points, and ALARA Radiation Work Permit (RWP) re-evaluation meetings.
- Completed work is evaluated via post-job reviews, maintenance of job history files, and periodic process reviews of selected work evolutions.
- A temporary shielding program has been established.

- An ALARA suggestion system is maintained to solicit, evaluate, and reward employee ideas that save person-rem.
- Engineering design change packages receive an ALARA review prior to implementation.
- A system has been established to actively involve, guide, and monitor the performance of the station and individual departments toward meeting ALARA objectives.
- The location of the ISFSI within the Surry Power Station site allows the health physics facilities, equipment, and personnel to be readily available at all times to ensure that ALARA considerations are met. The ISFSI is located a sufficient distance from buildings and occupied spaces to minimize total personnel exposure.

Regulatory Guide 8.10 (May 1977), *Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Reasonably Achievable,* Regulatory Position 1, concerning management commitment to minimizing exposures, is addressed by Virginia Power administrative procedures. Regulatory Position 2, concerning radiation protection staff vigilance in ALARA matters, is addressed and implemented by Virginia Power administrative procedures and health physics technical procedures.

The health physics organization is described in an administrative procedure. The organization to maintain exposures ALARA is also described in Virginia Power administrative procedures. The Station ALARA Committee is a major part of that organization. An administrative procedure also lists Surry Power Station health physics administrative procedures by functional grouping. These procedures are also applicable to the Surry ISFSI.

The guidance of Regulatory Position 2 of Regulatory Guide 8.8 (June 1978) is followed as described in Section 7.1.2. The guidance of Regulatory Guide 8.10 (May 1977) is followed as described in this section.

Virginia Power personnel qualifications and experience are considered more than sufficient for operation of the Surry ISFSI since these personnel have gained considerable experience at the Surry Power Station. An administrative procedure provides the functional responsibilities and reporting relationships of the members of the health physics organization and the personnel qualification requirements for positions in the station health physics organization.

Health physics equipment, instrumentation, and facilities for the Surry ISFSI will be those of the Surry Power Station. Radiation surveys with portable instruments will be performed during surveillance of the SSSCs and other activities at the ISFSI. Portable instruments required for measuring dose rates and radiation characteristics are maintained in accordance with approved health physics procedures.

As indicated in Section 7.2.2, respiratory protection equipment will not be needed at the Surry ISFSI.

Radiation protection facilities, instrumentation, and equipment available at the Surry Power Station are similar to that described by Regulatory Position 4 of Regulatory Guide 8.8 (June 1978). These include count room equipment, portable instruments, personnel monitoring instruments, protective equipment, and their associated support facilities.

The guidance for testing, rejection criteria, and use in mixed radiation fields being followed for the dosimeters at the Surry Power Station will be used at the Surry ISFSI.

The bioassay program in use for personnel at the Surry Power Station will also apply to the Surry ISFSI.

The methods and procedures for conducting radiation surveys at the Surry ISFSI will comply with the approved health physics procedures in effect at the Surry Power Station.

This section describes the health physics and ALARA procedures and planning for the Surry Power Station which will be used at the ISFSI. The complete details are in the applicable Virginia Power station and departmental administrative procedures and health physics technical procedures.

The radiological respiratory protection program is outlined in Virginia Power administrative procedures and implemented by health physics technical procedures.

Access control will be accomplished by means of a perimeter fence with a locked gate surrounding the Surry ISFSI. Control of the keys will be in accordance with security and health physics policies and procedures.

The bases and methods for monitoring and controlling personnel, equipment and surface contamination control, and radiation protection training program content are described in Virginia Power administrative procedures and health physics technical procedures.

The guidance provided by Regulatory Guide 8.10 (May 1977) will be followed as described in this section and Section 7.1.3. The guidance of Regulatory Guide 8.15 (October 1976), *Acceptable Programs for Respiratory Protection,* will be followed as described in this section. There should be no need for bioassay of personnel after surveillance activities at the Surry ISFSI. There should also be no need for radiological respiratory protection equipment.

Personnel dosimetry used at the Surry ISFSI will be controlled by the external dosimetry program approved for the Surry Power Station. An ALARA feedback mechanism using dosimeter results for preplanning future tasks is included in Virginia Power administrative procedures and their implementing documents.

The criteria for performing routine and non-routine whole-body counting and bioassay are contained in Virginia Power administrative procedures and health physics technical procedures for the Surry Power Station. Methods and procedures for evaluating and controlling airborne radioactive material are also given in these procedures.

Respiratory protection program requirements, equipment use and maintenance guidance, and fit testing protocol are delineated in Virginia Power administrative procedures and health physics technical procedures. Radiological respiratory protection training is conducted in accordance with Nuclear Training Department procedures.

7.1.2 Design Considerations

The ISFSI has been located in an area adjacent to the existing Surry Low Level Waste Storage Facility (LLWSF). This location was chosen based on several considerations, including ALARA, as follows:

1. The ISFSI and LLWSF are centrally located within the Surry site boundary, thus minimizing offsite exposures.
2. The centralized location of the ISFSI and LLWSF is of sufficient distance from the Surry Power Station such that the increased dose to Surry Station personnel is not significant.
3. The LLWSF is a facility that has limited occupancy, and, as such, represents a low exposure potential for personnel. In addition, the dose rates to workers from sources within the LLWSF are much greater than those that will result from ISFSI operations.
4. A proven heavy load route has been built past the LLWSF and a perimeter fence has already been built. Both of these are also utilized by the ISFSI.

The layout of the ISFSI is designed to minimize exposures since the casks will be stored with sufficient separation between them to allow adequate personnel access between the casks for surveillance and handling operations.

The equipment design considerations are ALARA since the fuel will be stored dry, inside sealed, heavily-shielded casks. The heavy shielding will minimize personnel exposures. To avoid personnel exposure, the casks will not be opened nor fuel removed from the casks while at the ISFSI. Storage of the fuel in dry sealed casks eliminates the possibility of leakage of contaminated liquids, and gaseous releases are not considered credible. The exterior of the casks will be decontaminated before leaving the Surry Power Station decontamination building, thereby avoiding exposure to surface contamination. There will be no other radioactive equipment at the ISFSI so that there will be no exposures from surface contamination associated with maintenance of equipment. The required maintenance and surveillance of the casks will be minimal and therefore ALARA. This method of spent fuel storage is also considered ALARA because it minimizes direct radiation exposures and eliminates the potential for contamination incidents.

Guidance provided by Regulatory Position 2 of Regulatory Guide 8.8 which concerns design considerations is being followed as described in the following paragraphs:

1. Regulatory Position 2.1 on access control is met by use of a fence with a locked gate that surrounds the ISFSI and prevents unauthorized access.

2. Regulatory Position 2.2 on radiation shielding is met by the heavy shielding of the casks which minimizes personnel exposures.

3. Regulatory Position 2.3 on process instrumentation and controls is met since there are no radioactive systems at the ISFSI. No process controls are required for the cask; however, there will be minor exposure attributed to calibration of instrumentation.

4. Regulatory Position 2.4 on control of airborne contaminants is met because no gaseous releases are expected. No significant surface contamination is expected either because the exterior of the casks will be decontaminated before they leave the decontamination building.

5. Regulatory Position 2.5 on crud control is not applicable to the ISFSI because there are no radioactive systems at the ISFSI that could transport crud.

6. Regulatory Position 2.6 on decontamination is met because the exteriors of the casks are decontaminated before they are released from the decontamination building.

7. Regulatory Position 2.7 on radiation monitoring is met because the casks are sealed. There is no need for airborne radioactivity monitoring since no airborne radioactivity is anticipated. Area radiation monitors will not be required because the ISFSI will not normally be occupied; however, TLDs will be installed along the controlled access fence. Portable survey meters will normally be used. Personnel dosimetry will be used at all times.

8. Regulatory Position 2.8 on resin treatment systems is not applicable to the ISFSI because there will not be any radioactive systems containing resins.

9. Regulatory Position 2.9 concerning other miscellaneous ALARA items is not applicable because these items refer to radioactive systems not present at the Surry ISFSI.

7.1.3 Operational Considerations

The ALARA procedures for the ISFSI will be the same as those used in the health physics program for the Surry Power Station. Section 7.1.1 describes the policy and procedures that ensure that ALARA occupational exposures and contamination levels are achieved. Section 7.1.2 describes how the design considerations are ALARA.

Storage of spent fuel in SSSCs is expected to involve lower exposures than alternative methods or designs for onsite storage. For example, storage in a fuel pool would involve use of radioactive water cooling and cleanup systems and filtered HVAC that would result in higher operator exposures during pump, valve, and motor maintenance of these systems, and filter and resin replacement. This alternative would also lead to additional airborne and liquid releases that will not be present at the Surry ISFSI.

The order of cask placement in the ISFSI has been developed based on ALARA considerations. Figure 7.3-1 shows the slabs numbered in the order of their use. Slab 2 will not be used until slab 1 is filled and, likewise, slab 3 will not be used until slab 2 is filled. Casks will be placed on a slab in rows of two starting at the northern end and finishing at the southern end. In

this manner, personnel placing casks on the next available slab are closer to the older spent fuel and further from the younger spent fuel, thus minimizing the amount of radiation exposure from previously filled slabs.

The guidance provided by Regulatory Position 4 of Regulatory Guide 8.8 is being followed. That section of the Regulatory Guide concerns radiation protection facilities, instrumentation, and equipment. The counting room, portable instruments, personnel monitoring instruments, protective equipment, and support facilities for the ISFSI called for in Regulatory Position 4 will be provided by the health physics facilities and personnel at the Surry Power Station Units 1 and 2. The procedures and methods that ensure that occupational radiation exposures at the ISFSI are ALARA have been described in Sections 7.1.1, 7.1.2, and 7.1.3. The procedures and methods of operation to ensure ALARA exposures given in Regulatory Position 4 of Regulatory Guide 8.8 and in Regulatory Guide 8.10 will be followed as described in Sections 7.1.1, 7.1.2, and 7.1.3.

Operational requirements for surveillance are incorporated into the design considerations in Section 7.1.2 in that the casks are stored with adequate spacing to allow ease of surveillance. The operational requirements are incorporated into the radiation protection design features described in Section 7.3 since the casks are heavily shielded to minimize occupational exposure.

The criteria and conditions under which certain ALARA techniques are implemented to ensure ALARA exposures and contamination levels are described in Section 7.1.1. ALARA techniques will be implemented at all times.

As the number of potential man-rem per task increases, the ALARA techniques employed become more stringent as described in the Virginia Power ALARA Program.

The ISFSI does not contain any systems that process liquids or gases or contain, collect, store, or transport radioactive liquids or solids other than the stored fuel. Therefore, the ISFSI is ALARA since there are no such systems to be maintained, be repaired, or be a source of leaks.

7.2 RADIATION SOURCES

7.2.1 Characterization of Sources

Shielding of the spent fuel is provided by the casks. Physical characteristics of the fuel used at the Surry Power Station are summarized in Table 3.1-1. Typical fuel assembly sources are given in Tables 7.2-1 through 7.2-4. These tables were generated by Westinghouse using ORIGEN II. Descriptions of the fuel which the SSSCs are designed to store are provided in the SSSC topical reports or Appendix A. The exterior surfaces of the casks will be decontaminated prior to transfer to the ISFSI. The fuel will not be removed from the casks or the casks opened while at the ISFSI. The only source of radioactivity on the ISFSI pads will be the direct radiation from the fuel stored inside the SSSCs. Located within the ISFSI perimeter fence, but outside the security fences for the ISFSI pads, is a Low Level Waste Storage Facility (LLWSF). Section 7.3.2.2 provides a discussion of the contribution from the LLWSF on radiological doses.

7.2.2 Airborne Radioactive Material Sources

Respiratory protection is not needed at the ISFSI because of the lack of airborne radioactivity.

Table 7.2-1

AVERAGE NEUTRON SOURCE[a] FOR WESTINGHOUSE 15x15 FUEL

Nominal Burnup (MWd/MtU)	Time After Discharge 150 Days	Time After Discharge (years)									
		1	2	3	4	5	6	7	8	9	10
35,000	1.26+6	1.07+6	9.42+5	8.89+5	8.53+5	8.22+5	7.92+5	7.63+5	7.36+5	7.09+5	6.84+5
45,000	l.98+6	1.71+6	1.53+6	1.45+6	1.39+6	1.34+6	1.29+6	1.24+6	1.20+6	1.15+6	1.11+6

a. Neutrons/second/cm active fuel length

Table 7.2-2
AVERAGE PHOTON SOURCES[a] 150 DAYS AFTER DISCHARGE
FOR WESTINGHOUSE 15x15 FUEL

Feed Enrichment (wt.% U235)	3.09	4.13
Average Burnup (MWd/MtU)	35,000	45,000
E Mean (Mev)	Twelve Group Energy Release Rates (Mev/sec)	
3.00-l	1.48+12	1.74+12
6.30-l	5.69+13	7.20+13
1.10+0	1.61+12	2.06+12
1.55+0	9.62+11	1.28+12
1.99+0	6.18+11	7.21+11
2.38+0	2.31+9	2.72+9
2.75+0	4.01+7	4.72+7
3.25+0	1.58+7	1.86+7
3.70+0	0	0
4.22+0	0	0
4.70+0	0	0
5.25+0	0	0
Total	6.15+13	7.78+13

a. Basis is 1 cm of active fuel length

Table 7.2-3

PHOTON SPECTRUM AS A FUNCTION OF TIME FOR FISSION PRODUCTS

FEED ENRICHMENT FUEL - 3.09 wt.% U-235 - W 15X15 ASSY 35,000 MWd/MtU 4 CYCLES

Average Power = 0. Mw Average Burnup = 4.715E+0l MWd Average Flux = 0. N/cm^2-sec

Twelve Group Energy Release Rates (Mev/sec) Basis = One cm of Active Fuel Length

E Mean	Time After Discharge (Yr)										
(Mev)	Initial	1.00E+00	2.00E+00	3.000E+00	4.000E+00	5.000E+00	6.000E+00	7.000E+00	8.000E+00	9.000E+00	1.000E+01
3.00E-01	3.49E+14	7.60E+11	3.66E+11	2.05E+11	1.36E+11	1.05E+11	9.03E+10	8.24E+10	7.74E+10	7.38E+10	7.09E+10
6.30E-01	1.42E+15	2.35E+13	1.47E+13	1.10E+13	8.53E+12	6.84E+12	5.65E+12	4.80E+12	4.18E+12	3.72E+12	3.38E+12
1.10E+00	8.76E+14	1.15E+12	8.37E+11	6.50E+11	5.30E+11	4.46E+11	3.87E+11	3.41E-11	3.05E+11	2.74E+11	2.49E+11
1.55E+00	8.04E+14	6.52E+11	3.98E+11	2.58E+11	1.73E+11	1.19E+11	8.38E+10	5.96E+10	4.28E+10	3.10E+10	2.26E+10
1.99E+00	2.05E+14	3.61E+11	1.48E+11	6.09E+10	2.50E+10	1.03E+10	4.30E+09	1.82E+09	7.96E+08	3.76E+08	2.02E+08
2.38E+00	2.00E+14	1.98E+04	5.00E-05	1.26E-13	3.19E-22	8.05E-31	2.03E-39	5.13E-48	1.30E-56	3.26E-65	8.26E-74
2.75E+00	1.00E+14	3.43E+02	8.67E-07	2.19E-15	5.52E-24	1.39E-32	3.52E-41	8.89E-50	2.24E-58	5.67E-67	1.43E-75
3.25E+00	2.43E+14	1.35E+02	3.41E-07	8.62E-16	2.18E-24	5.49E-33	1.39E-41	3.50E-50	8.84E-59	2.23E-67	5.67E-76
3.70E+00	1.72E+13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4.22E+00	4.33E+13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4.70E+00	2.27E+13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5.25E+00	5.97E+12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Total	4.28E+15	2.64E+13	1.64E+13	1.21E+13	9.40E+12	7.52E+12	6.22E+12	5.29E+12	4.61E+12	4.10E+12	3.72E+12
Gamma Watts	6.86E+02	4.23+00	2.63E+00	1.95E+00	1.51E+00	1.21E+00	9.97E-01	8.47E-01	7.38E-01	6.58E-01	5.97E-01

Table 7.2-4

PHOTON SPECTRUM AS A FUNCTION OF TIME FOR FISSION PRODUCTS

FEED ENRICHMENT FUEL - 4.13 wt.% U-235 - W 15X15 ASSY 45,000 MWd/MtU 3 CYCLES

Average Power = 0. Mw Average Burnup = 5.943E+01 MWd Average Flux = 0. N/cm^2-sec

Twelve Group Energy Release Rates (Mev/sec) Basis = One cm of Active Fuel Length

E Mean	Time After Discharge (Yr)										
(Mev)	Initial	1.00E+00	2.00E+00	3.000E+00	4.000E+00	5.000E+00	6.000E+00	7.000E+00	8.000E+00	9.000E+00	1.00E+01
3.00E-01	4.10E+14	8.97E+11	4.36E+11	2.48E+11	1.68E+11	1.32E+11	1.14E+11	1.05E+11	9.96E+10	9.42E+10	9.06E+10
6.30E-01	1.68E+15	3.14E+13	1.99E+13	1.49E+13	1.15E+13	9.18E+12	7.52E+12	6.33E+12	5.47E+12	4.83E+12	4.35E+12
1.10E+00	1.04E+15	1.49E+12	1.10E+12	8.56E+11	7.01E+11	5.92E+11	5.13E+11	4.51E+11	4.02E+11	3.62E+11	3.27E+11
1.55E+00	9.50E+14	8.82E+11	5.47E+11	3.58E+11	2.43E+11	1.68E+11	1.19E+11	8.45E+10	6.07E+10	4.39E+10	3.20E+10
1.99E+00	2.43E+14	4.20E+11	1.73E+11	7.09E+10	2.92E+10	1.21E+10	5.02E+09	2.13E+09	9.38E+08	4.48E+08	2.46E+08
2.38E+00	2.37E+14	2.33E+04	5.89E-05	1.49E-13	3.75E-22	9.47E-31	2.39E-39	6.04E-48	1.52E-56	3.85E-65	9.72E-74
2.75E+00	1.19E+14	4.04E+02	1.02E-06	2.58E-15	6.50E-24	1.64E-32	4.15E-41	1.05E-49	2.64E-58	6.67E-67	1.68E-75
3.25E+00	2.83E+14	1.59E+02	4.02E-07	1.01E-15	2.56E-24	6.47E-33	1.63E-41	4.12E-50	1.04E-58	2.63E-67	6.64E-76
3.70E+00	2.07E+13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4.22E+00	5.20E+13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4.70E+00	2.72E+13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5.25E+00	7.18E+12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Total	5.06E+15	3.15E+13	2.22E+13	1.64E+13	1.27E+13	1.01E+13	8.27E-12	6.97E+12	6.03E+12	5.33E+12	4.80E+12
Gamma Watts	8.11E+02	5.62E+00	3.56E+00	2.64E+00	2.03E+00	1.62E+00	1.33E+00	1.12E+00	9.66E-01	8.54E-01	7.70E-01

7.3 RADIATION PROTECTION DESIGN FEATURES

7.3.1 Installation Design Features

A description of the Surry ISFSI, including layout and characteristics is provided in Section 4.1.

The ISFSI has a number of design features which ensure that exposures are ALARA.

1. [Deleted]
2. The casks are loaded, sealed, and decontaminated prior to transfer to the ISFSI.
3. The fuel is not unloaded nor are the casks opened at the ISFSI.
4. The fuel is stored dry inside the casks, so that no radioactive liquid is available for leakage.
5. The casks are sealed airtight.
6. The casks are heavily shielded to minimize external dose rates.

Also, the ISFSI will not normally be occupied. Therefore, no personnel areas, equipment decontamination areas, contamination control areas, or health physics facilities need be located at the ISFSI. These types of facilities are available at the Surry Power Station Units 1 and 2.

7.3.2 Shielding

Details on the SSSC shielding designs are provided in the SSSC topical reports. No shielding other than that afforded by the SSSCs themselves is required.

Except during cask placement and scheduled surveillance, the ISFSI will not be normally occupied. A fence with a locked gate surrounds the ISFSI to control access. If the dose rate beyond the ISFSI fenced-in area exceeds 5 mrem per hour at any time during ISFSI operation, additional control measures such as extending the fence as illustrated in Figure 7.3-1 will be enacted.

7.3.2.1 **Cask Surface Dose Rates**

The gamma dose rate on the cask surface with its photon energy spectrum, and the neutron dose rate on the cask surface with its neutron energy spectrum are dependent on the cask design. The cask surface gamma and neutron dose rates are also dependent on the burnup and initial enrichment of the fuel stored in the casks. Therefore, cask-specific analyses have been performed for representative Surry Power Station fuel. See Appendix A. The assumptions used in the cask-specific analyses for cask surface dose rates and energy spectra are provided in the SSSC topical reports or Appendix A.

The TN-32 cask (Appendix A.5) loaded with fuel with an initial enrichment of 3.5 weight percent U-235, burnup of 45,000 MWD/MTU and cooling time of 7 years has been chosen as the base case for analysis purposes. Using an enrichment lower than the 4.05 weight percent U-235

approved for the TN-32 yields a bounding isotope inventory, and is in accordance with NUREG-1536 and NRC Interim Staff Guidance.

Source terms for the fuel were calculated using the SAS2H/ORIGEN-S module of SCALE4.3 as described in Section 5.1 of Reference 1. These source terms are then passed through a SAS2H cask shield model for a 1-dimensional dose assessment. Section 5.2 (Reference 1) describes the source specification and Section 5.3 (Reference 1) describes the shielding analyses performed for the TN-32 cask.

In addition to the spent fuel, the TN-32 is capable of storing BPRAs and TPAs. BPRAs and TPAs with combinations of cumulative exposures and cooling times are permissible for storage in the TN-32 cask. The source evaluation of the BPRAs and TPAs is described in Section 5.2 (Reference 1).

Virginia Power conducted an independent analysis of the TN-32 surface dose rate. This analysis was used to form the basis for the cask surface dose rate limit in the ISFSI Technical Specifications. The surface dose rates calculated for the TN-32 base case cask were 224 mrem/hr (neutron and gamma) for the side surface and 76 mrem/hr (neutron and gamma) for the top surface.

Appendix A provides the cask-specific analyses for surface dose rates.

7.3.2.2 **Dose Rate Versus Distance**

Analyses have been completed to determine dose rates at the ISFSI perimeter fence, the site boundary and the nearest permanent resident. These analyses were performed using the MCNP Monte Carlo transport code (Reference 2) and the following conservative inputs.

1. Isotope inventories were based on 32 fuel assemblies with enrichment of 3.5 weight percent U-235, burnup of 45,000 MWD/MTU and seven years decay.
2. The three storage pads were filled with 84 base case TN-32 casks, each pad having 28 casks. This input is conservative, since the first storage pad is filled with CASTOR V/21, CASTOR X/33, MC-10 and NAC-I28 storage casks, all of which have maximum surface dose rates that are lower than the base case TN-32. In addition, using 84 TN-32 cask results in an amount of fuel stored on the pads which exceeds the current licensed limit of 811.44 TeU, providing additional conservatism to the analysis.
3. The analyses assume no decrease in the gamma and neutron emission rates as a result of decay beyond the initial seven-year requirement. That is, all 84 casks were assumed to be placed simultaneously at the ISFSI.
4. The effects of irradiated insert components were included in the MCNP analyses. Each cask was assumed to contain 32 irradiated insert components with the source spectrum and source strength identified in Reference 1.

Figure 7.3-1 shows the layout of the ISFSI. The MCNP analysis of the dose rate at the ISFSI perimeter fence using base case TN-32 casks resulted in peak dose rates that range from 2.9 to 12.2 mrem/hr when all three pads were full. Dose rate measurements at the ISFSI perimeter fence will be used to ensure that the requirements of 10 CFR 20 are met.

The MCNP analysis for the nearest site boundary indicated that the maximum dose rate at this location was less than 100 mrem/yr, which meets the requirements of 10 CFR 20.1301.

The licensing basis for the annual dose to the nearest permanent resident was based on 84 GNSI CASTOR V/21 casks, adjusted for decay, and air and distance attenuation of neutron and gamma rays. The annual dose to the nearest permanent resident (1.53 miles away) for this case was 6.0E-05 mrem, based on Section 2.3 of the NRC's Safety Evaluation Report for the Surry Dry Cask Independent Spent Fuel Storage Installation and Section 6.2 of the NRC's Environmental Assessment Related to the Construction and Operation of the Surry Dry Cask Independent Spent Fuel Storage Installation. The MCNP analysis using 84 base case TN-32 casks resulted in an annual dose to the nearest permanent resident from normal ISFSI operation that is bounded by the ISFSI licensing basis.

7.3.3 Ventilation

As indicated in Section 3.3.2.2, the ISFSI does not require a ventilation system. The ALARA provisions of 10 CFR 20 and of appropriate regulatory guides will be satisfied since no exposure will be incurred in ventilation system maintenance or filter changing.

7.3.4 Area Radiation and Airborne Radioactivity Monitoring Instrumentation

As indicated in Section 3.3.5, area radiation and airborne radioactivity monitors are not needed at the Surry ISFSI; however, TLDs will be used to record dose rates along the ISFSI perimeter fence.

7.3.5 References

1. *TN-32 Safety Analysis Report,* Revision 0, Transnuclear Inc., January 2000.
2. MCNP Version P01.3, *Monte Carlo N-Particle Transport Code System,* CCC-660, Los Alamos National Laboratory.

Figure 7.3-1
ISFSI LAYOUT

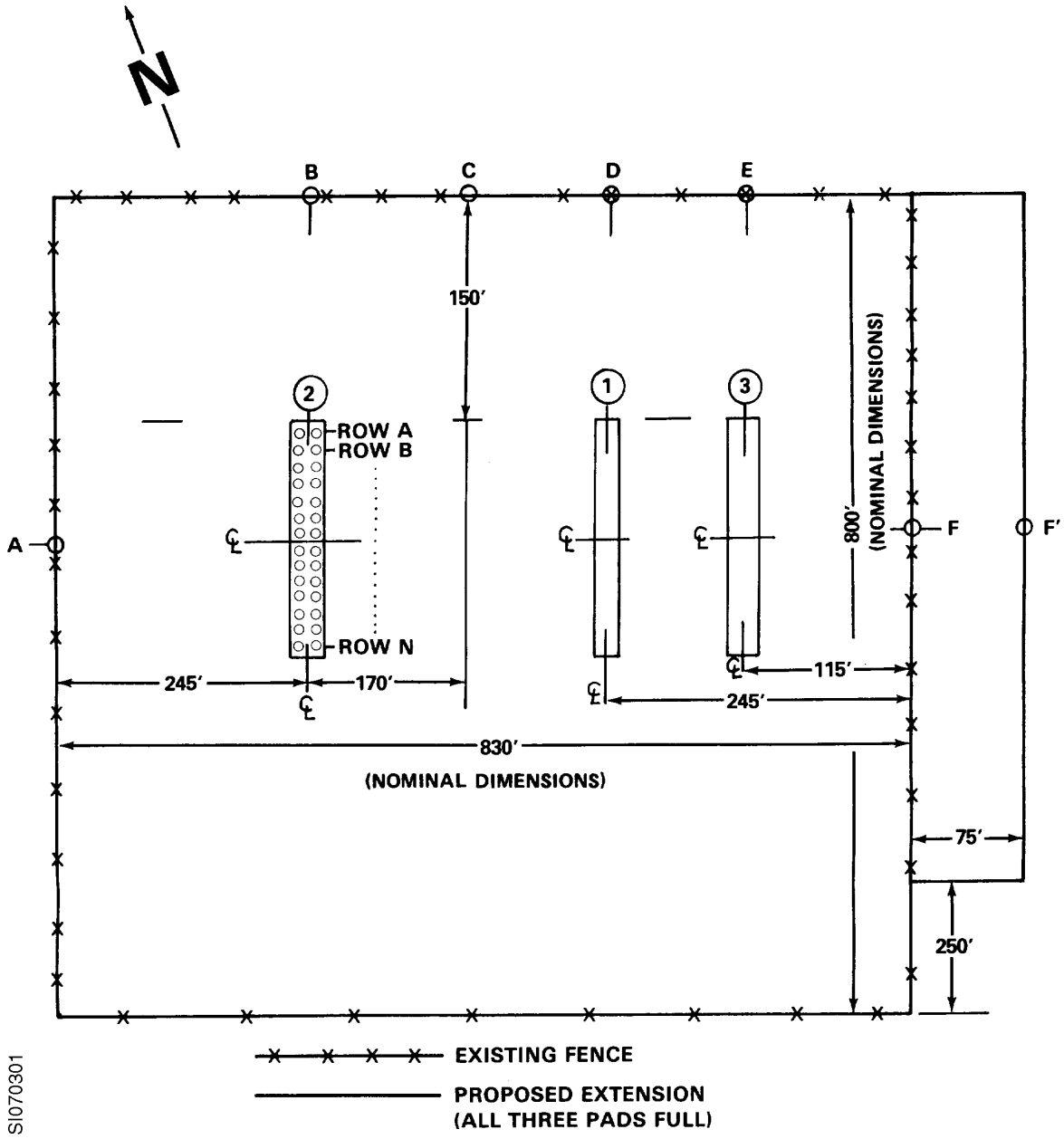
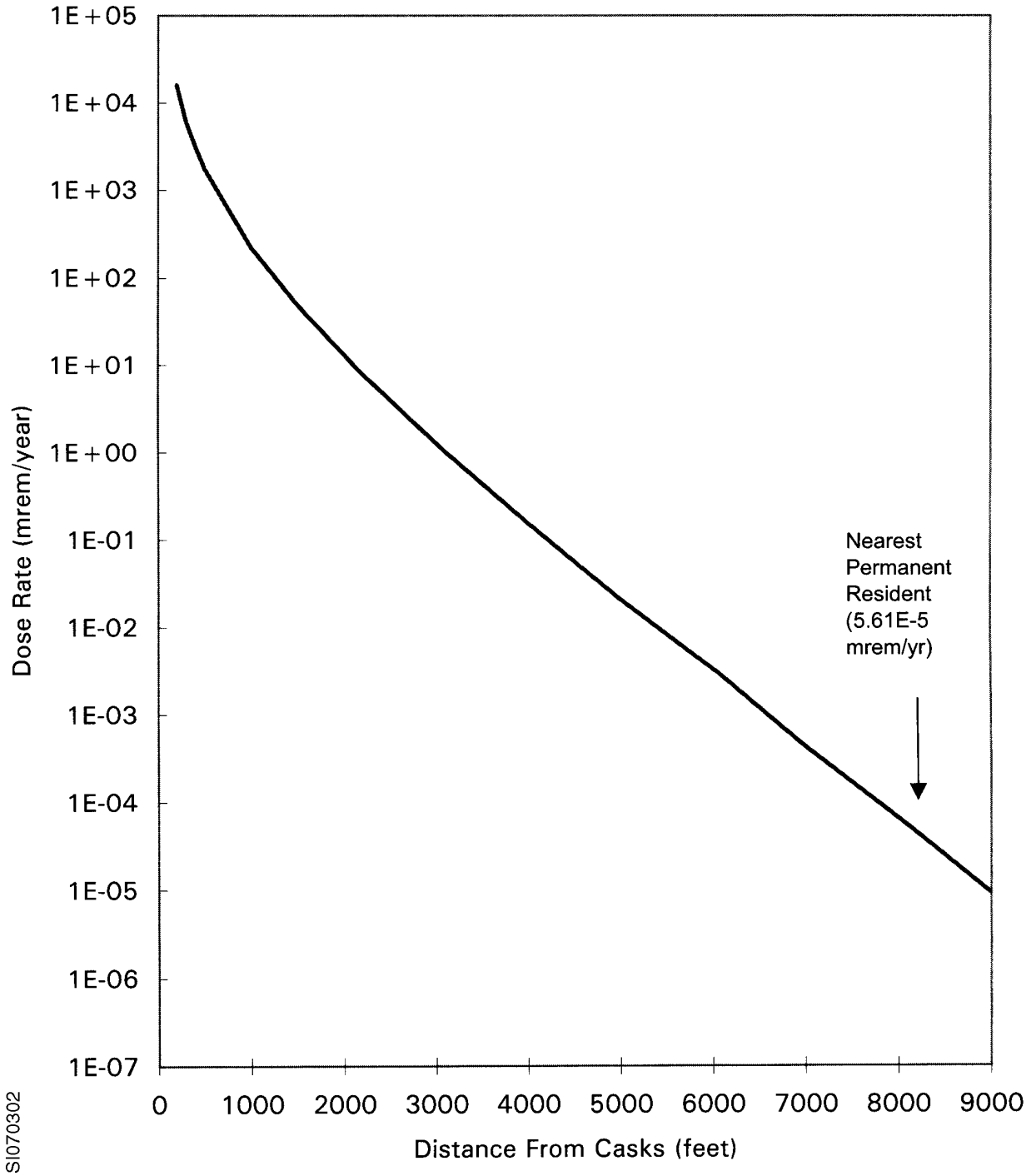


Figure 7.3-2
DOSE RATE FOR 84 BASE CASE CASKS VERSUS DISTANCE



7.4 ESTIMATED ONSITE COLLECTIVE DOSE ASSESSMENT

7.4.1 Exposure to ISFSI Personnel

Table 7.4-1 shows the estimated occupational exposures to ISFSI personnel during the loading, transport, and emplacement of the SSSCs. Base case TN-32 surface dose rates were utilized for all cases except cask transfer, when individuals will typically be at least 10 feet away from the cask.

Table 7.4-2 shows the estimated annual man-rem for surveillance and maintenance activities. Base case TN-32 surface dose rates were utilized assuming all storage pads were filled with casks. To estimate the dose rates for operability tests and calibration, the worker was assumed to be located at the control panel at the perimeter fence entrance. Visual surveillance was based on a walkdown of each of the three pads at a distance no closer than 2 meters to the casks. During surface defect repairs, the worker was assumed to be positioned next to a cask. The five surrounding casks (all within 16 feet of the worker) are the predominant dose contributors during repair work.

Both Table 7.4-1 and 7.4-2 provide for each task the estimated time required for the task, number of personnel required, the dose rates, and man-rem.

The total annual occupational dose for ISFSI operations is given in Table 7.4-3.

7.4.2 Exposure to Power Station Personnel

To evaluate the additional dose to station personnel from ISFSI operations, a conservative analysis has been performed using the assumptions given in Section 7.3.2.2. The occupational dose calculation considers all workers at the Surry Power Station to be in offices, nonshielded buildings, or in the plant yard. This population includes a normal work force of utility and contractor personnel as well as the increased staffing required during outages. As a bounding estimate, the total number of workers assumed was 600 spending a total of 1,248,000 man-hours per year in the Surry yard area and in offices.

The minimum distance between the Surry Units 1 and 2 perimeter fence and the nearest cask is approximately 2100 feet. The dose rate from the ISFSI to a yard location 2100 feet away is 1.00E-3 mrem/hr. The annual exposure for station workers due to the ISFSI is calculated to be 1.3 man-rem per year.

7.4.3 Exposure to LLWSF Personnel

The dose to workers at the LLWSF due solely to LLWSF operations is calculated to be in the range of 3.6 to 7.1 man-rem per year. This is based on a typical, historical, LLWSF occupancy time of 712 man-hours per year. Depending on exactly what operations are taking place (package handling, movement, monitoring, etc.), these 712 man-hours are assumed to be spent in radiation areas corresponding to the LLWSF average values of 5 to 10 mrem/hr.

The dose to workers at the LLWSF due to the ISFSI is calculated to be 1.3 man-rem per year. Credit was taken for air attenuation of neutrons and gammas; however, no credit was taken for the shielding effect of one cask behind another and the shielding provided by the LLWSF building to the personnel. This dose is calculated from 84 base case TN-32 casks.

Table 7.4-1
OCCUPATIONAL EXPOSURES FOR CASK LOADING, TRANSPORT, AND EMPLACEMENT [a]
(ONE TIME EXPOSURE)

Task	Time Required (hr)	No. of Persons	Dose Rate (rem/hr)	Man-Rem
Placement in pool	1	3	0.005	0.015
Loading process	3	2	0.005	0.030
Removal from pool	2	3	0.028	0.168
Processing of cask	6	2	0.056	0.672
Helium leak test	4	2	0.056	0.448
Decontamination and inspection	3	2	0.056	0.336
Transfer from preparation area	1	3	0.028	0.084
Preparation for transport	1	3	0.028	0.084
Transfer to ISFSI	1	3	0.028	0.084
Emplacement on pad	1	2	0.028	0.056
Installation of monitoring equipment	3	2	0.112	0.672
Total				2.649

a. Dose rates are from the base case TN-32 cask.

Table 7.4-2
SURRY ISFSI MAINTENANCE OPERATIONS ANNUAL EXPOSURES

Task	Time Required (hr)	No. of Persons	Dose Rate[a] (mrem/hr)	Man-Rem
Visual Surveillance of Casks[b]	1	1	224	0.224
Monitoring System Operability Tests[c]	1	2	20	0.040
Monitoring System Alarm Response and Repairs[d]	2	2	20	0.080
Cask Surface Defect Repairs[e]	3	1	336[f]	1.008
Total				1.352

a. Dose rates are from the base case TN-32 cask. Assumes ISFSI is full.
b. Based on four surveys per year, 15 minutes each.
c. Based on two tests per year, 30 minutes each.
d. Based on two responses per year, one hour each.
e. Based on repair of three casks per year, one hour each.
f. Based on base case dose rate (224 mrem/hr) plus 50%.

Table 7.4-3
ANNUAL DOSES FROM ISFSI OPERATIONS

	Man-Rem
LLWSF [a]	1.3
Surry Power Station [a]	1.3
ISFSI Operations -	
Cask Preparation and Placement [b]	7.9
Maintenance and Surveillance	1.4
Total	11.9

a. Assumes completed ISFSI (84 design basis casks).
b. Assumes 3 TN-32 casks per year.

7.5 HEALTH PHYSICS PROGRAM

The current health physics organization and the health physics equipment associated with operation of the Surry Power Station are considered sufficient for the operation of the ISFSI. The health physics technical procedures directing routine surveys include ISFSI activities.

7.6 ESTIMATED OFFSITE COLLECTIVE DOSE ASSESSMENT

Figure 1.2-1 illustrates the plant site boundary, which is also the boundary of the restricted area. This restricted area will remain the same after addition of the ISFSI. It is the controlled area as defined in 10 CFR 72.

There are 48 permanent residents located within the 2-mile radius. The nearest permanent resident is located at 1.53 miles from the site. Based on the dose rate versus distance curve (Figure 7.3-2) and the conservative assumption that all of the residents within 2 miles are located at the same distance from the ISFSI as the nearest resident at 1.53 miles, the collective annual dose from ISFSI operations would be 2.69E-6 man-rem per year. This dose assumes a total of 84 TN-32 casks and no adjustment for fuel source decay. Considering the conservatisms in the above calculation and the rapid attenuation of neutron and gamma dose rates with distance, the collective dose for the more distant population would be negligible.

7.6.1 Effluent and Environmental Monitoring Program

The environmental monitoring program to be followed at the ISFSI is the same in effect at the Surry Power Station, but will be augmented by additional TLDs along the ISFSI restricted area fence. Since no effluents are expected from the ISFSI, the operation of the ISFSI will have minimal impact on the monitoring program.

7.6.1.1 Gas Effluent Monitoring

The Surry ISFSI does not require gaseous effluent monitoring.

7.6.1.2 Liquid Effluent Monitoring

The Surry ISFSI does not require liquid effluent monitoring.

7.6.1.3 Solid Waste Monitoring

The Surry ISFSI does not require solid waste monitoring.

7.6.1.4 Environmental Monitoring

The environmental sampling program at the ISFSI will be the same as that in effect at the Surry Power Station Units 1 and 2. The specific details of the program are described in the Surry Offsite Dose Calculation Manual (ODCM).

In addition to the TLDs maintained in areas around the ISFSI as part of the environmental and radiation monitoring program for the Surry Power Station as described above, area radiation

monitoring will also be performed routinely by extra TLDs located on the ISFSI area fence. To provide continuous monitoring capability, at least 2 gamma-sensitive TLDs will be placed at the fence on each side of the ISFSI area. For cask surveillance, portable neutron and gamma survey meters will normally be used. A correlation between gamma measurements from portable survey meters and the TLDs will first be established in preparation for assessing the neutron dose at the fence. Neutron dose rates at the ISFSI area fences will be measured by the neutron survey meters. The integrated neutron dose at the ISFSI area fence can be estimated by using the ratio of the integrated gamma dose and gamma dose rate measured in the same location. By following this procedure, the neutron dose to the environment from the ISFSI can be determined.

No individual cask radiation monitoring is necessary.

7.6.2 Analysis of Multiple Contribution

For the purpose of determining offsite exposure from the ISFSI, the design basis total dose rate versus distance curve is shown in Figure 7.3-2. Using Figure 7.3-2, the annual dose to the nearest permanent resident (1.53 miles away) due to ISFSI operations would be 5.61E-5 mrem.

The annual dose to the nearest permanent resident from the LLWSF has been estimated to be 4.4E-2 mrem. Using the whole-body dose guidelines from 10 CFR 50 Appendix I, the maximum annual dose to the nearest permanent resident from the Surry Power Station would be 3 mrem due to liquid effluents and 5 mrem due to gaseous effluents for each unit. The maximum total annual dose to the nearest permanent resident would be:

5.61E-5 mrem (ISFSI) + 4.4E-2 mrem (LLWSF) + 16 mrem (normal operation Units 1 and 2) = 16 mrem

As shown in the above equation, the dose to the nearest permanent resident from the ISFSI and LLWSF operations, in combination with the maximum permissible dose from the Surry Power Station, will not exceed the 25 mrem per year limit specified in 10 CFR 72.104(a). The above calculation is conservative, since the actual Surry Power Station effluent doses are below the 10 CFR 50 Appendix I guidelines. This is shown in Appendix 11A to the Updated FSAR for Surry Power Station Units 1 and 2.

The general population dose is not expected to increase by a detectable amount, due to the addition of the ISFSI, and will be well within the limits specified by 10 CFR 72.67(a).

7.6.3 Estimated Dose Equivalents

No radioactive effluents are expected at the Surry ISFSI.

7.6.3.1 Identification of Sources

This section does not apply for reasons stated in Section 7.6.3.

7.6.3.2 **Analysis of Effects and Consequences**

This section does not apply for reasons stated in Section 7.6.3.

7.6.4 Liquid Release

This section does not apply for reasons stated in Section 7.6.3.

7.6.4.1 **Treated Process Effluent (from Waste Treatment Area)**

This section does not apply for reasons stated in Section 7.6.3.

7.6.4.2 **Sewage**

There will be no sewage systems at the ISFSI.

7.6.4.3 **Drinking Water**

There will be no drinking water at or in the vicinity of the ISFSI.

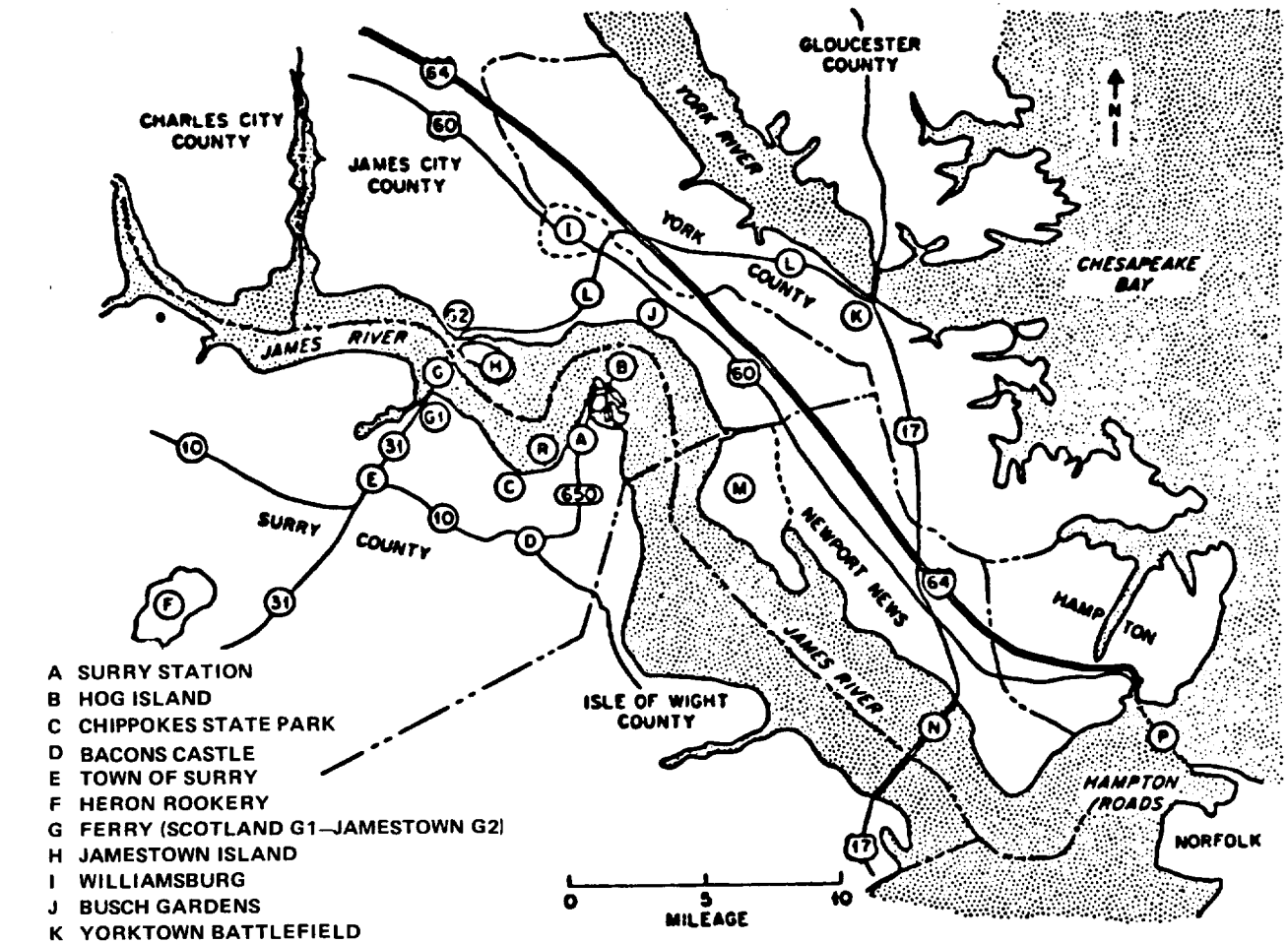
7.6.4.4 **Rain Runoff**

There are no sources of contamination at the Surry ISFSI. Therefore, rain runoff at the ISFSI will not be contaminated.

7.6.4.5 **Laundry Waste**

There will be no laundry at the ISFSI.

Figure 7.6-3
ENVIRONS OF SURRY ISFSI SITE



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Chapter 8
ACCIDENT ANALYSES

An evaluation of the safety of the Surry ISFSI with respect to postulated accident events is presented in this chapter. The facility response is analyzed in terms of event causes and precursors, recognition and quantification, and consequence mitigation for the spectrum of postulated occurrences.

Four categories of design events have been considered. Design event categories are designated as:

I. Events that are expected to occur regularly or frequently in the course of normal operation

II. Events which can be expected to occur with moderate frequency as on the order of once per year

III. Events anticipated to occur infrequently or, at most, once during the lifetime of the installation

IV. Events which are not considered credible, but nevertheless are postulated in order to bound the consequences.

8.1 OFF-NORMAL OPERATIONS

The design and operation of the Surry ISFSI include features intended to minimize or preclude the compromise of safety functions due to off-normal conditions. These features are described in Chapters 4 and 5. Nevertheless, design events have been postulated and analyzed to demonstrate the inherent safety of the facility.

Design events in Category I (normal operations) have been previously discussed in Chapters 4, 5, and 6 and are not presented further here. A loss of electric power design event has been included as a Category II event and is discussed in the following section. The SSSC topical reports postulate additional off-normal events for the casks. The topical reports analyze the effects of these additional events and identify the corrective actions.

8.1.1 Loss of Electric Power

A total loss of ac power is postulated to occur in the feeder cabling which supplies power to the ISFSI. The failure could be either an open or a short to ground circuit, or any other mechanism capable of producing an interruption of power.

8.1.1.1 Postulated Cause of the Event

A loss of power to the ISFSI may occur as a result of natural phenomena, such as lightning or extreme wind, or as a result of undefined disturbances in the nonsafety-related portion of the electric power system of the Surry Power Station.

If electric power is lost, the following systems would be de-energized and rendered nonfunctional:

1. Area lighting.
2. Cask monitoring instrumentation (pressure, temperature, etc.).

8.1.1.2 **Detection of Events**

A loss of ac power at the Surry site would be indicated and/or alarmed in the main control room of the Surry Power Station. If the loss of power were localized solely at the ISFSI, this would be indicated at the local annunciator.

8.1.1.3 **Analysis of Effects and Consequences**

This event has no safety or radiological consequences. None of the systems whose failure could be caused by this event are necessary for the accomplishment of the safety function of the ISFSI. The lighting system functions merely for convenience and visual monitoring, and the instrumentation monitors the long-term performance of the SSSCs with respect to heat transfer and leakage. None of these parameters are expected to change rapidly and their status is not dependent upon electric power.

8.1.1.4 **Corrective Actions**

Following a loss of electric power to the ISFSI, plant maintenance forces will be informed and will isolate the fault and restore service by conventional means. Such an operation is straightforward and routine for the maintenance crews of an electric utility.

A loss of power will not affect the integrity of the SSSCs, jeopardize the safe storage of the fuel, nor result in radiological releases.

8.1.2 Reference

1. *Topical Safety Analysis Report for the CASTOR V/21 Cask Independent Spent Fuel Storage Installation (Dry Storage)*, GNSI, January 1985.

8.2 ACCIDENTS

This section addresses more serious occurrences which are expected to happen on an extremely infrequent basis, if ever, during the lifetime of the facility (Event Category III). In addition, a maximum hypothetical accident, which is not considered credible (Event Category IV), is identified and analyzed.

8.2.1 Earthquake

8.2.1.1 Cause of Accident

The design earthquake (DE) is postulated to occur as a design basis extreme natural phenomenon. As described in Sections 2.6.2 and 3.2.3, the DE (0.07g) is expected to occur less than once in 500 years.

8.2.1.2 Accident Analysis

Seismic response characteristics of the SSSCs are provided in the SSSC topical reports. Results of these analyses show that cask leak-tight integrity is not compromised and that no damage will be sustained.

8.2.1.3 Accident Dose Calculations

As demonstrated in the SSSC topical reports, the DE is not capable of producing leakage from the cask and hence, no radioactivity is released. There is no associated dose from this event.

8.2.2 Extreme Wind

8.2.2.1 Cause of Accident

The extreme winds due to passage of the design tornado as defined in Section 3.2.1 are postulated to occur as an extreme natural phenomenon.

8.2.2.2 Accident Analysis

The effects and consequences of extreme winds on the casks are presented in Appendix A and the SSSC topical reports.

8.2.3 Flood

As shown in Section 3.2.2, the Surry ISFSI is considered flood-dry. Therefore, floods are not considered as design bases events.

8.2.4 Pipeline Explosion

8.2.4.1 Cause of Accident

An explosion is postulated to occur as a result of a failure of the natural gas pipeline at a point approximately 400 yards from the ISFSI. This occurrence is described in detail in Section 2.2.3. A pressure wave of less than 1 psi is estimated.

8.2.4.2 Accident Analysis

The SSSC topical reports describe the response of the casks to a gas cloud explosion.

8.2.4.3 **Accident Dose Calculations**

As shown in the analyses referenced above, the potential cask tip over due to a gas cloud is not capable of producing leakage from the cask. Since no radioactivity is released, no resultant doses would occur.

8.2.5 Fire

The only combustible materials in the ISFSI slabs are in the form of insulation on instrumentation wiring, and coating of the outside surface of the SSSCs. No other combustible or explosive materials are allowed to be stored on the ISFSI slabs. As described in Section 2.2.3.2.3, the ISFSI area will be cleared of trees and seeded with grass. In addition, other equipment in the area have been provided with adequate separation from the ISFSI slabs. Therefore, no fires other than small electrical fires are considered credible at the ISFSI slab. The ability of the casks to withstand postulated fires and the consequence of postulated fires are addressed in Appendix A and the SSSC topical reports.

The fire protection capabilities available at the ISFSI are described in Section 4.3.8. These include portable fire extinguishers within the ISFSI and the availability of the fire protection system for the Surry Power Station.

8.2.6 Dropped Fuel Assembly

8.2.6.1 **Cause of Accident**

Notwithstanding the multiple layers of safeguards against a fuel handling accident, it is postulated that an assembly is dropped in the worst possible orientation while being loaded into the cask.

8.2.6.2 **Accident Analysis**

The dropped fuel assembly accident is the limiting fuel handling accident analyzed in Section 14.4.1 of the Surry Power Station FSAR.

8.2.6.3 **Accident Dose Calculation**

The FSAR analysis has been modified to reflect the age of the fuel to be stored in the SSSCs. In this analysis, it is assumed that all 204 fuel rods in the assembly rupture and there is a sudden release of the gaseous fission products held in the voids between the pellets and cladding of the fuel rods. The low temperature of the fuel during handling operations precludes further significant release of gases from the pellets themselves after the cladding is breached. After a year’s decay period, the only gas of significance is Kr-85. I-131 with its 8-day half-life would have decayed to an insignificant level within 1 year out of core. Table 8.2-1 gives the inventory for Kr-85 for various decay times for an average assembly with assumed fuel enrichments and burnup. Only the Kr-85 released to the water would escape from the pool.

Since the fuel assembly is postulated to be dropped in the spent fuel pool in the fuel building, the escaping Kr-85 mixes with the fuel building air and is exhausted through the fuel building exhaust. For the purpose of site boundary dose calculations, it is conservatively assumed that all the Kr-85 activity released to the pool becomes airborne, exhausted from the fuel building, and is transported to the nearest site boundary instantaneously. It is further assumed that Pasquill "F" meteorology conditions exist with a 1 meter per second wind speed yielding a dispersion coefficient, χ/Q, equal to 8.14×10^{-4} sec/m^3, at the nearest site boundary. This χ/Q is consistent with the value used to evaluate the radiological consequences of the fuel handling accident presented in Section 14.4.1 of the Surry Power Station FSAR.

Table 8.2-2 gives the assumptions used to determine the radiological consequences. Where applicable, assumptions from Regulatory Guide 1.25, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors* (Safety Guide 25, 3/23/72), are employed in the analysis.

Table 8.2-3 gives the amount of activity released from the breached assembly and the resulting exposure to an individual at the closest site boundary and to the population out to 50 miles from the facility. Refer to Section 8.2.11 for a discussion on the methodology to determine population exposures. Dose models and conversion factors are taken from Regulatory Guide 1.109, *Calculations of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix 1,* Rev. 1, October 1977.

8.2.7 Inadvertent Loading of a Newly Discharged Fuel Assembly

The possibility of a premature assembly (one with a heat generation rate greater than the maximum allowable) being erroneously selected for storage in an SSSC has been considered.

8.2.7.1 Cause of Accident

The cause of this accident is postulated to be an error during the loading operations, e.g., wrong assembly picked by the fuel handling crane, or a failure in the administrative controls governing the fuel handling operations.

8.2.7.2 Accident Analysis

The maximum allowable heat generation rate for fuel assemblies to be stored in the SSSCs is provided in the SSSC topical reports and the Surry ISFSI Technical Specifications. The fuel assemblies require several years of storage in the spent fuel pool before the heat generation decays to an acceptable rate. This accident scenario postulates the inadvertent loading of an assembly not intended for storage in the SSSC, and possibly with a heat generation rate in excess of that specified for the particular SSSC.

In order to preclude this accident from going undetected, and to ensure that appropriate rectification actions can take place prior to the sealing of the casks, a final verification of the assemblies loaded into the casks and a comparison with fuel management records are performed to ensure that the loaded assemblies do not exceed any of the specified limits.

These administrative controls and the records associated with them are included in the procedures described in Chapter 9 and in the proposed license requirements described in Chapter 10, and will comply with the applicable requirements of the Quality Assurance Program described in Chapter 11.

Therefore, appropriate and sufficient actions will be taken to ensure that an erroneously loaded fuel assembly does not remain undetected. In particular, the storage of a fuel assembly with a heat generation in excess of the maximum allowable for an SSSC is not considered credible in view of the multiple administrative controls.

8.2.7.3 **Accident Dose Calculations**

The inadvertent loading of a fuel assembly not intended for storage in the SSSC will not result in unsafe fuel conditions or releases of radioactive products.

8.2.8 Loss of Neutron Shield

The design of some SSSCs includes neutron absorbing material both internal and external to the cask body. For those casks to be stored at the Surry ISFSI which feature an outer shell of neutron absorbing material, a solid shield material is used. None of the casks at the Surry ISFSI utilize a liquid neutron shield.

As applicable to the particular SSSC design, Appendix A and the SSSC topical reports discuss a postulated loss of neutron shield. As concluded in these documents, a total loss of neutron shield is not a credible event for the Surry ISFSI.

8.2.9 Cask Seal Leakage

The SSSCs feature redundant seals in conjunction with extremely rugged body designs. Additional barriers to the release of radioactivity are presented by the sintered fuel pellet matrix and the zircaloy cladding. Furthermore, the casks are not artificially pressurized above the small amount due to heating of the air or due to the inert gas (helium) in the cask. As a result, no credible mechanisms that could result in leakage of radioactive products have been identified. Nevertheless, a complete loss of the SSSCs confinement capability is postulated in Section 8.2.11, and the results found to be negligible.

Discussions of postulated cask seal malfunctions or loss of confinement barrier are presented in the SSSC topical reports or Appendix A.

8.2.10 Cask Drops

Cask handling and drop accidents postulated to occur within the fuel and decontamination buildings are addressed as part of the Surry Power Station operating license.

The SSSCs are designed to withstand drops onto the ISFSI pads without compromising the cask integrity. Technical Specifications limit the lift height for each cask. Cask drops in excess of these heights at the ISFSI, or enroute to it, are not considered credible because of procedures that preclude the lifting of the casks any higher. Analyses of cask drop accidents are presented in the SSSC topical reports.

If an off-normal handling accident were to occur, the following steps will be taken:

1. Health Physics personnel will perform radiation surveys of the cask.
2. A visual inspection of the cask body will be performed with particular attention to the area of the lifting trunnion. The trunnion will be removed and replaced if required.
3. The cask will be moved to the Surry Power Station decontamination building where the lid seals will be leak tested.
4. A gas sample will be obtained from the interior of the cask body to check for an unusual amount of Kr-85.
5. If there is no lid seal damage and no Kr-85 present at a level indicating fuel failure, the cask will be resealed using normal procedures and moved back to the ISFSI and placed on the storage pad.
6. If it is determined that the fuel must be removed from the cask, the interior of the cask will be flooded and then the water in the interior will be sampled prior to placing in the pool. If the water sample shows unacceptable levels, the water will be drained and processed as radwaste. The cask will then be reflooded and resampled prior to removing the lid to prevent uncontrolled releases of contamination to the fuel pool water.
7. The cask will then be moved into the fuel pool; the primary lid and the fuel will be removed.
8. If the fuel was removed due to the detection of potential fuel damage, the fuel will be inspected and any fuel assemblies containing rods with clad damage will be identified as being damaged and these assemblies will be stored in the fuel pool.
9. If the fuel was removed due to seal damage, the cask will be removed from the pool and repaired prior to further use.
10. The cask will then be reloaded with fuel using normal procedures and will be moved back to the ISFSI and placed on the storage pad.

8.2.11 Loss of Confinement Barrier

The following postulated accident scenario is not considered to be credible. It is hypothesized solely to demonstrate the inherent safety of the Surry ISFSI by subjecting it to a set of simultaneous multiple failures, any one of which is far beyond the capability of natural phenomena or man-made hazards to produce.

8.2.11.1 Cause of Accident

A simultaneous failure of all protective layers of confinement is postulated to occur by unspecified nonmechanistic means in an SSSC.

8.2.11.2 Accident Analysis

In this accident, the confinement function is nonmechanistically removed for the noble gas Kr-85. Heat removal and radiation shielding functions operate in the normal passive manner.

This is equivalent to breaking the cask seal barriers (no release), removing the closure lids (no release), failing all the cladding in all the loaded fuel assemblies (gap activity release), and finally, failing the fuel pellets themselves such that matrix confinement is no longer operable (remaining Kr-85 release).

8.2.11.3 Accident Dose Calculations

An analysis has been performed to determine the radiological consequences of a release of the entire gaseous inventory in a cask. The resulting dose at the nearest site boundary to an individual is well within the 5 rem criteria given in 10 CFR 72.68(b). The assumptions are given in Table 8.2-4. The dose models and dose conversion factors given in Regulatory Guide 1.109, Rev. 1, are used in this analysis. The resulting doses are given in Table 8.2-5.

To evaluate the impact upon the general population due to this postulated failure of a cask, the population exposure from this postulated event is compared to the population exposure resulting from background radiation sources. The plume of gaseous radioactivity is conservatively assumed to remain within the sector which would result in the highest population exposure. No credit is taken for the meandering of the plume which would greatly decrease the gaseous concentration in the plume and the fraction of the plume that would approach a given sector. Using Figure 2.1-3, which shows the 0- to 50-mile population distribution, and Figure 2.3-14 of Surry Power Station Units 3 and 4 PSAR, which shows χ/Q values as a function of distance from the site, to obtain the appropriate accident χ/Q at the midpoint of each annular sector, the population exposure doses are estimated. The sector receiving the highest estimated population exposure is the east-southeast sector. This sector receives an estimated exposure of approximately 153 man-rem, which is a small fraction of the annual population dose estimated to be approximately 49,000 man-rem from exposure to background radiation. In other words, the exposure due to a hypothetical incredibly severe accident at the Surry ISFSI would result in a general population dose approximately equal to 3 tenths of 1 percent of background.

8.2.12 Reference

1. *Topical Safety Analysis Report for the CASTOR V/21 Cask Independent Spent Fuel Storage Installation (Dry Storage)*, GNSI, January 1985.

Table 8.2-1
Kr-85 INVENTORY[a] FOR WESTINGHOUSE 15x15 FUEL

Nominal Burnup (MWd/MtU)	Time After Discharge 150 days	Time After Discharge (years)									
		1	2	3	4	5	6	7	8	9	10
35,000	4.65+3	4.46+3	4.21+3	3.91+3	3.69+3	3.45+3	3.23+3	3.03+3	2.84+3	2.66+3	2.50+3
45,000	5.89+3	5.67+3	5.30+3	4.97+3	4.68+3	4.39+3	4.10+3	3.84+3	3.61+3	3.38+3	3.17+3

a.Curies/assembly

Table 8.2-2
ASSUMPTIONS USED TO EVALUATE RADIOLOGICAL CONSEQUENCES FROM A FUEL HANDLING ACCIDENT DURING ISFSI OPERATIONS

Spent Fuel Characteristics	
U-235 Enrichment	4.13 wt.%
Burn-Up	45,000 MWd/MtU
Time Out of Core	5 years
Number of Assemblies Damaged	1
Number of Failed Rods	204
Radial Assembly Peaking Factor	1.65
Kr-85 Inventory in Average Assembly	4.39E+3 Ci
Percent Assembly Inventory in Fuel Rod Gaps	30
Percent Gap Activity Released to Pool	100
Percent Activity Released to Pool Becoming Airborne	100
χ/Q at Nearest Site Boundary from Surry Power Station	8.14E-4 sec/m^3
Duration of Release	Instantaneous

Table 8.2-3
RADIOLOGICAL CONSEQUENCES FROM A FUEL HANDLING ACCIDENT DURING ISFSI OPERATIONS

Kr-85 Activity Released	2.17E+3 Ci
Total Body Dose at Site Boundary	0.90 mrem
Population Exposure (0 to 50 miles, ESE sector)	3.2 man-rem

Table 8.2-4
ASSUMPTIONS USED FOR LOSS OF CONFINEMENT BARRIER ANALYSIS

Activity Release Assumptions	
Spent Fuel Assembly Characteristics	
U-235 Enrichment	4.13 wt.%
Burn-up	45,000 MWd/MtU
Time out of core	5 yr
Kr-85 Inventory Per Assembly	4.39E+3 Ci
No. Assemblies per Cask	24
Gaseous Inventory Released	100%
Duration of Release	Instantaneous
Dose Model Assumptions	
Nearest Site Boundary from ISFSI χ/Q	1.56E-3 sec/m^3

Table 8.2-5
RADIOLOGICAL CONSEQUENCES FROM
LOSS OF CONFINEMENT BARRIER ANALYSIS

Kr-85 Activity Released	1.05E+5 Ci
Total Body Dose from Cloud Immersion at Nearest Site Boundary	84 mrem

8.3 SITE CHARACTERISTICS AFFECTING SAFETY ANALYSIS

Site characteristics have been considered in the formation of the bases for these safety analyses. Conditions of meteorology were used in the determination of χ/Q values as well as the characteristics of extreme winds and their contribution to maximum flood level. Regional and site seismology and geology were used to help define the design earthquake acceleration value. Population distribution and other demographic data were used to determine radiation doses.

Other site characteristics affecting safety analyses include the natural gas pipeline located 400 meters from the ISFSI which was used to develop the bases for the pipeline explosion (Section 8.2.4).

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Chapter 9
CONDUCT OF OPERATIONS

9.1 ORGANIZATIONAL STRUCTURE

9.1.1 Corporate Organization

The ISFSI will be operated under the same corporate management organization responsible for operation of the Surry Power Station. This organization is depicted in the Virginia Electric and Power Company Operational Quality Assurance Program Topical Report, VEP-1-5A (QA Program Topical Report).

9.1.1.1 Corporate Functions, Responsibilities, and Authorities

Corporate functions, responsibilities, and authorities for the Surry ISFSI are discussed in the QA Program Topical Report.

9.1.1.2 Applicant's In-House Organization

A discussion of Virginia Power's in-house organization is provided in the QA Program Topical Report

9.1.1.3 Relationships with Contractors and Suppliers

Bechtel Power Corporation was contracted for the engineering design of the Surry ISFSI, excluding the casks, and for the preparation of the license application.

The SSSC suppliers are responsible for the fabrication and testing of the SSSCs, and for recommending SSSC handling procedures. The Nuclear Analysis and Fuel Department is the primary interface with the SSSC supplier and other equipment vendors.

Site preparation and construction will be performed by Virginia Power, using specialty subcontractors, as required.

9.1.1.4 Applicant's Technical Staff

Virginia Power's technical staff is described in the QA Program Topical Report. Radiation dose assessment support services are being provided to the Nuclear Analysis and Fuel Department by Bechtel Power Corporation.

9.1.2 Operating Organization, Management, and Administrative Control System

9.1.2.1 Onsite Organization

The Surry Power Station onsite organization is described in the QA Program Topical Report.

9.1.2.2 **Personnel Functions, Responsibilities, and Authorities**

Personnel functions, responsibilities, and authorities are described in the QA Program Topical Report.

9.1.3 Personnel Qualification Requirements

9.1.3.1 **Minimum Qualification Requirements**

Each member of the Surry Power Station staff is required to meet or exceed the minimum qualifications specified in the QA Program Topical Report.

9.1.3.2 **Qualifications of Personnel**

The qualification requirements for the managerial and technical positions are described in the QA Program Topical Report.

9.1.4 Liaison with Other Organizations

Bechtel Power Corporation provides technical expertise on the design and licensing of the facility, and in the development of computer models to assess radiation doses. SSSC vendors provide technical expertise in the design, fabrication and use of the SSSCs.

9.2 STARTUP TESTING AND OPERATION

9.2.1 Administrative Procedures for Conducting Test Program

The administrative procedures and instructions for the Surry ISFSI are the same as those used for the Surry Power Station. Any changes to, or deviations from, these procedures and instructions are reviewed and approved in accordance with the QA Program Topical Report.

9.2.2 Test Program Description

The objectives of the startup testing program are to ensure that the SSSCs perform their safety functions as intended and that the means to fulfill the commitments made in Chapter 10 are available.

9.2.2.1 **Physical Facilities**

Before or during operation of the ISFSI, the SSSC monitoring instrumentation, the electrical system, the communications system, and the security system are tested to ensure their proper functioning. The ISFSI security system is tested after completion of its installation. Details on the security system are provided in the Security Plan.

The SSSC monitoring instrumentation alarms are tested to ensure that individual alarm signals annunciate at the local annunciator enclosure at the ISFSI location.

The electrical system is tested to ensure that power is available for the SSSC monitoring instrumentation and the local annunciator. The lighting and service receptacles are also tested for proper operation.

The communications system is tested to ensure that the telephone at the local annunciator is properly connected into the station telephone system.

9.2.2.2 **Operations**

Testing of SSSC operations, i.e., loading, drying, sealing, and unloading, shall be conducted prior to the first use of each SSSC design. This simulation shall include all SSSC loading and unloading operations, with the exception of loading actual fuel assemblies in the SSSC. SSSC loading will instead be tested with a dummy fuel assembly to ensure that fuel assemblies will fit properly into the SSSC. All SSSCs are tested for fuel assembly fit by the vendor at the fabrication facility. The SSSCs are also tested by the vendor to ensure that they seal properly. New seals are installed prior to and tested following fuel loading.

The function of the transporter is tested prior to its first use with each new SSSC design using an empty SSSC for a transport simulation to and from the ISFSI, including placement of the SSSC at a storage location.

9.2.3 Test Discussion

The pre-operational test purposes, responses, acceptance criteria, margins, and corrective actions are discussed in the Technical Specifications.

Instrumentation, electrical, and communications equipment shall be functionally tested to confirm operability. Acceptance criteria for the SSSC seal testing shall be as specified in Section 3.3.

9.3 TRAINING PROGRAM

9.3.1 Program Description

The training program has the objective of providing and maintaining a well-qualified work force for the safe and efficient operation of the ISFSI. All personnel working in the fuel storage area receive radiation and safety training. Those personnel actually performing SSSC and fuel handling functions are given additional training in specific areas as required by the radiological protection program in effect at the Surry Power Station.

All personnel working at the Surry ISFSI receive training and indoctrination geared toward providing and maintaining a well-qualified work force for the safe and efficient operation of the ISFSI. The existing Surry training programs are INPO accredited and are directly applicable to the Surry ISFSI, and provide this training and indoctrination. Additional training requirements specific to the ISFSI will address the following subjects:

- ISFSI Licensing Basis and Technical Specifications

- ISFSI Layout and Function
- ISFSI Security
- ISFSI Communications Systems
- ISFSI Operation, Emergency, Maintenance, and Administrative Procedures
- SSSC Loading and Unloading, Handling and Onsite Transportation
- SSSC Decontamination Techniques

Following completion of the ISFSI training program, trainees are given a written and practical exam to ensure they understand the important aspects of the information described above. Retention of training records and certifications of proficiency is consistent with that for personnel involved in fuel handling operations.

ISFSI retraining is consistent with the retraining requirements in effect at the Surry Power Station for personnel involved in fuel handling operations.

Training records are maintained in accordance with the QA Program Topical Report. Such records include dates and hours of training and other documentation on training subjects, information on physical requirements, job performance statements, copies of written examinations, information pertaining to walk-through examinations, and retesting particulars.

9.4 NORMAL OPERATIONS

9.4.1 Procedures

Written procedures for all normal operating, maintenance, and testing at the ISFSI will be prepared and will be in effect prior to operation of the Surry ISFSI. These procedures are briefly described in Sections 9.4.1.1 through 9.4.1.8.

These procedures, and any subsequent revisions, will be reviewed and approved in accordance with the QA Program.

The Nuclear Oversight Department periodically audits (on a sampling basis) the procedures to ensure revisions are made promptly and that obsolete material is deleted.

9.4.1.1 Administrative Procedures

Administrative procedures will provide a clear understanding of operating philosophy and management policies to all ISFSI personnel. These procedures include instructions pertaining to personnel conduct and control, including consideration of job-related factors which influence the effectiveness of operating and maintenance personnel, e.g., work hours, entering and exiting the ISFSI, organization, and responsibility, etc.

9.4.1.2 **Annunciator Procedures**

Operating procedures for Post-Alarm testing provide information relative to each alarm annunciator which monitors SSSC parameters. Alarm setpoints are provided in the Technical Specifications. The procedures provide appropriate corrective action.

9.4.1.3 **Health Physics Procedures**

Health physics procedures are used to implement a radiation protection plan. The radiation protection plan involves the acquisition of data and provision of equipment to perform necessary radiation surveys, measurements, and evaluations for the assessment and control of radiation hazards associated with the operation of the ISFSI. Procedures have been developed and implemented for monitoring exposures of employees, utilizing accepted techniques, radiation surveys of work areas, radiation monitoring of maintenance activities, and for records maintenance demonstrating the adequacy of measures taken to control radiation exposures of employees and others within prescribed limits and as low as practicable. These procedures will be revised as needed to address ISFSI operations prior to operation of the ISFSI. The revised procedures will ensure the safety of personnel performing loading, transport and unloading operations, and surveillance and maintenance at the ISFSI. Entrance to the ISFSI and all work performed inside will require a radiation work permit and will be controlled by health physics and security personnel.

9.4.1.4 **Maintenance Procedures**

Maintenance procedures will be established for performing preventative and corrective maintenance on ISFSI equipment and the SSSCs. Preventative maintenance will be performed on a periodic basis to preclude the degradation of ISFSI systems, equipment, and components. Corrective maintenance will be performed to rectify any unexpected system, equipment, or component malfunction, as the need arises.

9.4.1.5 **Operating Procedures**

The operating procedures will provide instructions for handling, loading, sealing, transporting, storing, and unloading the SSSCs.

9.4.1.6 **Test Procedures**

Periodic test procedures will be established to verify operability of the ISFSI systems, equipment, and components on a routine basis.

9.4.1.7 **Startup Test Procedures**

Startup test procedures will be established to ensure that ISFSI structures, systems, and components satisfactorily perform their required functions. These test procedures will further ensure that the ISFSI has been properly designed and constructed and is ready to operate in a manner that will not endanger the health and safety of the public.

9.4.1.8 **Procedures Implementing the QA Program**

Procedures will be established to ensure that the operation and maintenance of the ISFSI is performed in accordance with the QA program described in Chapter 11.

9.4.2 Records

Records for decommissioning of the ISFSI that will be retained under 10 CFR 72.30(d) are described below. Records Management will maintain these records until the site is released for unrestricted use.

- Records of spills or other unusual occurrences involving the spread of contamination in and around the ISFSI.
- As-built drawings and modifications of structures and equipment at the ISFSI
- A list contained in a single document and updated no less than every two years of (a) all areas designated and formerly designated as restricted areas as defined by 10 CFR 20.1003, and (b) all areas outside of restricted areas that require documentation under item 1.
- Records of the cost estimate performed for the decommissioning funding plan and the funding method used for assuring funds.

Records on the spent fuel stored at the ISFSI that will be retained under 10 CFR 72.72(a) are described below. These records will be maintained by Records Management for the period that spend fuel is stored at the ISFSI plus five years after transfer.

- Fuel manufacturer
- Date of delivery to the Station
- Reactor exposure history
- Burnup
- Calculated special nuclear material content
- Inventory control number
- Pertinent data on discharge and storage at the reactor, transfer to the ISFSI, storage at the ISFSI and disposal
- Other information needed to verify compliance with ISFSI Technical Specifications

A record of the current physical inventory of spent fuel at the ISFSI required by 10 CFR 72.72(b) will be retained by Records Management until the ISFSI license is terminated by the US NRC. The current material control and inventory procedures required by 10 CFR 72.72(c) will be retained by Records Management until the ISFSI license is terminated by

the US NRC. Records of spent fuel transferred out of the ISFSI will be preserved for a period of five years after the date of transfer.

9.5 EMERGENCY PLANNING

The Surry Emergency Plan (SEP) describes the organization, assessment actions, conditions for activation of the emergency organization, notification procedures, emergency facilities and equipment, training, provisions for maintaining emergency preparedness, and recovery criteria used at the Surry Power Station. This emergency plan will also be used for any radiological emergencies that may arise at the Surry ISFSI.

Portions of SEP Section 4 and Appendix 10.8 and the applicable implementing procedure reflect the conditions and indications that require entry into the Emergency Plan. Appropriate response actions and notifications have been established in the Emergency Plan. SSSC seal leakage and SSSC drop or other handling mishap requires declaration of a Notification of Unusual Event. Loss of all SSSC and fuel containment barriers requires declaration of an Alert.

9.6 DECOMMISSIONING

Decommissioning considerations are discussed in Section 3.5, and in the Decommissioning Plan attached to the License Application.

9.6.1 Decommissioning Program

The dry cask design concept utilized at the Surry ISFSI features inherent ease and simplicity of decommissioning. At the end of its service lifetime, cask decommissioning could be accomplished by one of the following options:

1. The ISFSI cask, including the spent fuel stored inside, could be shipped to an offsite facility for temporary or permanent storage. Depending on licensing requirements existing at the time of shipment offsite, placement of the entire ISFSI cask inside a supplemental shipping container or overpack would be considered

2. The spent fuel could be removed from the ISFSI cask and shipped in a licensed shipping container to a suitable fuel repository. If desirable, cask decontamination could be accomplished through the use of conventional high pressure water sprays to further reduce contamination on the cask interior. The sources of contamination on the interior of the cask would be crud from the outside of the fuel pins and the crud left by the spent fuel pool water. The expected low levels of contamination from these sources could be easily removed with a high pressure water spray. After decontamination, the ISFSI cask could either be cut-up for scrap or partially scrapped and any remaining contaminated portions shipped as radioactive waste to a disposal facility.

Cask activation analyses have been performed to quantify specific activity levels of cask materials after years of storage. These activation calculations and the assumptions under which they were performed are described in the SSSC Topical Reports. Based on the results of the

analyses, the cask materials will be only slightly activated by the low level neutron flux emanating from the stored spent fuel. Consequently, it is expected that after application of the surface decontamination process as described above, the radiation level due to activation products will be negligible and the cask could be scrapped. A detailed evaluation will be performed at the time of decommissioning to determine the appropriate mode of disposal.

Due to the zero-leakage design of the SSSCs, no residual contamination is expected to be left behind on the concrete base pad. The base pad, fence, and peripheral utility structures are de facto decommissioned when the last cask is removed.

The spent fuel pool at Surry Power Station will remain functional until the ISFSI is decommissioned. This will allow the pool to be utilized to transfer fuel from the storage casks to licensed shipping containers for shipment offsite if this decommissioning option is chosen.

9.6.2 Cost of Decommissioning

Virginia Power presently owns and operates four nuclear power generating units. In view of the financial qualifications represented by this fact, it is anticipated that decommissioning costs of the Surry ISFSI will not be an issue. It is expected that decommissioning costs will represent a small fraction of the costs of decommissioning the Surry Power Station Units 1 and 2.

9.6.3 Decommissioning Facilitation

The volume of waste material produced incidental to ISFSI decommissioning will be limited to that necessary to accomplish surface decontamination of the casks once the spent fuel elements are removed. Furthermore, it is estimated that the cask materials will be only very slightly activated as a result of their long-term exposure to the relatively small neutron flux emanating from the spent fuel, and that the resultant activation level will be well below allowable limits for general release of the casks as noncontrolled material. Hence, the casks may be decommissioned from nuclear service by surface decontamination alone.

Chapter 10
OPERATING CONTROLS AND LIMITS

This chapter provides safety limits, limiting conditions for operation, and surveillance requirements for the Surry ISFSI which were incorporated into the ISFSI operating license.

Part of the evaluation of the ISFSI is the evaluation of the "Independence" of an ISFSI on an existing reactor site such as is the case with the Surry ISFSI. This evaluation has been performed using the definition for "Independent" contained in 10 CFR Part 72.

The results of this evaluation are as follows:

1. The ISFSI can operate independently without affecting the safety and operation of the nuclear units at Surry Power Station as there are no physical connections between the reactor units and the ISFSI other than connections which serve no safety-related functions (power for ISFSI lighting and security equipment) and the ISFSI security alarm indications.
2. The ISFSI can recover from normal or off-normal incidents or accidents without affecting the safety and operation of the nuclear units at Surry Power Station.
3. The nuclear reactor units at the Surry Power Station do not affect the safety and operation of the ISFSI.
4. No changes to the Surry Power Station 10 CFR Part 50 operating licenses are required as a result of the ISFSI.

In conclusion, the Surry Dry Cask ISFSI is "Independent" as defined in 10 CFR Part 72.

10.1 TECHNICAL SPECIFICATIONS

The Surry ISFSI Technical Specifications govern the safety of the receipt, possession, and storage, of irradiated nuclear fuel at the Surry Dry Cask. Independent Spent Fuel Storage Installation and transfer of such irradiated nuclear fuel to and from the Surry Nuclear Power Station and the Surry Dry Cask Independent Spent Fuel Storage Installation.

10.2 RECORDS

10.2.1 Records

10.2.1.1 Records shall be kept identifying the spent fuel assemblies stored in each SSSC, manufacturer, date of delivery, their storage location within the SSSC basket, initial enrichment, reactor exposure history, estimated burnup, time since discharge from the core, and the estimated heat rate.

10.2.1.2 Records shall be kept of the radiation measurements specified in Technical Specifications.

10.2.1.3 Records shall be kept of fuel transferred out of the ISFSI.

10.2.2 Retention of Records

10.2.2.1 Records specified in Section 10.2.1.1 shall be retained as long as the stored fuel remains within the Surry site.

10.2.2.2 Records specified in Sections 10.2.1.2 and 10.2.1.3 shall be retained for 5 years.

10.3 REPORTS OF ACCIDENTAL CRITICALITY OR LOSS OF SPECIAL NUCLEAR MATERIAL

Any case of accidental criticality or any loss of special nuclear material at the ISFSI shall be reported immediately to the appropriate NRC authorities, as specified in 10 CFR 72.74.

10.4 MATERIAL STATUS REPORTS

Material Status Reports shall be completed and submitted to the NRC, as specified in 10 CFR 72.76.

10.5 NUCLEAR MATERIAL TRANSFER REPORTS

Nuclear material stored in the ISFSI will not be transferred from Virginia Power to other ownership. Hence, assuming the existing Reporting Identification Symbol (RIS) for Surry fuel remains the same, Nuclear Material Transaction Reports (DOE/NRC Form-741) required by 10 CFR 72.78 will not be needed for operation of the ISFSI.

10.6 FINANCIAL REPORTS

A copy of the Virginia Power annual financial report, including certified financial statements shall be submitted to the NRC, as specified in 10 CFR 72.80(b).

10.7 ISFSI ACTIVITIES REPORTS

The Monthly Operating Reports for the Surry Power Station Units 1 and 2 shall include pertinent information regarding operation of the ISFSI.

10.8 ADMINISTRATIVE CONTROLS

10.8.1 The Surry Power Station Units 1 and 2 Site Vice President shall be responsible for the safe operation of the ISFSI. In his absence or unavailability, the Director Station Operations and Maintenance shall be responsible for the safe operation of the ISFSI. During the absence or unavailability of both, the Site Vice President shall delegate in writing the succession to this responsibility.

10.8.2 The station and offsite organization for management and technical support of the ISFSI, and their functions, shall be the same as for the Surry Power Station, as applicable.

10.9 MONITORING AND SURVEILLANCE COMMITMENTS

Monitoring and surveillance commitments are provided in the Surry ISFSI Technical Specifications.

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Chapter 11
QUALITY ASSURANCE

11.1 QUALITY ASSURANCE PROGRAM DESCRIPTION—VIRGINIA POWER

10 CFR 72.140 requires that a quality assurance program be established and implemented for the structures, systems, and components of an ISFSI that are important to safety, commensurate with their importance to safety. However, 10 CFR 72.140 provides for the use of previously approved programs.

Since Virginia Power is currently licensed under 10 CFR Part 50 to operate nuclear power facilities, a quality assurance (QA) program meeting the requirements of 10 CFR Part 50, Appendix B, is already in place. The governing document for this program is the Virginia Electric and Power Company Operational Quality Assurance Program Topical Report (QA Program Topical Report), VEP-1-5A (updated) which has been reviewed and approved by the NRC. (See Section 1.5.) The document is updated in accordance with 10 CFR 50.54(a). The NRC is periodically notified of changes to the document. This program is implemented through the Virginia Power administrative and technical procedures. The objective of the company Quality Assurance Program for operating nuclear power stations is to comply with the criteria as expressed in 10 CFR 50, Appendix B, as amended, and with the quality assurance program requirements for nuclear power plants as referenced in the Regulatory Guides and ANSI standards referenced in Table 17.2-0 of the QA Program Topical Report. This program will be applied to those activities associated with the Surry ISFSI that are important to safety. No changes to this program are required for the ISFSI activities.

As indicated in previous chapters, the SSSCs are the only components with a safety function. As such, Virginia Power procedures delineate the requirements for the engineering, procurement, fabrication, and inspection of this equipment. The procurement documents (specifications, requisitions, etc.) are reviewed technically prior to use to ensure that the proper criteria have been specified. During the SSSC design phase, vendor information (drawings, specifications, procedures, etc.) are reviewed to ensure compliance with Virginia Power’s technical requirements. During SSSC fabrication, Virginia Power’s vendor surveillance representative will visit the vendor’s shop to ensure compliance with Virginia Power’s requirements and to witness parts of the cask fabrication and testing.

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QUESTIONS AND RESPONSES

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Question 1.1.1

It is stated in Section 2.1.3.1 that the population projections (0-10 mile radii) are the same as those presented in the environmental report on the Surry Power Station Units 3 and 4, and they are used in this SAR because there was little change in this population between 1970 and 1980. This seems inconsistent with the projections of population for the 1980-1990 period for the 0-5 mile radii showing a decrease of over 60 percent and for the 5-10 mile radii which more than doubled. Explain the difference in the population trends between these two decades.

Response

Surry ISFSI ER Section 2.1 and SAR Section 2.1 have been updated to reflect revised 0- to 10- and 10- to 50-mile estimates and projections of population.

Question 1.1.2E

The large increase in population within 10 miles between 1980 (61,711) Figure 2.1-3 and 1990 (161,454) Figure 2.1-4 seem unreasonable. Subsequent rates of growth to 2020 are much smaller. Please justify or correct these numbers.

Response

Surry ISFSI ER Section 2.1.2 and SAR Section 2.1.3 have been updated to reflect revised 0- to 10- and 10- to 50-mile estimates and projections of population.

Question 1.1.3E

Attachment 1 to Figure 2, page 4-C-13 of the Virginia Radiological Emergency Plan, revised August 1981, indicates a 1980 population within the 10 mile EPZ of 79,991. This is considerably higher than the 61,711 reported in 2.1.2.1. Please explain the basis of the difference.

Response

The population estimates in ISFSI ER Section 2.1 and SAR Section 2.1 have been revised.

Question 1.1.4

The projected population distributions in Figures 2.1-3 through 7 should be checked for errors. For example, the NE sector in Figure 2.1-3 for 40 to 50 miles has an indicated population of 4,000; yet, this area is totally within the Chesapeake Bay. How were the population distributions for 10-50 mile area estimated.

Response

Surry ISFSI ER Section 2.1 and SAR Section 2.1 have been updated to reflect revised 0- to 10- and 10- to 50-mile estimates and projections of population.

Question 1.1.5E

Why are 10-year old transient population estimates incorporated by reference in Section 2.1.2.3 when more current estimates are available in the Virginia Radiological Emergency Plan, referred to above? Does VEPCO still consider the population estimates and projections from the Surry 3 and 4 Environmental Report to be valid? If not, furnish the most and valid current population data.

Response

Surry ISFSI ER Section 2.1 and SAR Section 2.1 have been updated to reflect revised 0- to 10- and 10- to 50-mile estimates and projections of population.

Question 1.2.1

It is stated in Sections 2.2.1, 2.2.3, and 2.2.3.1.4 that the Commonwealth Natural Gas Corporation and the Colonial Pipeline Company own pipelines which cross the southeast corner of the Surry property. How many pipelines are there? Table 2.2-6 indicates six and notes that the two Commonwealth National Gas Corporation lines lie four feet beneath the river bed. How about the remaining four? Once these pipelines emerge from the river are they buried or aboveground?

Response

Table 2.2-6 of the Surry ISFSI SAR has been revised to include the information requested above.

Question 1.2.2

Section 2.2.3.1.2 of the SAR states the dredged channel in the river is 2.5 miles from the ISFSI at the closest point (this distance is also used in the accompanying accident analysis), but in Table 2.2-2, the distance is given as 1.5 miles. Which is correct?

Response

Section 2.2.3.1.2 of the Surry ISFSI SAR states that the dredged channel in the James River is 2.5 miles from the ISFSI site at its closest point. Inspection of Figure 2.3-25 of the Surry ISFSI ER confirms this statement. The 2.5-mile distance refers to the separation between the site and the mid-river channel.

The 1.5-mile distance given in the SAR Table 2.2-2 (referenced from the Surry Onsite Toxic Chemical Analysis, Vol. II, NUS, June 1981) refers to the minimum separation of the Surry Power Station control room and the James River. Note that the NUS analysis does not specify what part of the James River is used to calculate the minimum separation. The Surry ISFSI site is farther from the James River than the control room.

Question 1.3.1

Section 3.2.1.1 identifies the design basis extreme ambient temperatures of -20°F and 115°F. These temperatures were selected because they exceed the extreme temperatures recorded at the Norfolk and Richmond National Weather Service Stations as reported in Section 2.3.2.1.1. The conservatism of the upper temperature extreme should be clearly established in Section 2.3.2 because, for a truly passive spent fuel storage system, the unaided atmosphere will serve as the principal heat sink. Provide a rigorous basis for establishing these temperatures. The discussion could answer the following questions:

1. Are these temperatures reported from nearby weather service stations representative of the region?
2. Did the onsite meteorological station temperature records correlate with the nearby water service stations records?
3. Does the site have peculiar micrometeorological conditions that could cause a difference between its readings and the nearby weather stations readings?
4. What is the probable length and frequency of occurrence of excessively hot periods?
5. What is the worst combination of climatology conditions which would adversely affect the ability of the ambient air to remove heat from the cask surface?
6. What is the recurrence intervals and duration for the selected extreme temperatures?

The following references may be of help in developing the statistical bases for the discussion:

> "Extreme Meteorological Events in Nuclear Power Plants, Excluding Tropical Cyclones," IAEA Safety Guide No. 50-SG-S11A, and "Probability Estimates of Temperature Extremes for the Contiguous United States," NUREG/CR-1390, May, 1980.

Response

The response to this question has been incorporated into ISFSI SAR Section 2.3 and ER Section 2.3.

Question 1.3.2

Also in Section 2.3.2 the basis for insolation design parameters should be provided. The conversatism of the solar heat load burden at the ISFSI site should be substantiated in a discussion that justifies the selection of the 90 percent transmissivity factor and the 100-hour exposure period, or these should be changed to the more severe conditions.

Response

The response to this question has been incorporated into ISFSI SAR Section 2.3.

Question 1.3.3

Provide a discussion of the potential for lightning strikes at the ISFSI. This discussion could include the following topics:

1. Onsite experience with lightning strikes on Surry Power Station structures and switchyard facilities.
2. A correlation of the frequency and intensity of both single and multiple lightning strikes associated with regional thunderstorms.
3. The expected frequency of thunderstorms at the ISFSI site.
4. The limiting case for energy release associated with a lightning strike.

Response

ISFSI ER Section 2.3 and SAR Section 2.3 have been revised to reflect the response to this question.

Question 1.3.4

Provide a correlation between the Surry site specific data, developed over the years the onsite meteorological program has been established at the Surry site, and the Richmond and Norfolk data provided in Tables 2.3-l through 2.3-4.

Response

Surry ISFSI ER Section 2.3 and SAR Section 2.3 have been revised to reflect the response to this question.

Question 1.3.5E

Describe the methodology for obtaining the χ/Q values in Table 7.1-3 and Figure 7.1-1. Include the models and input data used.

Response

Surry ISFSI SAR Section 2.3 has been revised to reflect the response to this question.

Question 1.3.6

Provide an analysis of the χ/Q values based on onsite meterological data and appropriate atmospheric diffusion models.

Response

Surry ISFSI SAR Section 2.3 has been revised to reflect the response to this question.

Question 1.3.7

Since the ISFSI will be located close to the primary and back-up meteorological towers, and the casks provide a continuing heat source; provide an analysis of the impact of the meteorological measurements at these towers.

Response

Surry ISFSI SAR Section 2.3 has been revised to reflect the response to this question.

Question 1.3.8E

In Section 5.6.2, Climatological Impact, it is stated that the cask surface temperature may reach 260°F, concluded that the affected area for atmospheric heating and fogging during precipitation would be small and any enhancement of fog beyond the site boundary would be negligible. Provide the calculations and bases for these conclusions. Include input parameters and equations used in the calculation.

Response

Surry ISFSI ER Section 5.6.2 has been revised to reflect the response to this question.

Question 1.4.1

The historical earthquake data presented and the development of the ISFSI design earthquake (0.07g) utilizing Trifunac and Brady's 1975 study *The Correlation of Seismic Intensity Scales with Peaks of Recorded Strong Ground Motion* does not correspond to the information presented for the selection of 0.15g safe shutdown earthquake for the Surry Power Station. For example, the 1927 Coastal Plain earthquake occurring near the central New Jersey coast is not identified in the historical earthquake data for the ISFSI. Adopt the corresponding g value developed for the nuclear power plant, or justify this new analysis in terms of the criteria of Appendix A of 10 CFR Part 100. In any case the g value should not be less than 0.10g per paragraph 72.66 (a)(b)(iii) or 10 CFR Part 72.

Note: Section 2.6.2.5 uses Applied Technology Council's seismic zonation map in their 1978 publication, *Tentative Provisions for the Development of Seismic Regulations for Buildings* NBS special publications 510, for additional justification. This reference is based on USGS Open File Report published in 1978, and it is not suitable for determining design earthquakes for structures. This was discussed in supplementary information published in the *Federal Register*, Volume 45, No. 220 on November 12, 1980 accompanying the promulgation of 10 CFR Part 72. In addition, there is an update on the USGS report. It is *Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States*, by S. T. Algermissen, D. M. Perkins, P. C. Thenhaus, S. L. Hauson and B. L. Bender, U.S.G.S., Open-File Report 82-1033, 1982. This report includes preliminary maps of horizontal acceleration (expressed as percent of gravity) with a 90 percent probability of not being exceeded in 10, 50 and 250 years. On the 10-year map, the maximum g value for site area is 0.04, on the 50-year map, the maximum g value for the site area is 0.10 and on the 250-year map, the maximum g value for the site area is 0.20. The differences between the results of this study and those presented in Surry ISFSI SAR are significant relative to both g values and recurrence interval. This report is more recent than any of the references cited in connection with Section 2.6 of the SAR.

Response

1. NRC Questions 1.4.1, 3.2.1, and 3.2.2 presented NRC concerns with respect to the seismological, geological, and structural design bases for the Surry Dry Cask ISFSI. A meeting was held between Virginia Power and the NRC on March 8, 1984 to discuss the issues raised in the NRC questions. Due to the nature of the questions, and the fact all three deal with the determination of the design seismic event and its effect on the structural slab, cask, and stored spent fuel, no individual responses are made to these questions. Instead, a single response that answers the concerns raised by the NRC, as related to all three questions, was prepared and is presented below. This approach was discussed and agreed upon at the March 8, 1984 meeting.

   The Surry Dry Cask Independent Spent Fuel Storage Installation (ISFSI) is designed to store spent fuel resulting from the operation of Surry Power Station Units 1 and 2. The spent fuel will be stored in dry sealed surface storage casks (SSSCs), which provide shielding and confinement of the radioactive fission products. The ISFSI facility will consist, in its final stage, of three separate reinforced concrete slabs. A general site layout for the ISFSI is shown in Figure 4.1-1 of the Safety Analysis Report. Each concrete slab, which will have overall dimensions of 32 feet in width, 230 feet in length, and 3 feet in thickness, is designed to support 28 SSSCs. The slab will be supported on a 7-foot-thick bed of compacted backfill material, which is then underlain by the naturally occurring site soils.

Separate investigations and analyses, outside those previously performed for Surry Units 1 and 2 and the once proposed Surry Units 3 and 4, were conducted for the Surry ISFSI. These analyses were performed as part of the response to the NRC questions and later discussions with the NRC regarding these questions. At the March 8, 1984 meeting between Virginia Power and the NRC, specific criteria for the resolution of NRC concerns were discussed. These criteria are as follows:

a. A Design Earthquake (DE) that is developed based on criteria of 10 CFR 72.66(b).

b. A cask tip over must be assumed regardless of analyses that demonstrate that the integrity of the structural pad is maintained and that the cask will not tip over. This criteria is independent of a specific seismic acceleration. Assuming a cask tip over, the analysis must demonstrate that: 1) criticality is within acceptable limits, 2) there is no loss of confinement, and 3) fuel is removable after a tip over.

c. Analyses of the slab under DE must demonstrate that the design function of the ISFSI is not adversely affected and that there is no impact on the public health and safety.

In order to meet these criteria, the additional analyses and investigations which were performed included the determination of a Design Earthquake (DE) based on 10 CFR 72.66(b), a site specific investigation, a soil stability analysis (static and dynamic), and design analyses of the structural slab. Additional analyses in support of their licensing efforts are being performed by General Nuclear Systems, Inc. (GNS), the cask vendor, to determine the criticality, cask integrity, and basket integrity based on a hypothetical cask overturning event.

The extent of the information required to be submitted to address the NRC's concerns with respect to seismicity and stability of subsurface materials has been included in revised SAR Section 2.6 and new SAR Appendix 3A.

A summary of revised SAR Section 2.6 and new Appendix 3A is contained in Parts 2 and 3 of this response. A discussion of the structural analysis as requested by the NRC, the response of the cask due to a overturning event, and the conclusions of these additional analyses are provided in new Appendix 3A.

2. SEISMOLOGY

The requirements of 10 CFR 72.66(b) stipulate that for determining the seismic design level of a dry cask facility, a site specific investigation, must be performed to establish site suitability commensurate with the specific requirements of the ISFSI. Due to the inherent safety of the SSSCs and the fact that the structural slabs are not important to safety, the approach that was taken to determine the proper seismic design level was based on the use of a building code type seismic design level. Determination of this type of seismic design level depends principally on historic site intensity or probabilistic site

acceleration at approximately the 500-year return period and not on a maximum credible site intensity. Applicable studies, which are referenced in revised Section 2.6 of the Safety Analysis Report, indicate that the appropriate probabilistic acceleration is 5 percent of gravity or less and that the historic intensity is VI Modified Mercalli (MM) or less for the Surry ISFSI site. This intensity can be related to a peak horizontal acceleration of 6.6 percent of gravity.

Based on the results of this site specific investigation, a conservative value for the seismic design level or Design Earthquake (DE) of 7 percent of gravity at the foundation level was adopted for the Surry ISFSI. The details of the site specific investigation and the development of the Design Earthquake are contained in revised Section 2.6 of the Safety Analysis Report.

3. STABILITY OF SUBSURFACE MATERIALS

A site specific subsurface investigation and laboratory testing program was conducted for the ISFSI in April and May 1982. The investigation included the drilling of nine test borings, the installation of an observation well, and taking of both undisturbed and disturbed soil samples. The boring logs resulting from the investigation are shown in Figures 2.6-32 through 2.6-42 of the Safety Analysis Report. The boring location plan is shown in Figure 2.6-43. All field work was monitored by a geotechnical engineer. Select recovered samples obtained during the investigation were sent to a testing laboratory for determination of the engineering properties of the site soils. The results of both the field and laboratory investigations were then used to determine the static and dynamic stability of the site soils.

The static analyses, which were performed, included a bearing capacity and settlement analysis. Based on the results of these analyses, it was determined that it will be necessary to excavate and replace the upper soil with a compacted backfill material. In order to obtain the required minimum factor of safety of 3.0 for bearing capacity, 7 feet of soil below the bottom of the slab will be excavated and replaced with fill. The fill will be placed to a minimum density of 95 percent of optimum modified proctor density (ASTM D 1557). The bearing capacity factor of safety with the structural backfill in place is greater than 3.0. The calculated settlement due to static loading is less than 2.0 inches.

The dynamic analysis of the site soils was performed to determine the soil response to dynamic loading. The dynamic loading considered in the analysis was the Design Earthquake (DE) with a maximum ground acceleration of 7 percent of gravity at the foundation level. The analysis indicated that the stability of the site soils would not be adversely affected by the level of dynamic loading. The magnitude of subsidence under dynamic loading can be considered insignificant and will have no adverse effect on the structural slab. A liquefication analysis was also performed on all soil layers below the

maximum ground water level. The analysis, which was based on the "Simplified Procedure" developed by Seed and Idriss (References 1 and 2), indicated that the minimum factor of safety against liquefication occurring is 1.5. The calculations using the simplified procedure do not incorporate any adjustment factors for the silt content of any specific soil layer. In addition, the dynamic stresses induced by the DE in the cohesive soil layer are considerably less than the shear strength of these layers. Therefore, no reduction of shear strength will result.

In summary, it can be concluded that the site soils at the ISFSI site will provide a safe and stable foundation under both static and dynamic loading conditions. The details of the soil stability analysis are contained in revised Section 2.6 of the SAR.

4. REFERENCES

1. Seed, H. B., I. M. Idriss, "Simplified Procedure for Evaluating Soil Liquefication Potential," Journal of the Soil Mechanics and Foundation Division ASCE, Vol. 97, No. SM9, September 1971.

2. Seed, H. B., I. M. Idriss, I. Arrango, "Evaluation of Liquefaction Potential Using Field Performance Data," Journal of Geotechnical Engineering ASCE, Vol. 109, No 3, March 1983.

Question 1.5.1

Provide a summary of all factors developed in the site characteristics chapter that are deemed significant to the selection of design bases for the ISFSI. For each factor, identify if it was newly developed in the ISFSI SAR, or if it was referenced from a document previously submitted to the NRC. If it is referenced, provide the specific reference, its date and revision, and the applicable page numbers.

Response

Table 2.7-l of the ISFSI SAR has been added to include the response to this question.

Question 2.1.1

Section 3.1.1 should be expanded to include the allowable limits on all pertinent characteristics of the spent fuel that can affect the design and operation of any portion of the ISFSI system. An allowable limit should be in terms of maximum, minimum, or a range of values, as appropriate and not an average or typical value. These limits provide the basis for assessing the compatibility of the ISFSI system with the spent fuel to be stored. Confirmatory analyses and performance requirements of the design and operation of the ISFSI system and its components will be required to envelope these limits. It is expected that most of these limits will be included in the limiting conditions for operation of the ISFSI and as such should be readily verifiable.

NOTE: If no limit is identified for a pertinent characteristic, then it will be assumed that the design and operation of the ISFSI will accommodate all possible values of that particular characteristic. For example, Section 10.1.1.1 Fuel To Be Stored At ISFSI states “The fuel shall be stored unconsolidated and shall not be extensively damaged”. It further identifies damage relative to maintaining cooling geometry and the ability to insert and remove the fuel from the storage cask. There is no mention of the initial fuel pin cladding integrity relative to its function as the primary confinement barrier to the release of radioactive material. Therefore, if that is the intention, a substitute barrier for the fuel pin cladding would have to be provided in the ISFSI system.

Response

Surry ISFSI SAR Sections 3.1 and 10.1 have been revised to reflect the response to this question.

Question 2.1.2

For each pertinent characteristic identified in 2.1.1, provide the method by which the characteristic will be verified.

NOTE: A verification method need not directly measure a pertinent characteristic. Another characteristic, more amenable to verification, could be used to assure the existence of the pertinent characteristic. Also a verification method can accommodate more than one pertinent characteristic.

Response

Surry ISFSI SAR Sections 9.1 and 10.1 have been revised to reflect the response to this question.

Question 3.1.1

Elaborate on Table 3.3-l by providing the design criteria and performance specifications to be imposed on cask designers and suppliers. The following paragraphs present examples of topics that should be addressed as an indication of the breath of coverage needed. They should not be considered as a comprehensive listing of cask design requirements, nor should any example requirements be considered as mandatory for the Surry ISFSI system. The discussion of each topic should include the basis for any requirement.

Spent Fuel Storage Environment

Identify the required storage environment for the spent fuel inside the cask and the range of external conditions under which the environment must be maintained. This could include the following characteristics:

- Maximum Clad Temperature
- Cask Internal Pressure
- Storage Atmosphere and its Allowable Impurities (e.g., moisture)
- Corrosion Protection
- Fuel Element Spacing, Support and Protection

Physical Constraints

These are the limits placed on the physical characteristics of the cask due to pre-established ISFSI interfaces:

- Size limits due to at-reactor handling and decontamination facilities;
- Weight limits due to at-reactor crane constraints and design parameters of onsite transporter, roadways, storage pad and placement crane;
- Cask appendages required to match any existing cask handling; monitoring, and servicing hardware and subsystems.

Material Considerations

In order to assure material compatibility with its use and environment, consider the following topics:

- Limits on degradation due to radiation damage, weathering, and temperature extremes;
- Corrosion resistance and compatibility with fuel element materials; and
- Qualification of uncoded materials.

Mechanical Requirements

These following features are required for the proper operation of the casks:

- Support structure design constraints to preclude spent fuel loading damage, control criticality, and to assure post-storage and recovery operation fuel element removal;
- Cask appendages required to interface with cask handling, monitoring, servicing, closure, testing, onsite transport, and placement hardware and subsystem design;
- Cask lid closure and sealing requirements to control releases.

Structural Requirements

The following requirements identify the forces the cask must be able to resist:

- Identify all individual site and system related environmental and operational loads to be considered in the cask's structural analysis. (These loads should be quantified, or identified in such a manner that they can be readily quantified by the cask designer.)
- Specify the required variance for each load to be considered in the structural analysis.
- For each different operational or environmental condition to be analyzed, provide the applicable combined loading equations with the site and system defined loads inserted.
- List operational and environmental conditions not considered in the loading equations and the ISFSI design feature that precludes their consideration. (For example: "Impact loads due to casks overturning during the design earthquake are not considered. The casks are placed on a Seismic Category 1 concrete pad, and the following analysis shows that casks of a L/D ratio of less than 4 to 1 will not tip over due to the motion of the concrete pad during by the design earthquake. All cask having a L/D ratio in excess of 4 to 1 will be anchored to the concrete pad to prevent overturning due to the design earthquake." The mentioned analysis is then presented.)
- Specify any special structural code requirements.

Thermal Characteristics

Thermal performance specification for individual casks may include:

- Amount of heat to be used dissipated to the atmosphere under limiting operational and environmental conditions;
- The required heat capacity available to accommodate thermal fluctuations beyond the limiting conditions, during transient operational modes, and for accident recovery operations; and
- Allowable peak temperatures within the cask.

Nuclear and Radiological Characteristics

Provide the limiting specification for:

- Neutron and gamma shield requirements based on ALARA studies for all operational modes;
- Allowable leak rates for gaseous and particulate material; and
- Criticality considerations.

Special Features

Provide the requirements for special features associated with the cask. These could include:

- Cask Atmosphere Purging Appendages
- Monitoring Instrumentation for Stored Spent Fuel Condition, Cask Internal Atmosphere, and Cask Condition
- Material Accountability Seals
- Decontamination and Recovery Features
- Lightning Protection

Response

The information requested by this question is contained in the GNSI Topical Report[(1)].

Reference

1. *Topical Safety Analysis Report for the CASTOR V/21 Cask Independent Spent Fuel Storage Installation (Dry Storage)*, GNSI, January 1985.

Question 3.1.2

The various design criteria and performance specification identified in response to Question 3.1.1 will be reflected in actual design and manufacture of the storage casks. For each requirement identified in the response to Question 3.1.1, specify the actions that VEPCO will take to assure that the requirement is properly executed by the cask supplier. These actions could include: Specific quality control requirements in a quality assurance program, code usage and stamping, analytical verifications, acceptance tests, and prototype testing. Keep in mind that a performance characteristic or a design requirement need not be verified directly, it can be verified by qualifying a related characteristic or feature that is a good indicator for the basic requirement.

Response

Surry ISFSI SAR Section 11.1 has been revised to reflect the response to this question.

Question 3.2.1

Provide a detailed analysis of the stresses in stored spent fuel elements due to the forces caused by a cask tip over during the design earthquake. This analysis should include the basis for all assumptions and the factor of safety between the resultant stresses and the threshold stress for fuel damage. The verifiable post-reactor condition of the fuel should be quantified. That is, what allowance is made for the difference in structural integrity between irradiated and unirradiated fuel. How is this difference verified in terms of accepting individual spent fuel elements for storage in a cask.

Response

See response to Question 1.4. 1.

Question 3.2.2

In lieu of responding to Question 3.2.1, or if the resultant factor of safety identified from the analysis is too low; the concrete storage pad can be upgraded to a Seismic Category 1 item. If this is done, provide an appropriate structural analysis of the concrete slab and its supporting soil.

Response

See response to Question 1.4.1.

Question 3.3.1

What are the physical devices used on the handling equipment to limit impact loads during normal and off-normal operating conditions?

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 5.2.

Question 3.3.2

What are the physical devices used to prevent lifts in excess of these specified for handling equipment?

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 5.2.

Question 3.3.3

Provide the details of requalification activity for the cask and spent fuel following an off-normal handling accident.

Response

ISFSI SAR Section 8.2.10 has been revised to reflect the response to this question.

Question 4.1.1E

What was the neutron spectrum and flux-to-dose response used to estimate the neutron surface dose rate and dose vs. distance (Figures 3.5-2 and 3.5-3) for a cask?

Response

Surry ISFSI SAR Section 7.3 and Surry ISFSI ER Section 3.5 have been revised to reflect the response to this question.

Question 4.1.2E

What were the assumptions used in postulating the steel-lead-water wall used to shield the fuel for calculating the gamma surface dose rate and energy spectrum?

Response

The GNSI cask utilizes steel and polyethylene instead of steel-lead-water to shield the neutron and gamma radiation. The GNSI Topical Report (Reference 1) provides detailed discussion of the design features as well as the structures of the cask.

The assumptions used in calculating the cask surface dose rates and energy spectrum are discussed in Sections 3.3.5 and 7 of the GNSI Topical Report. A discussion of the calculation of neutron and gamma dose rates has been provided in revised Surry ISFSI SAR Section 7.3 and revised Surry ISFSI Section 3.5.

REFERENCE

1. *Topical Safety Analysis Report for the CASTOR V/21 Cask Independent Spent Fuel Storage Installation (Dry Storage)*, General Nuclear Systems, Incorporated, January 1985.

Question 4.1.3E

What computer code was used to generate the data in Tables 3.5-l and 3.5-2 of the ER and Tables 7.2-1, 7.2-2, 7.2-3 and 7.2-4 of the SAR?

Response

The response to this question has been incorporated in Surry ISFSI SAR Section 7.2 and Surry ISFSI ER Section 3.5.

Question 4.1.4

How will vendors demonstrate compliance with the cask surface dose rate criteria? What other computer codes or calculational techniques will be acceptable to VEPCO to demonstrate compliance? What are the key input parameters needed to demonstrate compliance?

Response

Sections 3.3.5 and 7 of the GNSI Topical Report (Reference 1) provide a discussion of the standard computer codes and calculational techniques used in determining the GNSI cask surface dose rates. The use of standard, industry-accepted computer codes is acceptable to Virginia Power for demonstrating compliance of the SSSCs with the design criteria. The key input data to be used in the calculations are the spent fuel design information (source term data) and the cask design information. Westinghouse source data, representative of the fuel to be stored in the SSSCs, have been utilized in the shielding calculations.

REFERENCE

1. *Topical Safety Analysis Report for the CASTOR V/21 Cask Independent Spent Fuel Storage Installation (Dry Storage)*, General Nuclear Systems, Incorporated, January 1985.

Question 4.2.1E

Section 7.3.2 of the SAR says, “Except during cask placement and scheduled surveillance the ISFSI will not be normally occupied.” What about operations at the LLWSF collocated with the ISFSI? No occupational exposure from the ISFSI to workers involved in operations at the LLWSF have been provided. Provide estimated occupational exposures to workers at the LLWSF from the ISFSI and the basis for your calculations.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.4 and ER Section 4.4.

Question 4.2.2

Provide an ALARA justification for collocating the LLWSF and the ISFSI.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.1.

Question 4.2.3E

Section 7.3.3.2 of the SAR indicates that the dose rate analysis at the restricted area fence does not include the contribution from the LLWSF. Revise Table 4.4-l of the ER and Table 7.3-l of the SAR to include the contribution from the LLWSF.

Response

Surry ISFSI SAR Section 7.3 and ER Section 4.4 have been revised to include the contribution from the LLWSF.

Question 4.2.4E

In Section 7.4 of the SAR, no total collective occupational dose is provided. How many workers at the Surry Power Station will receive the additional 56 mrem yr from the ISFSI? What is the additional occupational dose to workers at the LLWSF from the ISFSI? What are the bases for the dose rate estimates used in SAR Tables 7.4-1, 7.4-2 and 7.4-3 (ER Tables 4.4-2, 4.4-3 and 4.4-4)?

In SAR Table 7.4-3 (ER Table 4.4-4), what is the occupational dose due to excavation and construction? Provide a total collective occupational dose for ISFSI operations and assess how it affects the collective occupational dose at the Surry Power Station.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.4 and ER Section 4.4.

Question 4.3.1E

SAR Section 7.6 is titled “Estimated Offsite Collective Dose Assessment,” yet no collective offsite dose is evaluated. Only a maximum dose to an individual located at 1.53 miles is given. Figure 2.1-3 in the SAR indicates that 3 people reside within the 0-l mile annulus and 49 people in the l-2 mile annulus of the Surry Power Station. Explain the discrepancy about the location of the nearest individual and provide an offsite collective dose assessment.

Response

Surry ISFSI SAR Figure 2.1-3 has been revised and a collective offsite dose has been calculated accordingly and is reported in revised SAR Section 7.6 and ER Section 5.2.

Question 4.3.2E

Relative to SAR Section 7.6.1: the principle contributor to dose from the ISFSI will be neutrons, and the information about environmental monitoring does not provide enough information about capabilities for measuring doses from neutrons around the restricted area fence. Describe the type, number and locations of the TLD’s to be placed around the ISFSI restricted area fence.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.6 and ER Section 6.2.

Question 4.3.3E

Relative to SAR Section 7.6.2: If the maximum dose to an individual from ISFSI operations were added to the design objective doses specified in 10 CFR Part 50, Appendix I, for releases of radioactive material from reactor operation, the limits of 10 CFR 72.67 and 40 CFR Part 190 could be exceeded. Considering the uncertainty in calculating the neutron dose rate at distances of 1.5 miles, and the difficulty of measuring such low doses from neutrons; how will you ensure that the dose to an individual from ISFSI operations when combined with doses from reactor operations does not exceed these limits? Provide your method of demonstrating, by calculational procedures based on models and data, that the actual dose of an individual from ISFSI operations when combined with the doses from Surry Power Station Units 1 and 2 and other Uranium Fuel Cycle facilities does not exceed the 25 mrem/yr limit specified in 10 CFR 72.67 and 40 CFR Part 190.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.6 and ER Section 5.2.

Question 4.4.1

The procedures for the decommissioning of the ISFSI should be addressed conceptually for the purposes of demonstrating that it is a manageable task. To the extent possible, Vepco should identify: specific levels of contamination and activation products expected at the end of useful cask life, the specific procedures anticipated for clean-up of the cask, and the expected disposition of the cask.

Response

Surry ISFSI SAR Section 9.6 and ER Section 5.8 have been revised to reflect the response to this question.

Question 4.4.2E

Provide the basis and supporting analysis for your conclusion in ER Section 5.8 that “the cask materials will be only very slightly activated as a result of their long-term exposures to the relatively small neutron flux…”

Response

Surry ISFSI SAR Section 9.6 and ER Section 5.8 have been revised to reflect the response to this question.

Question 4.5.1E

Other radiation from the uranium fuel cycle is included in 10 CFR 2.67(a)(3). Provide an assessment of the combined effects of the ISFSI and the Surry Power Station.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.6 and ER Section 5.2.

Question 4.6.1E

More information is needed about your capabilities for assessing neutron dose in the environment.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.6 and ER Section 6.2.

Question 4.6.2

Provide a complete description of any radiation monitoring program to be established for the ISFSI related activities. This discussion should address the following issues as appropriate:

- Location and type of instrumentation for ISFSI storage area radiation monitoring;
- Type and location of instrumentation for individual cask radiation monitoring;
- Monitoring schedule; and
- High radiation alarm system.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.6 and ER Section 6.2.

Question 4.7.1

The radiation protection procedures related to a high radiation situation should discuss the following topics:

- Safety precautions
- Personnel required (by skilled/specialty level)
- Repair equipment/material required
- Provisions for workers protection
- Provisions for protection of other personnel

Response

Surry ISFSI SAR Section 9.4 has been revised to reflect the response to this question.

Question 5.1.1E

Report separately the capital cost, and operation and maintenance cost components of the total lifetime cost reported in Section 9.1.3 and 9.1.4.

Response

Surry ISFSI ER Section 9.1 has been revised to reflect the response to this question.

Question 5.2.1.

What special provisions will be added to your Quality Assurance Program to accommodate the ISFSI activity?

NOTE: During the development of the specific information for ISFSI Quality Assurance Program, it is suggested that you review your existing program for attributes described in the attachment “QA Checklist for Dry Storage Casks”.

Response

Surry ISFSI SAR Section 11.1 has been revised to reflect the response to this question

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Question 5.2.2

What special provisions will be added to your Emergency Plan to accommodate the ISFSI activity?

NOTE: It is suggested that an adjunct to the existing Emergency Plan adds the following events:

For the Notification of Unusual Events Category,

- Loss of Cask Neutron Shield
- Cask Seal Leakage
- Cask Drop or Other Handling Mishap

For the Alert Category,

- Loss of All Fuel Confinement Barriers From Some Undefined Cause

Response

Surry ISFSI SAR Section 9.5 has been revised to reflect the response to this question.

Question 5.2.1.

What special provisions will be added to your Quality Assurance Program to accommodate the ISFSI activity?

NOTE: During the development of the specific information for ISFSI Quality Assurance Program, it is suggested that you review your existing program for attributes described in the attachment “QA Checklist for Dry Storage Casks”.

Response

Surry ISFSI SAR Section 11.1 has been revised to reflect the response to this question

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Question dated October 1, 1984

The proposed revision to Section 2.6.4.8, “Liquefaction Potential,” of the Surry ISFSI Safety Analysis Report presents the procedure, including mathematical relations, used to predict soil liquefaction potential at various depths below the proposed ISFSI. This procedure consists of evaluating the shear stresses expected during the design earthquake loading. It is stated in Subsections 2.6.4.8.2 and 2.6.4.8.3 that the calculated factors of safety are 2.5 and 1.5, respectively, for the Pleistocene Sand and Miocene Silty Sand layers.

We understand that these liquefaction potential calculations were performed at a variety of depths below the water table. Please provide the calculational results for the range of depths examined in the two sand layers mentioned above. Please specify what specific parameters (e.g., effective overburden pressures, standard penetration field values, etc.) were used in making the above calculations. A tabular presentation form, which clearly identifies the values of the various parameters used in the calculation, as well as the calculational result, would be very useful.

Response

The response to this question has been incorporated into SAR Section 2.6.

Question 1 (November 14, 1984)

Regarding your response to Question 4.1.1E, what are the neutron energy flux response functions that were used to calculate the neutron dose rate versus distance from the cask flux leakage spectra supplied by GNS?

Response

The response to this question has been incorporated into Surry ISFSI SAR Sections 7.3 and 7.4 and Surry ISFSI ER Sections 3.5 and 4.4.

Question 2 (November 14, 1984)

In your response to Questions 4.2.4E and 4.3.1E, neutron and gamma dose rates were cited for distances greater than shown in ER Figure 3.5-2 and SAR Figure 7.3-4. Please provide additional figures showing neutron and gamma dose rates, from one cask of five-year-old spent fuel, versus distance out to the nearest permanent resident (1.53 mi). ER Figure 3.5-4 and SAR Figure 7.3-5 should also show the neutron and gamma components of the total dose rate.

Response

Surry ISFSI SAR Figures 7.3-5 and 7.3-6 and ER Figures 3.5-4 and 3.5-5 have been added to reflect the requested distance.

Question 3 (November 14, 1984)

Please provide revised figure showing the neutron and gamma dose rate at the cask surface versus time that was used to calculate dose rates from a full 84-cask configuration, adjusted for decay.

Response

Surry ISFSI ER Figure 3.5-3 and Surry ISFSI SAR Figure 7.3-2 have been revised to show the normalized GNSI cask surface dose rates versus time.

Question 4 (November 14, 1984)

Your response to Questions 4.2.1E and 4.2.2 discusses occupational exposures received at the LLWSF due to the ISFSI. In order to better assess the impact the ISFSI has on the LLWSF occupational exposures, please provide an estimate of the occupational exposure at the LLWSF without the collocated ISFSI.

Response

The response to this question has been incorporated into Surry ISFSI SAR Section 7.4 and ER Section 4.4.

Question 5 (November 14, 1984)

In your response to Question 4.2.3E, Table 4.4.1 does not include the dose rate contribution from the LLWSF as indicated in the accompanying narrative. Please revise this table to include the dose rate contribution from the LLWSF assuming that it was filled to design capacity.

Response

Surry ISFSI ER Table 4.4-l and SAR Table 7.3-l have been revised to include the dose rate contribution from the LLWSF assuming that it was filled to design capacity.

Question 6 (November 14, 1984)

In reviewing the ER, SAR and your response to Question 4.2.3E, some confusion has arisen about your use of the term “restricted area”. Please review the use of this term as applied to the ISFSI to ensure that it is consistent with health physics practices at the Surry Power Station.

Response

The Surry Updated FSAR Figure 2.1-12 illustrates the existing Surry Power Station restricted area boundary. The restricted area boundary for the ISFSI will be identical with the one shown on the figure. The Surry ISFSI SAR and ER have been revised accordingly. Designation of this boundary for the ISFSI is not in conflict with health physics practices at the Surry Power Station.

Question 7 (November 14, 1984)

The License Application (Chapters 1 and 3) indicate 82 casks at the ISFSI. Yet, the ER (Chapter 3) and the SAR (Chapters 4 and 7) imply 84 casks at the site. Please clarify.

Response

The response to this question has been incorporated into the License Application, ISFSI SAR Section 3.1 and ISFSI ER Section 3.5.

Appendix A
SSSC SPECIFIC INFORMATION

This appendix provides:

- A list of topical reports issued by cask manufacturers (Table A/1.5-1)
- A subappendix for each cask type that provides specific references to the SSSC topical reports (in tables) and specific information not contained in the SSSC topical reports

Table A/1.5-1
TOPICAL SAFETY ANALYSIS REPORTS ISSUED
BY CASK MANUFACTURERS

A.1 *Topical Safety Analysis Report for the CASTOR V/21 Cask Independent Spent Fuel Storage Installation (Dry Storage),* Revision 2A, General Nuclear Systems, Inc., June 1987.

A.2 *Topical Safety Analysis Report for the Westinghouse MC-10 Cask for an Independent Spent Fuel Storage Installation (Dry Storage),* Revision 2A, Westinghouse Nuclear Energy Systems, November 1987.

A.3 *Topical Safety Analysis Report for the NAC Storage/Transport Cask Containing 28 Intact Fuel Assemblies for Use at an Independent Spent Fuel Storage Installation,* Revision 1A, Nuclear Assurance Corporation, June 1990.

A.4 *Topical Safety Analysis Report for the CASTOR X Cask for an Independent Spent Fuel Storage Installation (Dry Storage),* Revision 4, General Nuclear Systems, Inc., September 1990.

A.5 *TN-32 Dry Storage Cask Topical Safety Report,* Revision 9A, Transnuclear, Inc., December 1996.

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Appendix A.1
CASTOR V/21 CASK

GENERAL DESCRIPTION

The GNSI CASTOR V/21 cask is a thick-walled nodular cast iron cylinder that is approximately 4.9 meters high (192.4 in.), 2.40 meters (94.5 in.) in diameter with fins, and weighs (empty) 92.3 metric tons (101.8 tons). The side wall thickness without fins is about 379 mm (14.9 in.). The cask has a cylindrical cask cavity which holds a fuel basket which is designed to accommodate 21 PWR fuel assemblies. The loaded weight of the cask is about 106 metric tons (116.9 tons).

The cask is sealed with two lids installed one on top of the other. Both lids are sealed with multiple seals consisting of metal seals and elastomer o-rings. The primary lid is constructed of stainless steel. The overall thickness is 290 mm (11.4 in.). The secondary lid is also made of stainless steel. The overall thickness is 90 mm (3.5 in.). The lids are fastened to the body with bolts.

For neutron shielding, two concentric rows of axial holes in the wall of the cask body are filled with polyethylene rods. The bottom and the secondary cover each have a slab of the same material inserted for the same purpose. The cast iron wall of the cask provides gamma radiation shielding.

In the area of the fuel assemblies, the body has cooling fins on the outside. Four trunnions are bolted on, two at the head end and two at the bottom end of the body.

A.1/3.1.1 Materials to be Stored

The structural evaluations of the CASTOR V/21 are provided in Chapters 4 and 8 of the Topical Report. These evaluations used a fuel assembly weight of 1442 lb, but the possible combinations of Surry Units 1 and 2 fuel assemblies containing a burnable poison rod assembly (BPRA) or thimble plugging device (TPD) could weigh up to 1525 lb. An evaluation has been performed by GNSI to evaluate the effect of the increased weight of the fuel assembly from 1442 lb to 1525 lb This evaluation concluded that the calculated stresses at all locations in the cask and basket were less than the allowable stresses. At one location, credit was taken in the evaluation for the actual basket temperature.

An evaluation has also been performed on the effect to the cask surface dose rates as a result of placing BPRAs or TPDs in the fuel stored in the CASTOR V/21. This evaluation confirmed that the calculated surface dose rates for the CASTOR V/21 remained less than the design basis dose rates used to calculate doses at the ISFSI perimeter and to the nearest resident.

An evaluation has been performed on the effect on criticality control from the storage of BPRAs or TPDs in the fuel stored in the CASTOR V/21. BPRA rods will displace water (a

moderator) in the fuel assembly thimble tubes, therefore, even the use of depleted BPRAs will reduce reactivity in a cask. TPDs are short and do not displace water in the thimble tubes, therefore, their use will not affect reactivity.

The CASTOR V/21 is designed for a maximum internal pressure under accident conditions, and helium buildup or pre-pressurization in BPRAs will affect this analysis. The confinement analysis for the CASTOR V/21 has been reanalyzed for twenty-one 20-finger BPRAs, and this reanalysis shows that the maximum pressure under accident conditions would be 3.4 bars absolute, when the design basis for this cask is 8 bars absolute. The impact of TPDs on the confinement analysis is bounded by the impact of BPRAs.

To account for the additional decay heat from BPRAs and TPDs, fuel assembly decay heat estimates must include an estimate for the decay heat from the actual component in each fuel assembly. Therefore, the combined decay heat from the fuel assembly and its component must be less than the limit for a fuel assembly in the CASTOR V/21.

Based on these evaluations, the storage of fuel assemblies with BPRAs or TPDs is acceptable for the CASTOR V/21.

A.1/7.3.2.1 Cask Surface Dose Rates

The assumptions used in calculating the GNSI CASTOR V/21 cask surface dose rates and energy spectra are provided in Sections 3.3.5 and 7.3.2.2 of the GNSI Topical Report (Reference 1). This analysis was performed using these same assumptions except that the values for fuel enrichment and burnup were increased to 3.7 weight percent U^{235} and 40,000 MWD/MTU, respectively.

Neutron and gamma source terms for the stored spent fuel were generated using OREST (ORIGEN II). Typical results from these runs are shown in Surry ISFSI SAR Tables 7.2-1, 7.2-2, 7.2-3, and 7.2-4. ANISN (Reference 4) and DOT (Reference 10) were used by GNSI to calculate the cask surface fluxes. Flux-to-dose rate conversion factors, as shown in Tables 7.2-2 and 7.2-3 of the *GNSI CASTOR V/21 Topical Report* (Reference 1), were then used to obtain the surface dose rates for the cask. The GNSI cask average surface dose rates for 5-year-old fuel are 9.5 mrem/hour neutron and 27.8 mrem/hour gamma for the side and 29.7 mrem/hour neutron and 0.7 mrem/hour gamma for the top. When these dose rates are combined, the side and top average surface dose rates are 37.3 mrem/hour and 30.4 mrem/hour, respectively. These dose rates are bounded by the total average surface dose rates of 224 mrem/hour for the side and 76 mrem/hour for the top reported in the Surry ISFSI SAR, Section 7.3.2.1.

Figure A.1/7.3-2 shows the normalized surface dose rates on the GNSI CASTOR V/21 cask versus age of spent fuel for both gamma and neutron radiation.

A.1/7.3.2.2 Dose Rate Versus Distance

The cask surface dose rates discussed in Section A.1/7.3.2.1 result in the dose rates at various distances as shown on Figures A.1/7.3-7a through A.1/7.3-10. The neutron transport results shown on these figures were generated using a series of adjoint (References 2 & 3) ANISN (Reference 4) runs. These calculations were performed with a BUGLE-80 (Reference 5) cross-section set for an infinite-air medium. As explained in References 2 and 3, the adjoint method is the preferred analytical technique when more than one set of sources must be evaluated at a given detector location for a response of interest. For the adjoint analyses reported here, the adjoint source is the flux-to-dose conversion factor reported in Reference 9. Four separate ANISN analyses were performed at distances of 50, 460, 1500, and 2460 meters. The resulting adjoint fluxes are presented in Tables A.1/7.3-3 and A.1/7.3-4. These adjoint fluxes were then folded with the cask surface leakage spectra supplied by GNSI over the area of the cask's top and side, respectively. Cask surface neutron leakage data are provided in Table A.1/7.3-2. (The 84-group structure in the GNSI cask's leakage spectrum for the side of the cask was collapsed to the 47-group BUGLE structure prior to folding the data.)

The resultant neutron dose rates were then used to construct the dose rate versus distance curves presented on Figures A.1/7.3-7a, A.1/7.3-8a and A.1/7.3-9a.

For the gamma-ray transport, simple point kernel calculations using infinite medium dose rate buildup factors in dry air were performed. Using a point source model and References 6 and 7, air-to-void correction factors were developed and applied to the gamma dose rates in void based on Reference 8. The gamma dose rates for the casks are shown on Figures A.1/7.3-7b, A.1/7.3-8b and A.1/7.3-9b.

For Figure A.1/7.3-10, decay factors have been used assuming that four casks are placed in the ISFSI each year for 21 years and each new group of four casks has a minimum of 5 years decay of the fuel. As shown on Figure A.1/7.3-10, the design basis dose rate for the ISFSI bounds the dose rate for the ISFSI filled to capacity with 84 GNSI CASTOR V/21 casks.

A.1/7.3.5 References

1. *Topical Safety Analysis Report for the GNSI CASTOR X Cask for an Independent Spent Fuel Storage Installation (Dry Storage),* General Nuclear Systems, Inc., June 1988.

2. V. R. Cain, *The Use of Discrete Ordinates Adjoint Calculations,* A Review of the Discrete Ordinates 5 Method for Radiation Transport Calculations, ORNL-RSIC-19, March 1968, pp. 85-94.

3. G. I. Bell, S. Glasstone, Nuclear Reactor Theory, Chapter 6.1 - *The Adjoint Function and Its Applications,* Van Nostrand Reinhold Company, New York, 1970.

4. W. W. Engle, Jr., *A User's Manual for ANISN, A One-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering,* K-1643, Union Carbide Corporation, Nuclear Division, June 1973.

5. *BUGLE-80, Coupled 47-Neutron, 20-Gamma-Ray, P3, Cross-Section Library for LWR Shielding Calculations,* DLC-75, R. W. Roussin, ORNL, June 1980.

6. Warkentin, J. K., *Polynominal Coefficients for Dose Buildup in Air,* Radiation Research Associates, Inc., August 15, 1975, RRA-N7511.

7. Hubbell, L. H., *Photon Cross-Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 KeV to 100 GeV,* National Bureau of Standards, August 1969, NSRDS-NBS29.

8. Spacetran II, *Dose Calculations at Detectors at Various Distances from the Surface of a Cylinder,* Neutron Physics Division of Oak Ridge National Laboratory, September 1973, ORNL-TM-2592.

9. ANSI/ANS-6.1.1-1977, *American National Standard - Neutron and Gamma Ray Flux to Dose Rate Factors,* American Nuclear Society, March 17, 1977.

10. Mynatt, F. R., Rhodes, W. A., et al., *The DOT-II Two Dimensional Discrete Ordinates Transport Code,* ORNL-TM-4280.

Table A.1/7.3-2 (SHEET 1 OF 2)
CASTOR V/21 CASK SURFACE NEUTRON LEAKAGES

Neutron Group	Upper[a] Energy (ev)	Cask Surface Leakage Spectra (n/cm^2 - sec)	
		Side	Top
1	1.7E+07	1.10E-03	1.49E-04
2	1.4E+07	3.06E-03	4.14E-04
3	1.2E+07	1.55E-02	1.86E-03
4	1.0E+07	2.67E-02	2.79E-03
5	8.6E+06	3.80E-02	3.56E-03
6	7.4E+06	7.11E-02	6.76E-03
7	6.1E+06	1.17E-01	1.18E-02
8	5.0E+06	2.68E-01	3.37E-02
9	3.7E+06	2.21E-01	3.31E-02
10	3.0E+06	2.44E-01	4.70E-02
11	2.7E+06	2.26E-01	4.53E-02
12	2.5E+06	1.35E-01	2.69E-02
13	2.4E+06	3.00E-02	5.99E-03
14	2.3E+06	2.95E-01	7.25E-02
15	2.2E+06	7.63E+01	1.87E-01
16	1.9E+06	1.67E+00	6.22E-01
17	1.6E+06	2.43E+00	9.47E-01
18	1.4E+06	6.90E+00	9.40E+00
19	1.0E+06	8.07E+00	1.41E+01
20	8.2E+05	3.51E+00	6.13E+00
21	7.4E+05	6.09E+00	1.06E+01
22	6.1E+05	1.31E+01	5.44E+02
23	5.0E+05	2.59E+01	1.24E+02
24	3.7E+05	1.46E+01	6.90E+01
25	3.0E+05	2.30E+01	1.09E+02
26	1.8E+05	1.46E+01	6.90E+01
27	1.1E+05	2.28E+01	6.76E+01
28	6.7E+04	1.39E+01	4.11E+01
29	5.0E+04	4.76E+00	1.41E+0l
30	3.2E+04	2.98E+00	8.83E+00
31	2.6E+04	9.90E-01	2.94E+00
32	2.4E+04	1.21E+00	3.56E+00
33	2.2E+04	3.60E+00	1.07E+01
34	1.5E+04	4.13E+00	1.22E+01

Table A.1/7.3-2 (SHEET 2 OF 2)
CASTOR V/21 CASK SURFACE NEUTRON LEAKAGES

Neutron Group	Upper[a] Energy (ev)	Cask Surface Leakage Spectra (n/cm^2 - sec)	
		Side	Top
35	7.1E+03	1.96E+00	5.80E+00
36	3.4E+03	7.76E+00	1.77E+01
37	1.6E+03	6.96E+00	1.50E+01
38	4.5E+02	4.71E+00	9.05E+00
39	2.1E+02	2.25E+00	4.32E+00
40	1.0E+02	6.87E+00	9.47E+00
41	3.7E+01	5.84E+00	7.87E+00
42	1.1E+01	3.97E+00	4.21E+00
43	5.0E+00	3.46E+00	3.14E+00
44	1.8E+00	1.81E+00	1.34E+00
45	8.8E-01	1.19E+00	7.33E-01
46	4.1E-01	3.01E-01	1.36E-01
47	1.0E-01	8.63E-02	3.91E-02

Note: CASTOR V/21 Cask Surface Area: 400,000 cm^2 (side), 47,000 cm^2 (top).

a. Reference 5.

Table A.1/7.3-3 (SHEET 1 OF 2)
SIDE OF GNSI CASTOR V/21 CASK ADJOINT FLUXES[a]
FOR A SOURCE OF 1 n/sec PER GROUP

	SIDE OF CASK (rem/hr per n/sec)			
Neutron Group	50 Meters	460 Meters	1500 Meters	2460 Meters
1	1.0E-12	6.8E-15	1.1E-17	4.7E-20
2	9.6E-13	6.4E-15	1.1E-17	4.4E-20
3	8.4E-13	6.4E-15	1.2E-17	5.2E-20
4	8.0E-13	6.9E-15	1.4E-17	6.4E-20
5	8.1E-13	6.8E-15	1.2E-17	5.0E-20
6	8.1E-13	6.7E-15	1.2E-17	4.7E-20
7	8.6E-13	6.2E-15	8.3E-18	2.2E-20
8	8.2E-13	5.5E-15	4.8E-18	7.2E-21
9	8.0E-13	6.3E-15	4.3E-18	5.4E-21
10	7.9E-13	6.9E-15	4.6E-18	6.0E-21
11	7.8E-13	7.3E-15	4.4E-18	5.4E-21
12	7.9E-13	7.4E-15	4.0E-18	4.4E-21
13	7.9E-13	7.4E-15	3.9E-18	4.2E-21
14	7.9E-13	6.9E-15	2.6E-18	1.7E-21
15	8.1E-13	6.5E-15	1.6E-18	6.9E-22
16	8.5E-13	5.4E-15	6.2E-19	9.7E-23
17	8.5E-13	4.7E-15	3.9E-19	4.7E-23
18	8.6E-13	4.0E-15	2.3E-19	2.3E-23
19	7.7E-13	2.9E-15	1.1E-19	7.4E-24
20	7.1E-13	2.3E-15	4.3E-20	1.4E-24
21	6.4E-13	1.7E-15	2.2E-20	4.9E-25
22	5.9E-13	1.3E-15	8.9E-21	1.2E-25
23	5.0E-13	7.7E-16	1.3E-21	1.7E-27
24	3.9E-13	6.3E-16	8.1E-22	9.1E-28
25	3.1E-13	5.2E-16	4.8E-22	4.5E-28
26	2.0E13	3.2E-16	7.6E-23	1.3E-29
27	1.4E-13	2.2E-16	1.2E-23	3.2E-31
28	9.8E-14	1.6E-16	2.4E-24	1.1E-32
29	7.4E-14	1.3E-16	6.8E-25	1.0E-33
30	6.5E-14	1.1E-16	4.6E-25	6.0E-34
31	6.1E-14	1.0E-16	3.6E-25	4.4E-34
32	5.9E-14	1.0E-16	3.3E-25	3.9E-34
33	5.6E-14	9.3E-17	2.7E-25	3.0E-34
34	5.1E-14	7.9E-17	1.6E-25	1.6E-34
35	5.2E-14	5.6E-17	5.0E-26	2.9E-35

Table A.1/7.3-3 (SHEET 2 OF 2)
SIDE OF GNSI CASTOR V/21 CASK ADJOINT FLUXES[a]
FOR A SOURCE OF 1 n/sec PER GROUP

	SIDE OF CASK (rem/hr per n/sec)			
Neutron Group	50 Meters	460 Meters	1500 Meters	2460 Meters
36	5.4E-14	3.8E-17	1.5E-26	6.1E-36
37	5.5E-14	2.7E-17	6.4E-27	2.3E-36
38	5.6E-14	1.4E-17	4.1E-28	0.0E+00
39	5.5E-14	8.8E-18	1.5E-28	0.0E+00
40	5.4E-14	5.7E-18	6.0E-29	0.0E+00
41	5.2E-14	2.8E-18	1.3E-29	0.0E+00
42	4.6E-14	8.6E-19	2.2E-31	0.0E+00
43	4.2E14	4.2E-19	5.5E-32	0.0E+00
44	3.5E-14	1.1E-19	1.2E-33	0.0E+00
45	2.8E-14	4.0E-20	1.6E-34	0.0E+00
46	2.2E-14	1.3E-20	2.7E-35	0.0E+00
47	1.4E-14	2.6E-21	2.1E-36	0.0E+00

Note: Enveloping factor of three is not included.

a. Reference 4.

Table A.1/7.3-4 (SHEET 1 OF 2)
TOP OF GNSI CASTOR V/21 CASK ADJOINT FLUXES[a]
FOR A SOURCE OF 1 n/sec PER GROUP

Neutron Group	TOP OF CASK (rem/hr per n/sec)			
	50 Meters	460 Meters	1500 Meters	2460 Meters
1	1.0E-12	6.8E-15	1.1E-17	4.7E-20
2	9.6E-13	6.4E-15	1.1E-17	4.4E-20
3	8.4E-13	6.4E-15	1.2E-17	5.2E-20
4 5	8.0E-13	6.8E-15	1.3E-17	5.8E-20
6 7 8 9 10	8.3E-13	6.2E-15	7.7E-18	2.2E-20
11 12 13 14 15 16 17 18	8.2E-13	5.7E-15	1.6E-18	1.5E-21
19 20 21 22 23	6.5E-13	1.9E-15	4.2E-20	2.4E-24
24 25 26 27	2.8E-13	4.7E-16	3.9E-22	3.9E-28
28 29 30	8.8E-14	1.5E-16	1.8E-24	0
31 32 33	6.1E-14	9.7E-17	3.0E-25	0
34 35	5.2E-14	7.2E-17	1.3E-25	0

Table A.1/7.3-4 (SHEET 2 OF 2)
TOP OF GNSI CASTOR V/21 CASK ADJOINT FLUXES[a]
FOR A SOURCE OF 1 n/sec PER GROUP

Neutron Group	TOP OF CASK (rem/hr per n/sec)			
	50 Meters	460 Meters	1500 Meters	2460 Meters
36	5.4E-14	3.8E-17	1.5E-26	0
37 38	5.5E-14	2.5E-17	6.8E-27	0
39 40	5.5E-14	7.7E-18	2.1E-28	0
41 42 43	5.0E-14	2.3E-18	1.3E-29	0
44 45 46 47	3.0E-14	7.1E-20	1.4E-33	0

Note: Enveloping factor of three is not included.

a. Reference 4.

Figure A.1/7.3-2
NORMALIZED SURFACE DOSE RATE ON GNSI CASTOR V/21
CASK VERSUS AGE OF SPENT FUEL

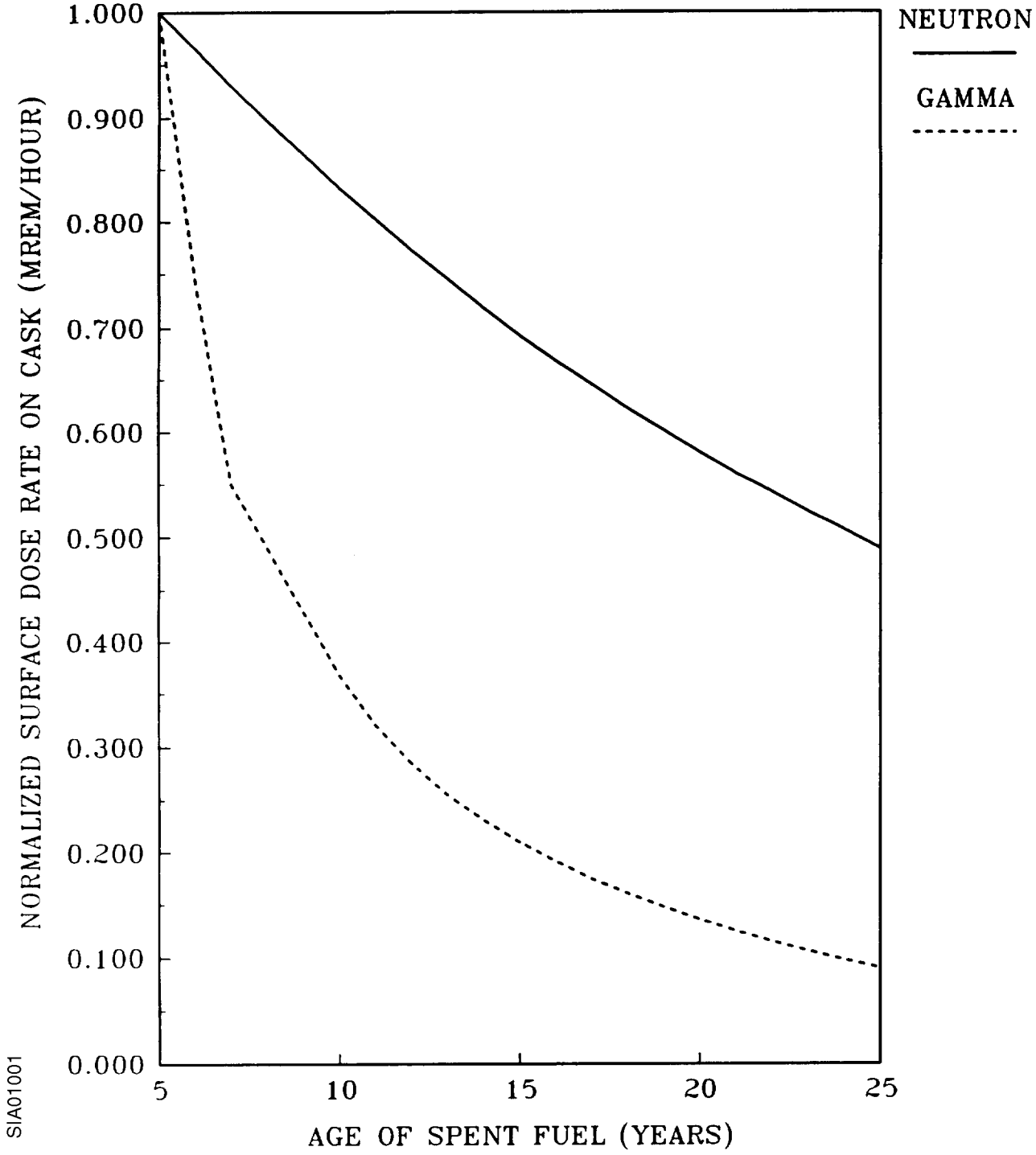


Figure A.1/7.3-7a
GNSI CASTOR V/21 NEUTRON DOSE RATE
FROM ONE CASK VS. DISTANCE
(0-140 FEET)

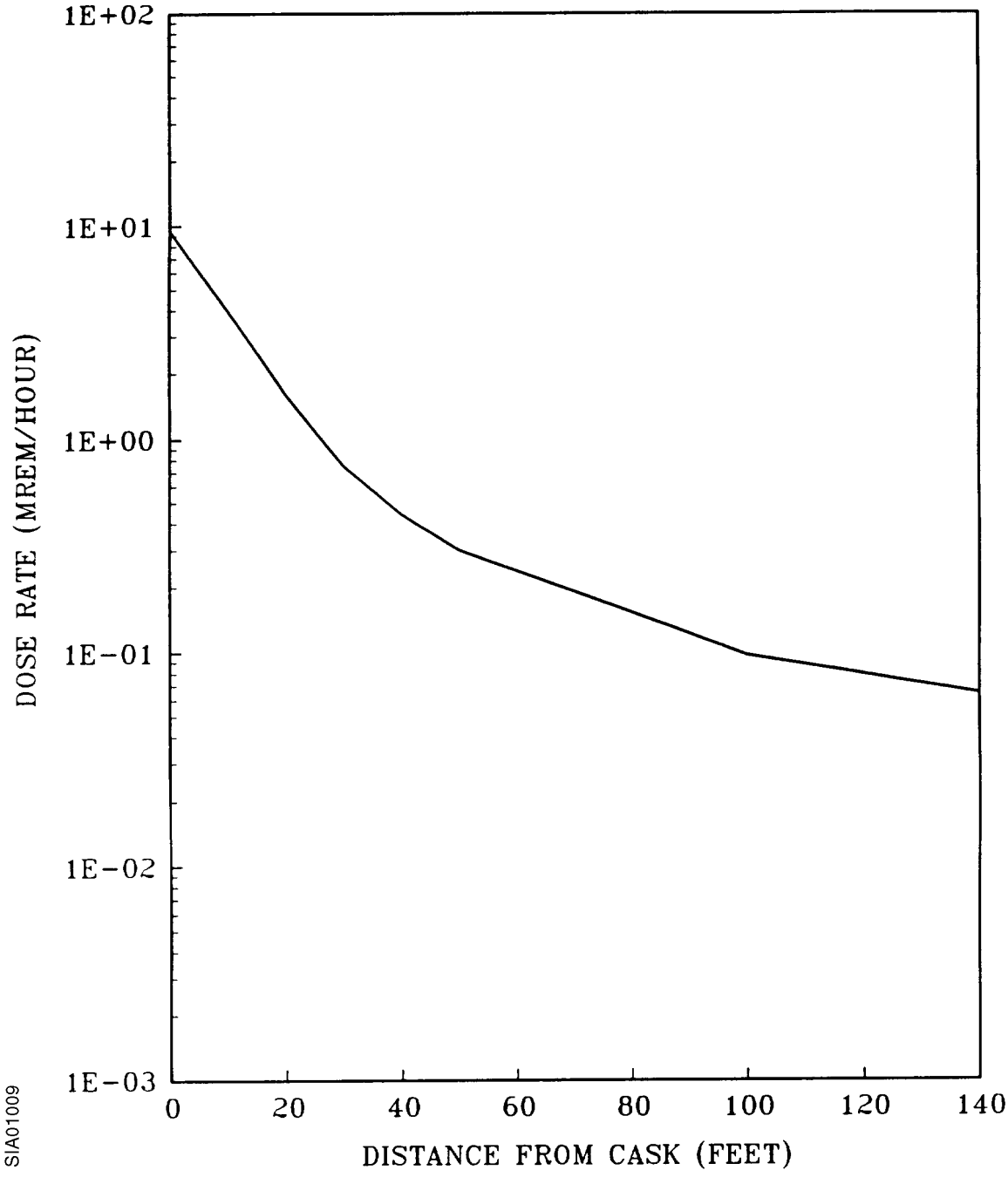


Figure A.1/7.3-7b
GNSI CASTOR V/21 GAMMA DOSE RATE
FROM ONE CASK VS. DISTANCE
(0-140 FEET)

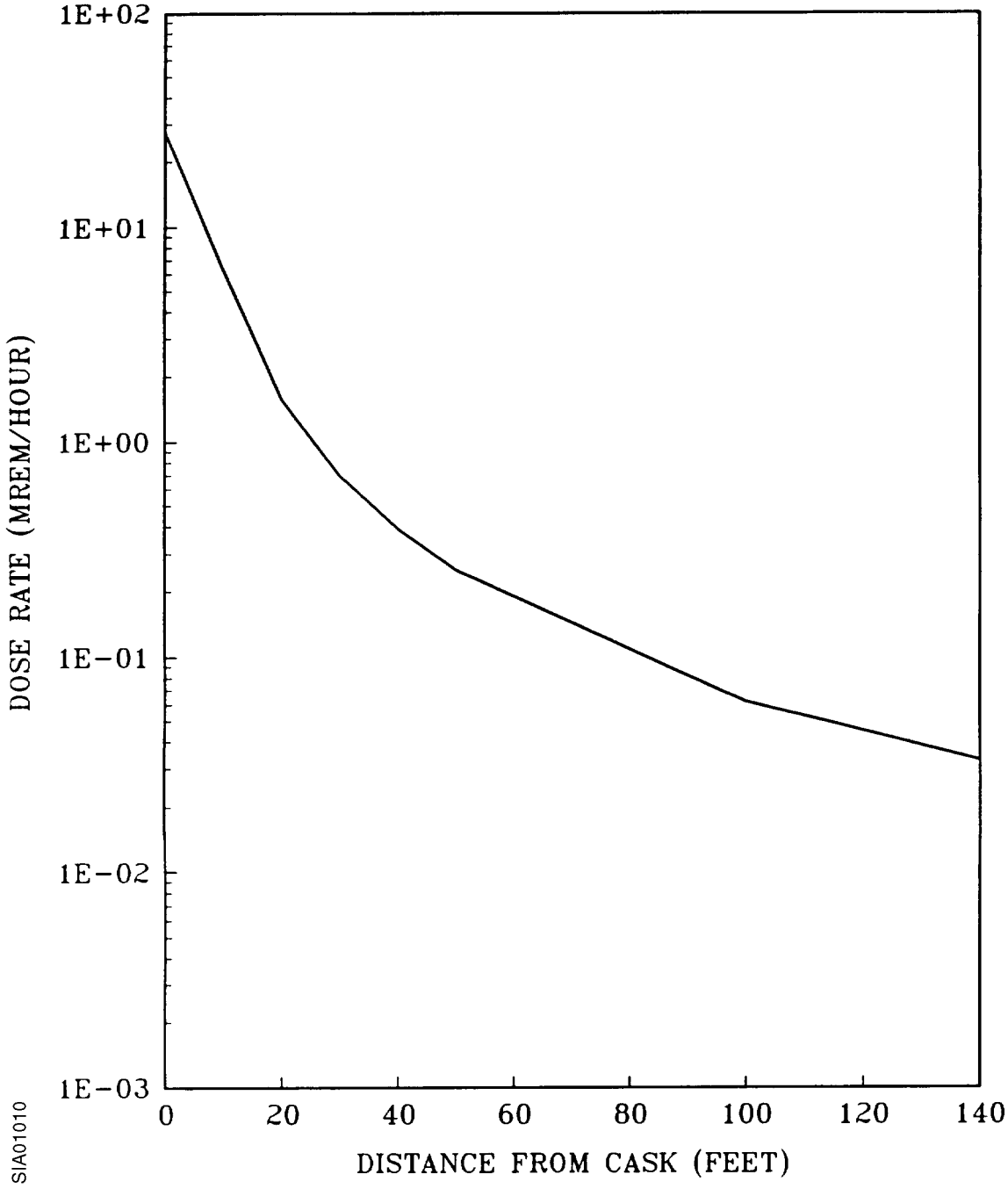


Figure A.1/7.3-8a
GNSI CASTOR V/21 NEUTRON DOSE RATE
FROM ONE CASK VS. DISTANCE
(0-700 FEET)

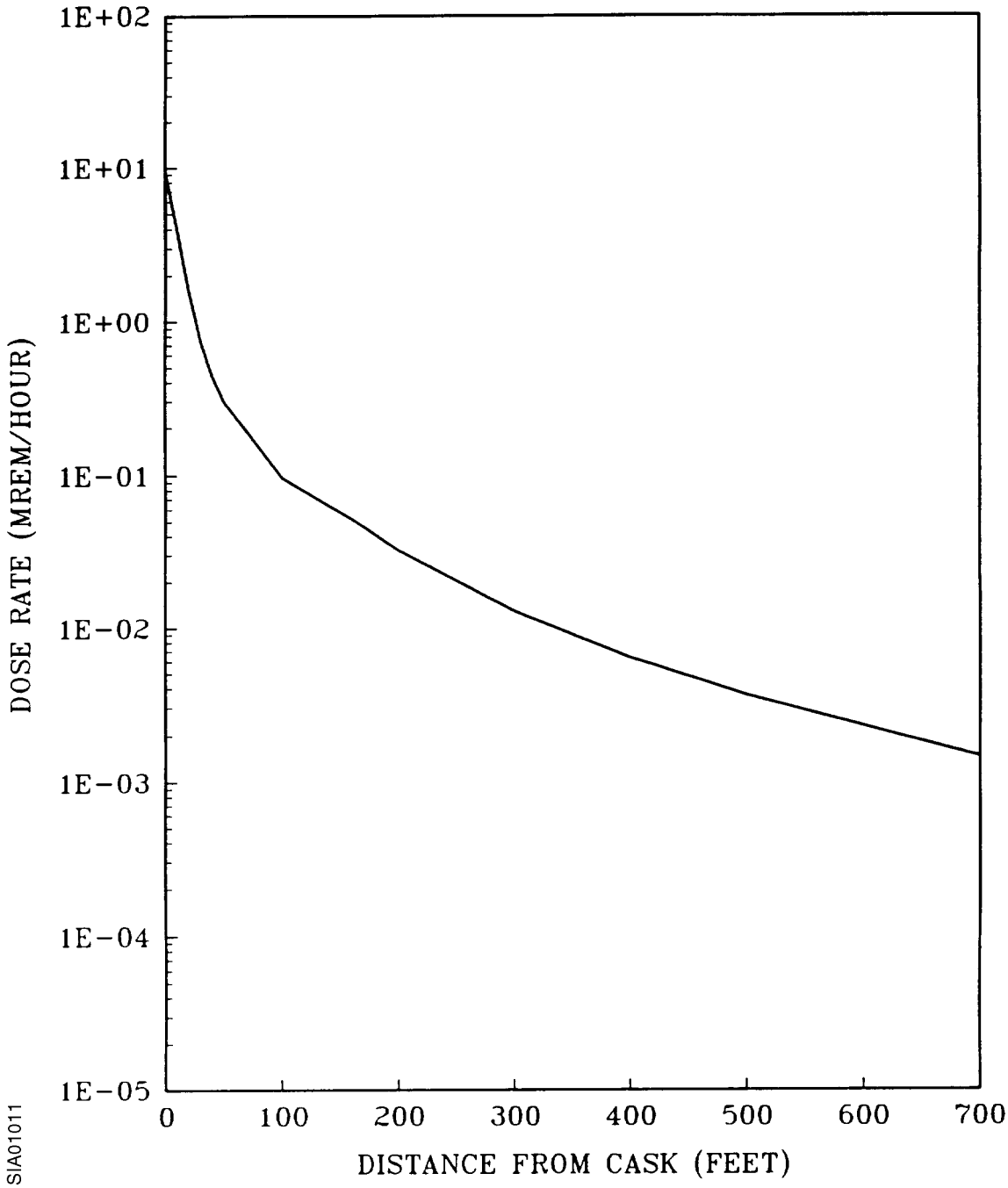


Figure A.1/7.3-8b
GNSI CASTOR V/21 GAMMA DOSE RATE
FROM ONE CASK VS. DISTANCE
(0-700 FEET)

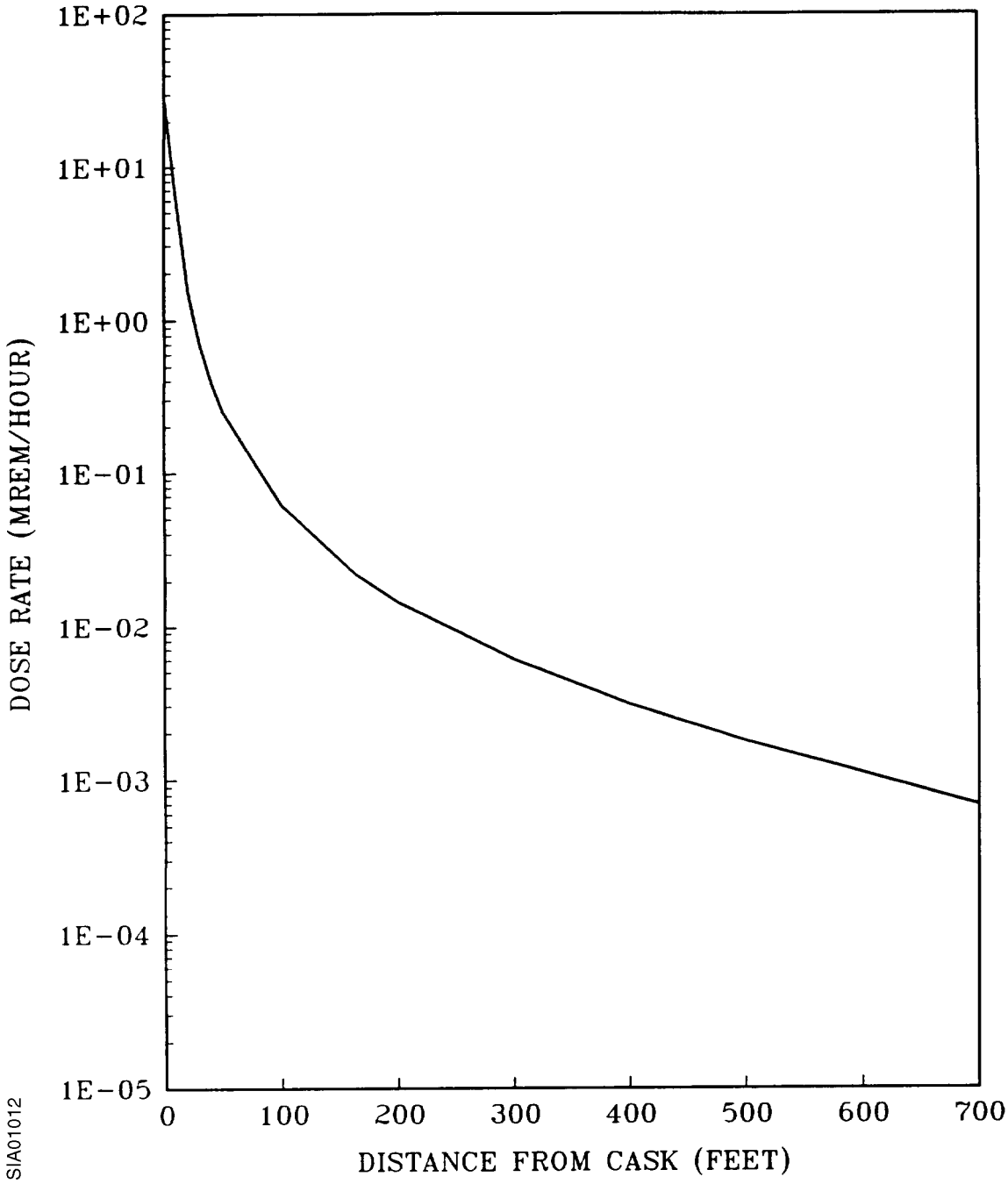


Figure A.1/7.3-9a
GNSI CASTOR V/21 NEUTRON DOSE RATE
FROM ONE CASK VS. DISTANCE
(0-9000 FEET)

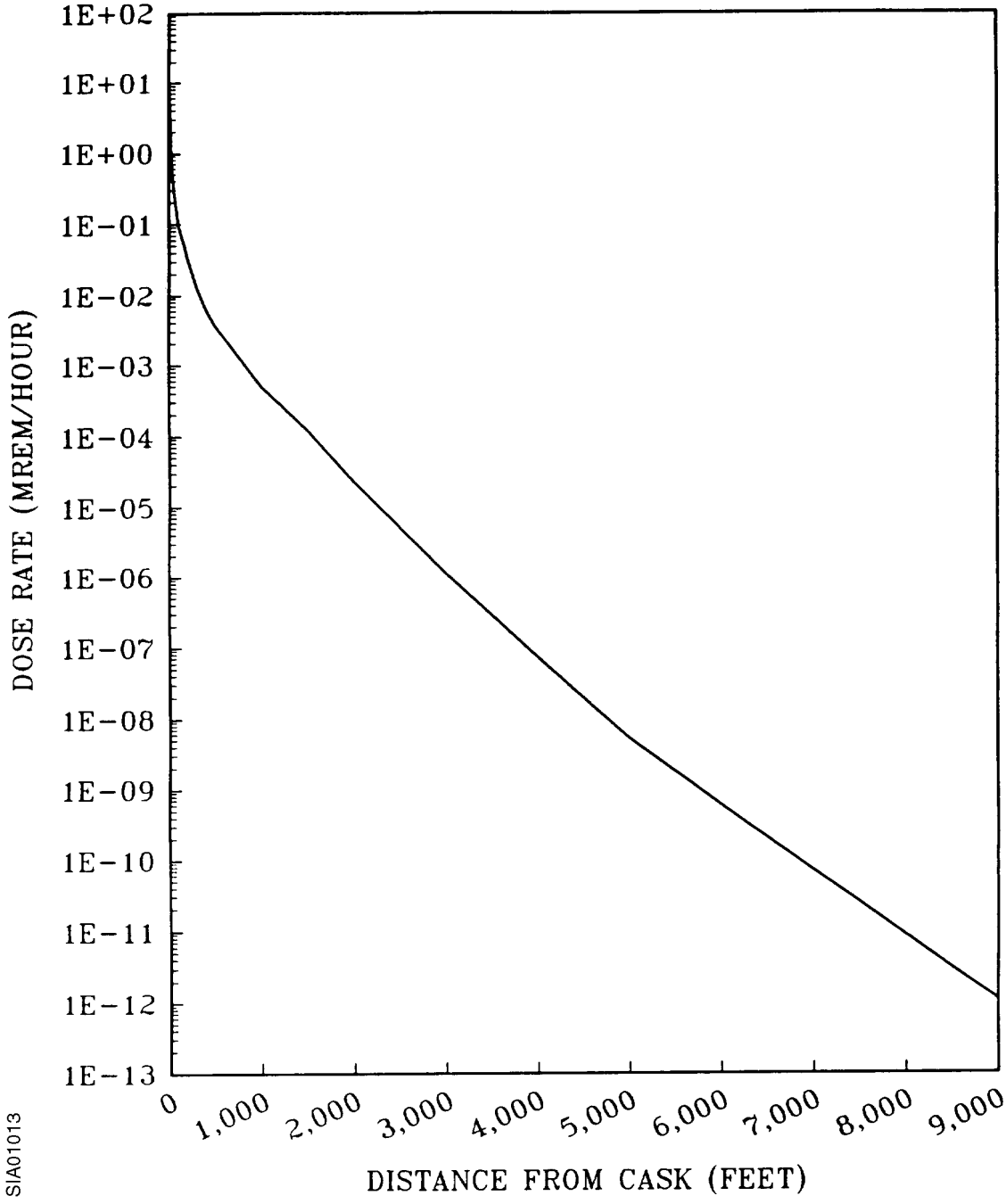


Figure A.1/7.3-9b
GNSI CASTOR V/21 GAMMA DOSE RATE
FROM ONE CASK VS. DISTANCE
(0-9000 FEET)

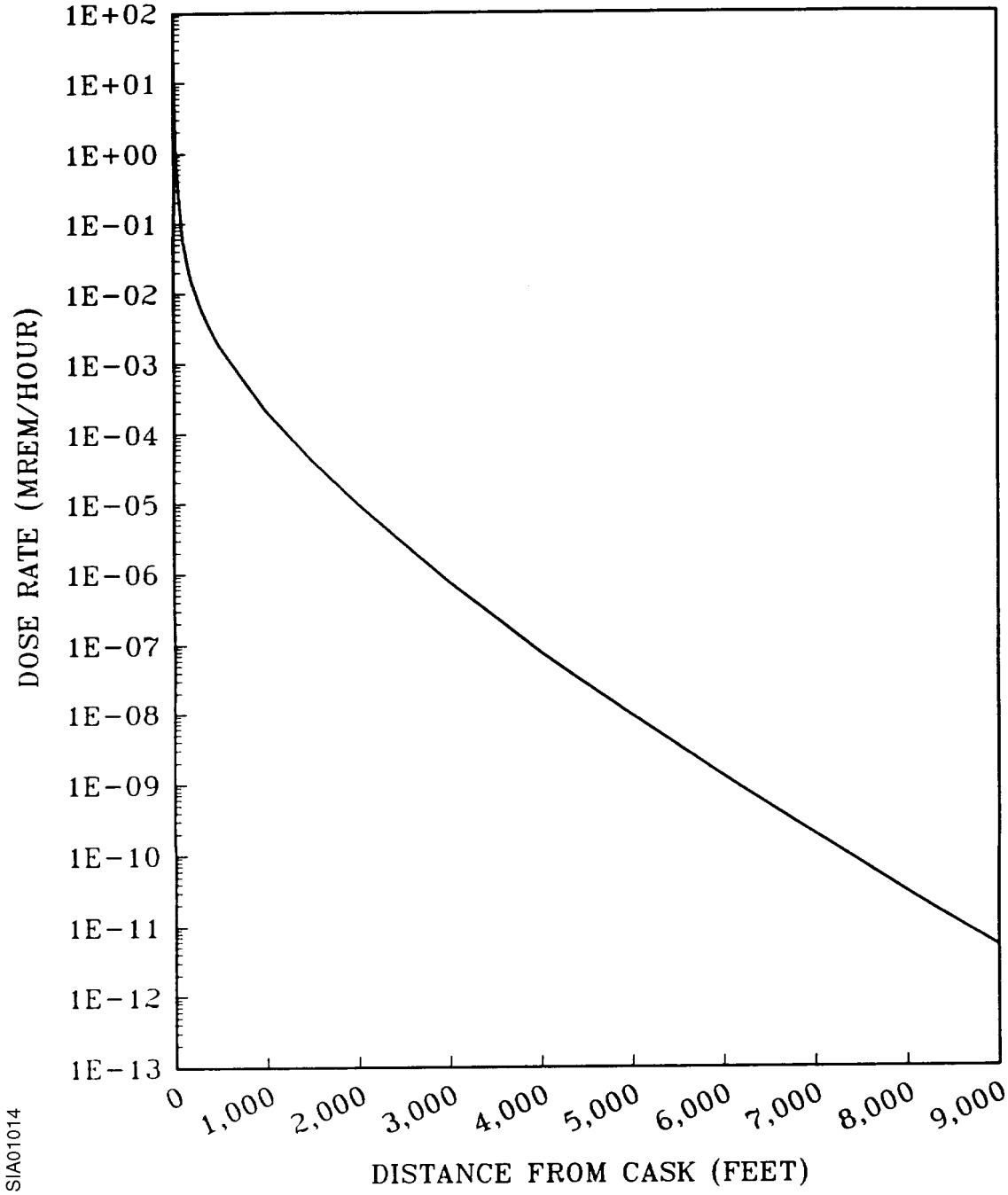
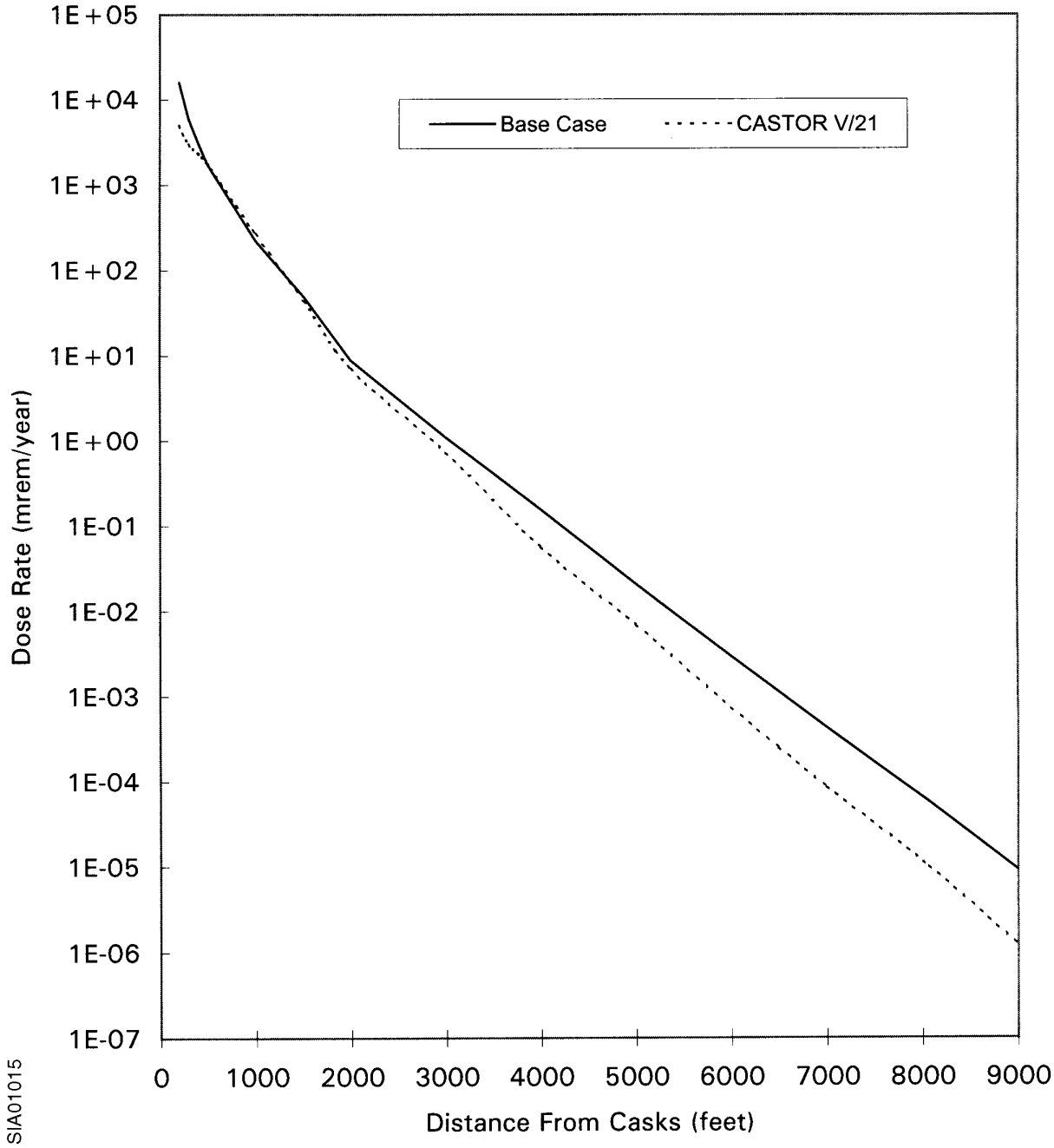


Figure A.1/7.3-10
DOSE RATE FOR 84 CASTOR V/21 CASKS VERSUS
DISTANCE COMPARED TO ISFSI BASE CASE DOSE RATE VERSUS DISTANCE



A.1/8.2.2 Extreme Wind

The effects and consequences of extreme winds on the GNSI cask are presented in Section 8.2.1.2.1 of the GNSI Topical Report. The GNSI analysis demonstrates that extreme winds are not capable of overturning their cask nor of producing leakage from it. Since no radioactivity would be released, no resultant doses would occur.

A.1/8.2.5 Fire

The ability of the GNSI cask to withstand postulated fires is presented in Section 8.2.1.2.7 of the GNSI Topical Report. As concluded in Surry ISFSI SAR Section 8.2.5, no fires other than small electrical fires are credible at the ISFSI slab. Based on the GNSI analyses referenced above, since no radioactivity would be released, no resultant doses would occur.

A.1/8.2.8 Loss of Neutron Shield

As discussed in Section 1.2.4 of the GNSI Topical Report, the neutron absorbing material for the GNSI cask includes polyethylene rods inserted into the cask wall. Thus, no loss of neutron shield is postulated.

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Appendix A.2
WESTINGHOUSE MC-10 CASK

GENERAL DESCRIPTION

The Westinghouse MC-10 cask is a low alloy steel shielded container which is approximately 88 inches in diameter and 188 inches long. The forged steel walls and bottom are approximately 10 inches thick and 11 inches thick, respectively, to provide radiation (gamma) shielding and structural integrity. Three covers are provided to seal the top end of the cask cylinder. A low alloy steel cover, approximately 9 inches thick, with a metallic o-ring provides initial seal and gamma shielding following fuel loading. A carbon steel cover, approximately 3.5 inches thick, with a dual-seal elastomer o-ring and metallic ring provides primary containment seal. The third cover, providing support for neutron absorbing material, may be welded over the first two covers to provide seal redundancy. The outside surfaces of the cask wall and bottom are jacketed with neutron absorbing materials.

The cask contains a basket assembly which consists of 24 storage locations utilizing a honeycomb-type basket structure. The stainless steel basket structure maintains the subcritical array of storage locations, provides lateral structural integrity, and conducts fuel assembly decay heat to the cask wall.

The exterior coating system employed on the MC-10 cask at the Surry ISFSI differs from the specific coating system identified on page 4.2-124 of the MC-10 TSAR. The coating system employed at Surry consists of a polyamide epoxy primer and epoxy enamel topcoat which provides a decontaminable finish and exterior corrosion protection, and is consistent with the surface emissivity referenced on page 4.2-19 of the MC-10 TSAR.

A.2/3.1.1 Materials to be Stored

The structural evaluations of the MC-10 are provided in Chapters 4 and 8 of the Topical Report. These evaluations used a fuel weight of 1442 lb, but the maximum weight of Surry Units 1 and 2 fuel assemblies containing a burnable poison rod assembly (BPRA) or thimble plugging device (TPD) in the one MC-10 at the Surry ISFSI is 1490 lb. An evaluation has been performed by Westinghouse to evaluate the effect of the increased weight of the fuel assembly from 1442 lb to 1490 lb. The Westinghouse evaluation concluded that the calculated stresses at all locations in the cask and basket were less than the allowable stresses.

An evaluation has also been performed on the effect to the cask surface dose rates as a result of placing BPRAs or TPDs in the fuel stored in the MC-10. This evaluation confirmed that the calculated surface dose rates for the MC-10 remained less than the design basis dose rates used to calculate doses at the ISFSI perimeter and to the nearest resident.

An evaluation has been performed on the effect on criticality control from the storage of BPRAs or TPDs in the fuel stored in the MC-10. BPRA rods will displace water (a moderator) in

the fuel assembly thimble tubes, therefore, even the use of depleted BPRAs will reduce reactivity in a cask. TPDs are short and do not displace water in the thimble tubes, therefore, their use will not affect reactivity.

The MC-10 is designed for a maximum internal pressure under normal and accident conditions, and helium buildup or pre-pressurization in BPRAs will affect this analysis. The confinement analysis for the MC-10 has been reanalyzed for twenty-four 20-finger BPRAs, and this reanalysis shows that the maximum pressure under normal conditions is 1.7 atm., when the design basis for this cask is 2.5 atm. The maximum pressure under accident conditions would be 3.4 atm. absolute, when the design basis for this cask is 3.5 atm. absolute. This analysis assumed that the maximum fuel rod internal pressure was 90 bars, instead of the 134.4 bars assumed in the MC-10 TSAR. This lower 90 bars limit must be applied for any fuel assembly containing BPRA that is placed in the MC-10 cask. The impact of TPDs on the confinement analysis is bounded by the impact of BPRAs.

To account for the additional decay heat from BPRAs and TPDs, fuel assembly decay heat estimates must include an estimate for the decay heat from the actual component in each fuel assembly. Therefore, the combined decay heat from the fuel assembly and its component must be less than the limit for a fuel assembly in the MC-10.

Based on these evaluations, the storage of fuel assemblies with BPRAs or TPDs is acceptable for the MC-10.

A.2/7.3.2.1 Cask Surface Dose Rates

The Westinghouse MC-10 cask is evaluated for fuel with an initial enrichment of 3.7 wt.% U-235 and burnup of 35,000 MWD/MTU

The assumptions used in calculating the Westinghouse MC-10 cask surface dose rates and energy spectra are provided in Section 7.3.2.2 of the Westinghouse Topical Report (Reference 1).

Neutron and gamma source terms for the stored spent fuel were generated using OREST (ORIGEN II). Typical results from these runs are shown in Surry ISFSI SAR Tables 7.2-1, 7.2-2, 7.2-3, and 7.2-4. ANISN-W (Reference 10) and DOT-IIW (Reference 11) were used by Westinghouse to calculate the cask surface fluxes. Flux-to-dose rate conversion factors, as shown in Table 7.3-6 of the Westinghouse Topical Report (Reference 1), were then used to obtain the average surface dose rates for the cask. The Westinghouse cask average surface dose rates for 10-year-old fuel are 9.96 mrem/hour neutron and 23.05 mrem/hour gamma for the side and 2.62 mrem/hour neutron and 2.46 mrem/hour gamma for the top. When these dose rates are combined, the side and top average surface dose rates are 33.01 mrem/hour and 5.08 mrem/hour, respectively. These dose rates are bounded by the total average surface dose rates of 224 mrem/hour for the side and 76 mrem/hour for the top reported in the Surry ISFSI SAR, Section 7.3.2.1.

Figure A.2/7.3-2 shows the normalized surface dose rates on a Westinghouse cask versus age of spent fuel for both gamma and neutron radiation.

A.2/7.3.2.2 Dose Rate Versus Distance

The cask surface dose rates discussed in Section A.2/7.3.2.1 result in the dose rates at various distances as shown on Figures A.2/7.3-3a through A.2/7.3-6. The neutron transport results shown on these figures were generated using a series of adjoint (References 2 & 3) ANISN (Reference 4) runs. These calculations were performed with a BUGLE-80 (Reference 5) cross-section set for an infinite-air medium. As explained in References 2 and 3, the adjoint method is the preferred analytical technique when more than one set of sources must be evaluated at a given detector location for a response of interest. For the adjoint analyses reported here, the adjoint source is the flux-to-dose conversion factor reported in Reference 9. Four separate ANISN analyses were performed at distances of 50, 460, 1500, and 2460 meters. The resulting adjoint fluxes are presented in Table A.1/7.3-3. These adjoint fluxes were then folded with the cask surface leakage spectra supplied by Westinghouse over the area of the cask's top and side. Cask surface neutron leakage data are provided in Table A.2/7.3-2.

The resultant neutron dose rates were then used to construct the dose rate versus distance curves presented on Figures A.2/7.3-3a, A.2/7.3-4a, and A.2/7.3-5a.

For the gamma-ray transport, simple point kernel calculations using infinite medium dose rate buildup factors in dry air were performed. Using a point source model and References 6 and 7, air-to-void correction factors were developed and applied to the gamma dose rates in void based on Reference 8. The gamma dose rates for the casks are shown on Figures A.2/7.3-3b, A.2/7.3-4b, and A.2/7.3-5b.

For Figure A.2/7.3-6, decay factors have been used assuming that four Westinghouse MC-10 casks are placed in the ISFSI each year for 18.5 years and each new group of four casks has a minimum of 10 years decay of the fuel. As shown on Figure A.2/7.3-6, the design basis dose rate for the ISFSI bounds the dose rate for the ISFSI filled to capacity with Westinghouse MC-10 casks.

A.2/7.3.5 References

1. *Topical Safety Analysis Report for the Westinghouse MC-10 Cask for an Independent Spent Fuel Storage Installation (Dry Storage)*, Proprietary and Nonproprietary Version WCAPs 10740 and 10741, Revision 2-A, Westinghouse Nuclear Energy Systems, November 1987.

2. V. R. Cain, The Use of Discrete Ordinates Adjoint Calculations, A *Review of the Discrete Ordinates 5 Method for Radiation Transport Calculations,* ORNL-RSIC-19, March 1968, pp. 85-94.

3. G. I. Bell, S. Glasstone, *Nuclear Reactor Theory,* Chapter 6.1 - The Adjoint Function and Its Applications, Van Nostrand Reinhold Company, New York, 1970.

4. W. W. Engle, Jr., *A User's Manual for ANISN, A One-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering,* K-1643, Union Carbide Corporation, Nuclear Division, June 1973.

5. *BUGLE-80, Coupled 47-Neutron, 20-Gamma-Ray, P3, Cross-Section Library for LWR Shielding Calculations,* DLC-75, R. W. Roussin, ORNL, June 1980.

6. Warkentin, J. K., *Polynominal Coefficients for Dose Buildup in Air,* Radiation Research Associates, Inc., August 15, 1975, RRA-N7511.

7. Hubbell, L. H., *Photon Cross-Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 KeV to 100 GeV,* National Bureau of Standards, August 1969, NSRDS-NBS29.

8. Spacetran II, *Dose Calculations at Detectors at Various Distances from the Surface of a Cylinder,* Neutron Physics Division of Oak Ridge National Laboratory, September 1973, ORNL-TM-2592.

9. ANSI/ANS-6.1.1-1977, *American National Standard - Neutron and Gamma Ray Flux to Dose Rate Factors,* American Nuclear Society, March 17, 1977.

10. CCC-255, *ANISN-W, A One Dimensional Discrete Ordinates Transport Computer Program,* Contributed by Westinghouse Advanced Reactors Division, Madison, Pennsylvania; ORNL Radiation Shielding Information Center, Oak Ridge, Tennessee, 1971.

11. CCC-89, *DOT-IIW, A Two Dimensional Discrete Ordinates Transport Computer Program,* Contributed by the Westinghouse Advance Reactors Division, Madison, Pennsylvania; ORNL Radiation Shielding Information Center, 1980. (DOT-IIW is an unpublished enhancement of DOT-IIW for the CRAY-IS computer).

Table A.2/7.3-2
WESTINGHOUSE MC-10 CASK SURFACE NEUTRON LEAKAGE

Neutron Group	Upper[a] Energy (ev)	Cask Surface Leakage Spectra (n/cm^2 - sec)	
		Side	Top
1	1.7E+7	5.64-4	8.10-5
2	1.4E+7	2.04-3	2.88-4
3	1.2E+7	6.86-3	9.56-4
4	1.0E+7	1.23-2	1.70-3
5	8.6E+6	2.02-2	2.78-3
6	7.4E+6	4.74-2	6.52-3
7	6.1E+6	7.09-2	9.70-3
8	5.0E+6	1.61-1	2.21-2
9	3.7E+6	1.59-1	2.23-2
10	3.0E+6	1.59-1	2.28-2
11	2.7E+6	2.00-l	2.89-2
12	2.5E+6	1.18-l	1.70-2
13	2.4E+6	4.69-2	6.98-3
14	2.3E+6	2.06-l	3.09-2
15	2.2E+6	4.46-l	6.66-2
16	1.9E+6	6.66-l	1.04-l
17	1.6E+6	9.27-l	1.46-1
18	1.4E+6	2.24	3.78-l
19	1.0E+6	1.75	3.16-1
20	8.2E+5	9.77-l	1.65-1
21	7.4E+5	4.71	9.14-1
22	6.1E+5	4.69	9.07-l
23	5.0E+5	4.30	8.38-l
24	3.7E+5	4.64	9.98-l
25	3.0E+5	8.34	1.68
26	1.8E+5	7.61	1.58
27	1.1E+5	6.50	1.32
28	6.7E+4	6.10	1.24
29	5.0E+4	2.42	4.53-l
30	3.2E+4	1.46	2.09-l
31	2.6E+4	1.13	3.20-l
32	2.4E+4	1.29	3.25-l
33	2.2E+4	4.65	1.07
34	1.5E+4	8.52	1.72
35	7.1E+3	9.54	2.01

Table A.2/7.3-2
WESTINGHOUSE MC-10 CASK SURFACE NEUTRON LEAKAGE

Neutron Group	Upper[a] Energy (ev)	Cask Surface Leakage Spectra (n/cm^2 - sec)	
		Side	Top
36	3.4E+3	9.77	2.02
37	1.6E+3	18.3	3.68
38	4.5E+2	11.9	2.36
39	2.1E+2	12.6	2.48
40	1.0E+2	17.9	3.53
41	3.7E+1	23.8	4.63
42	1.1E+1	14.1	2.69
43	5.0E+0	17.8	3.39
44	1.8E+0	12.0	2.27
45	8.8E-1	10.4	1.93
46	4.1E-1	17.6	3.23
47	1.0E-1	6.82	1.27

Note: Westinghouse MC-10 cask surface area: 3.58+05 cm^2 (side), 4.48+04 cm^2 (top).

a.Reference 5.

Figure A.2/7.3-2
NORMALIZED SURFACE DOSE RATE ON
WESTINGHOUSE MC-10 CASK
VERSUS AGE OF SPENT FUEL

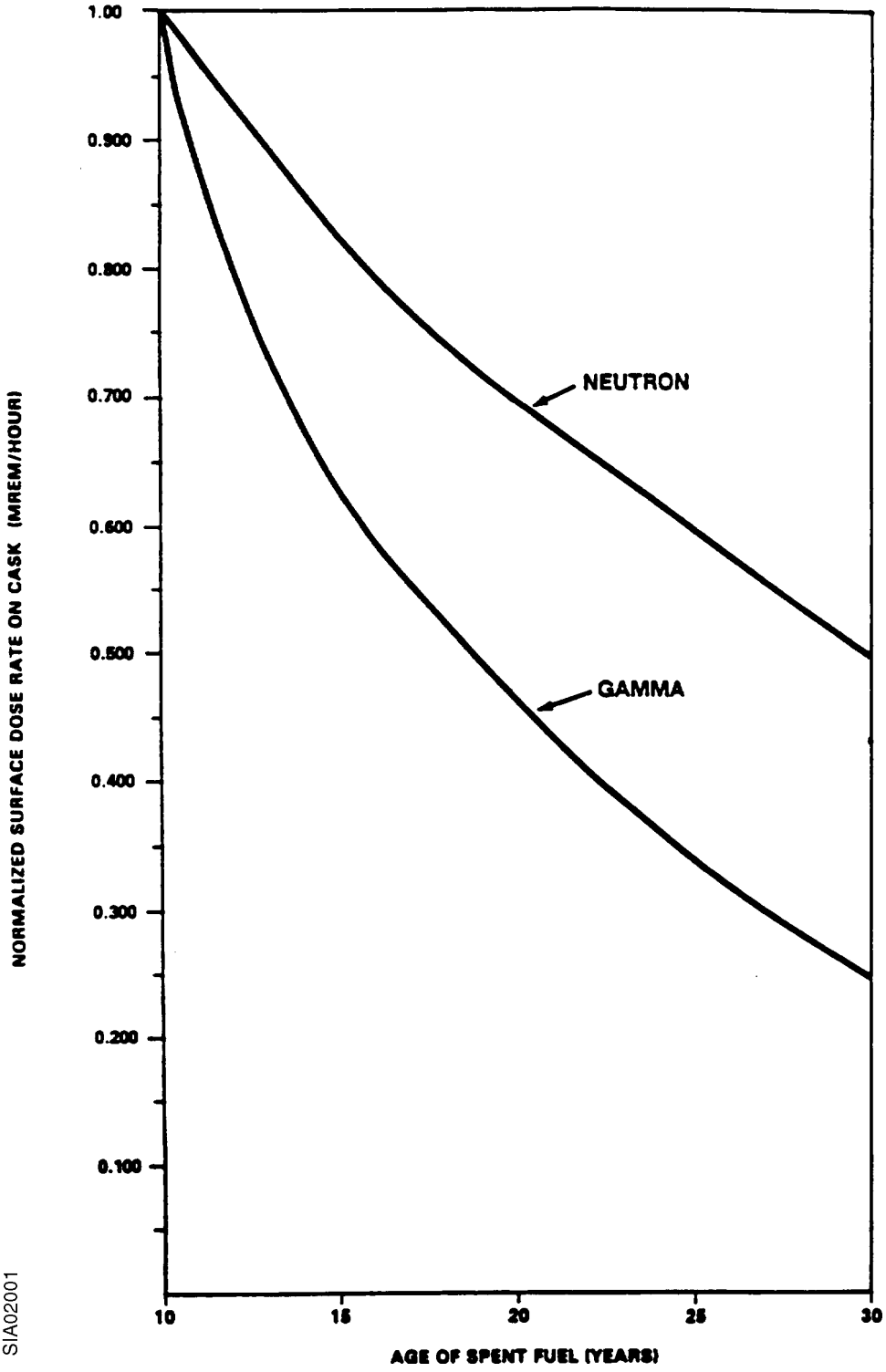


Figure A.2/7.3-3a
WESTINGHOUSE MC-10
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-140 FEET)

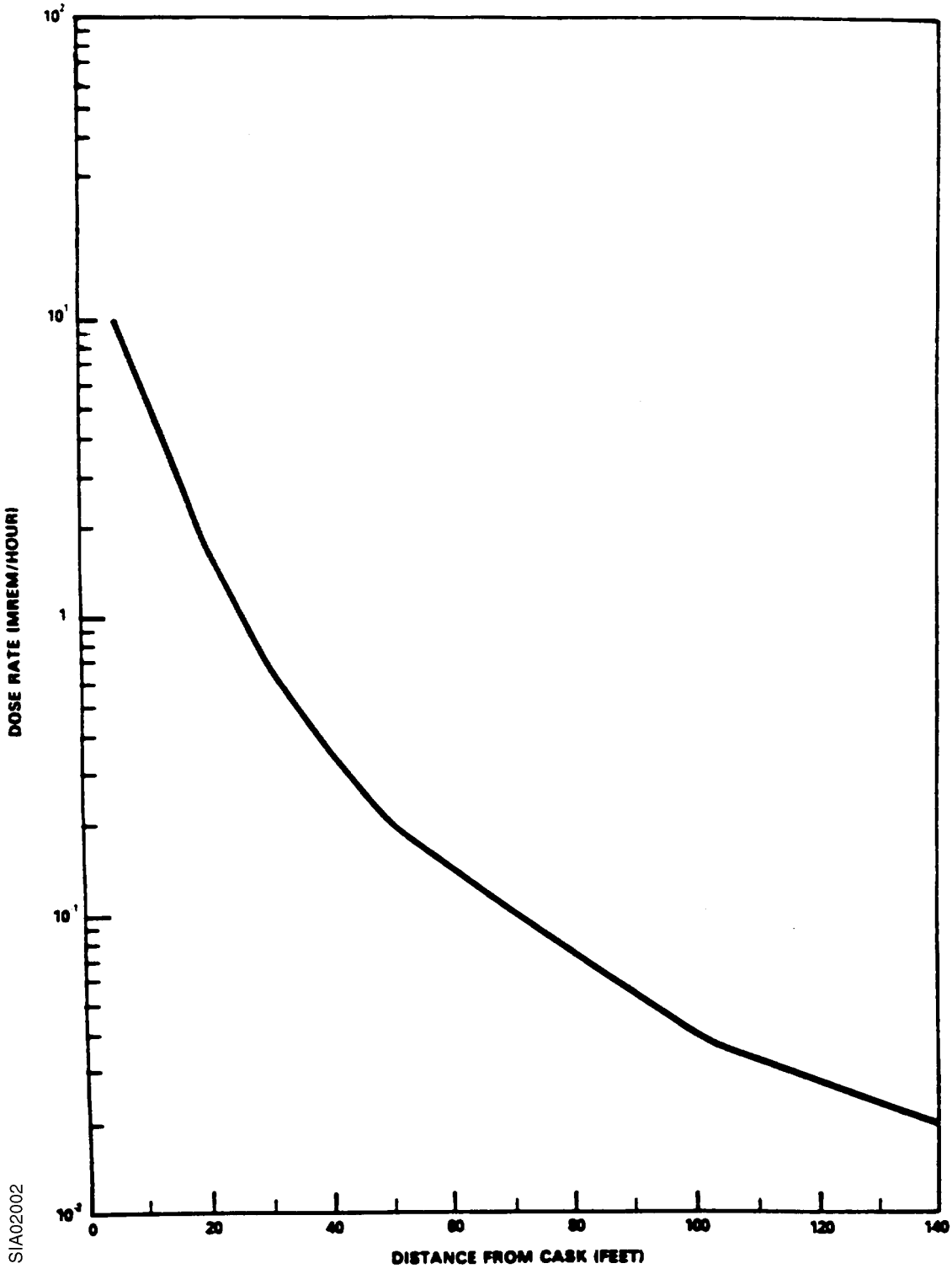


Figure A.2/7.3-3b
WESTINGHOUSE MC-10
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-140 FEET)

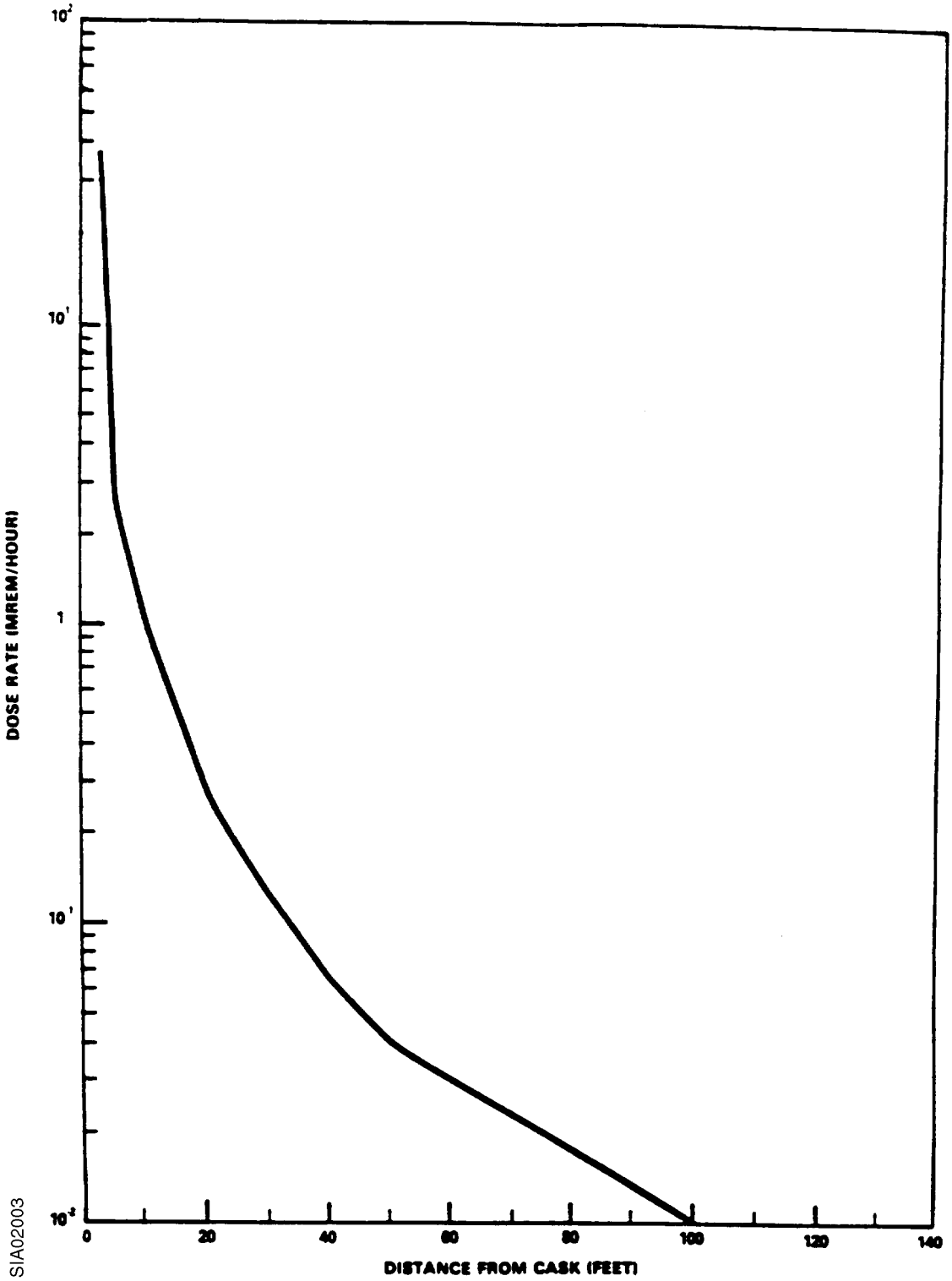


Figure A.2/7.3-4a
WESTINGHOUSE MC-10
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-700 FEET)

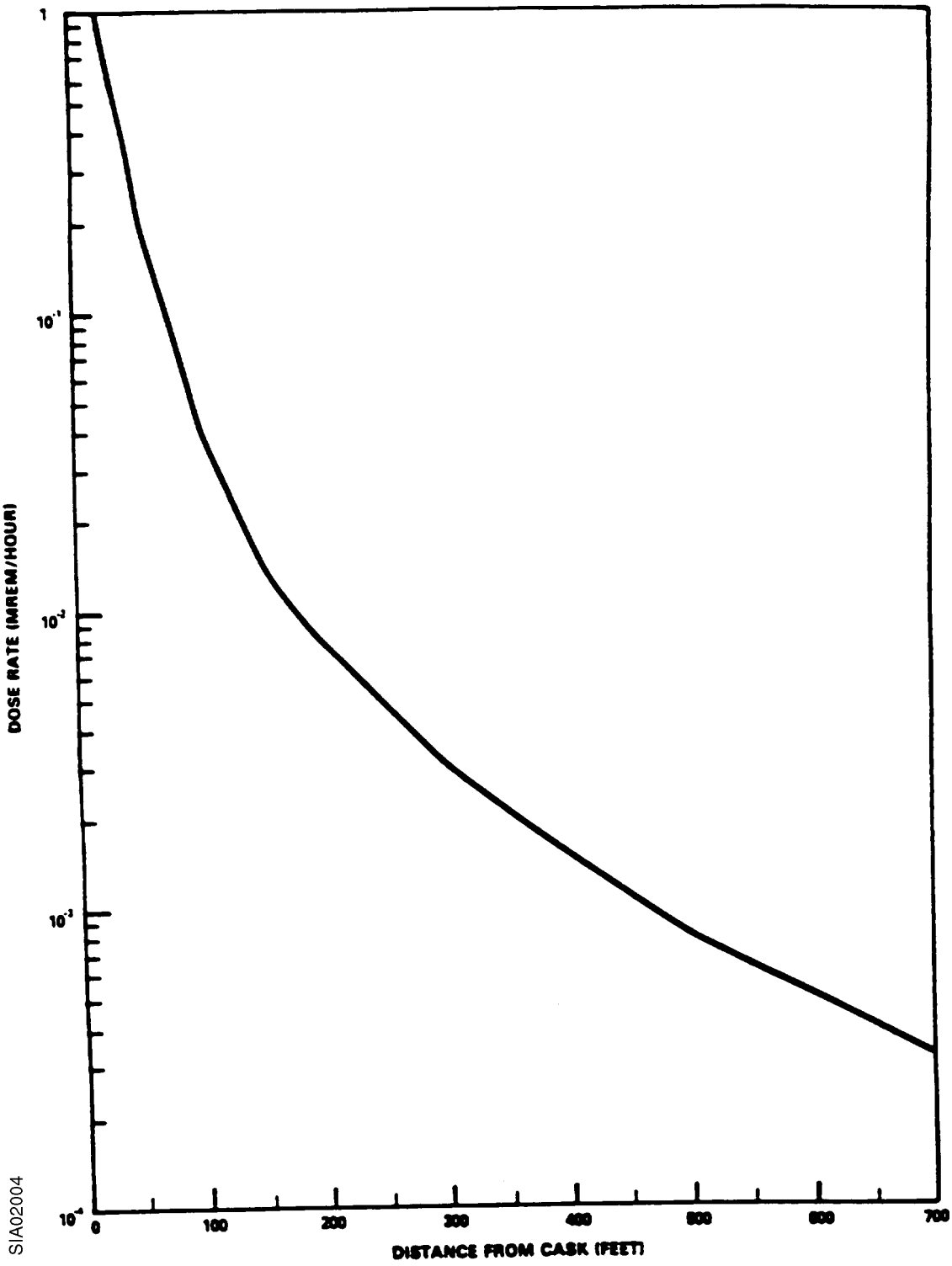


Figure A.2/7.3-4b
WESTINGHOUSE MC-10
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-700 FEET)

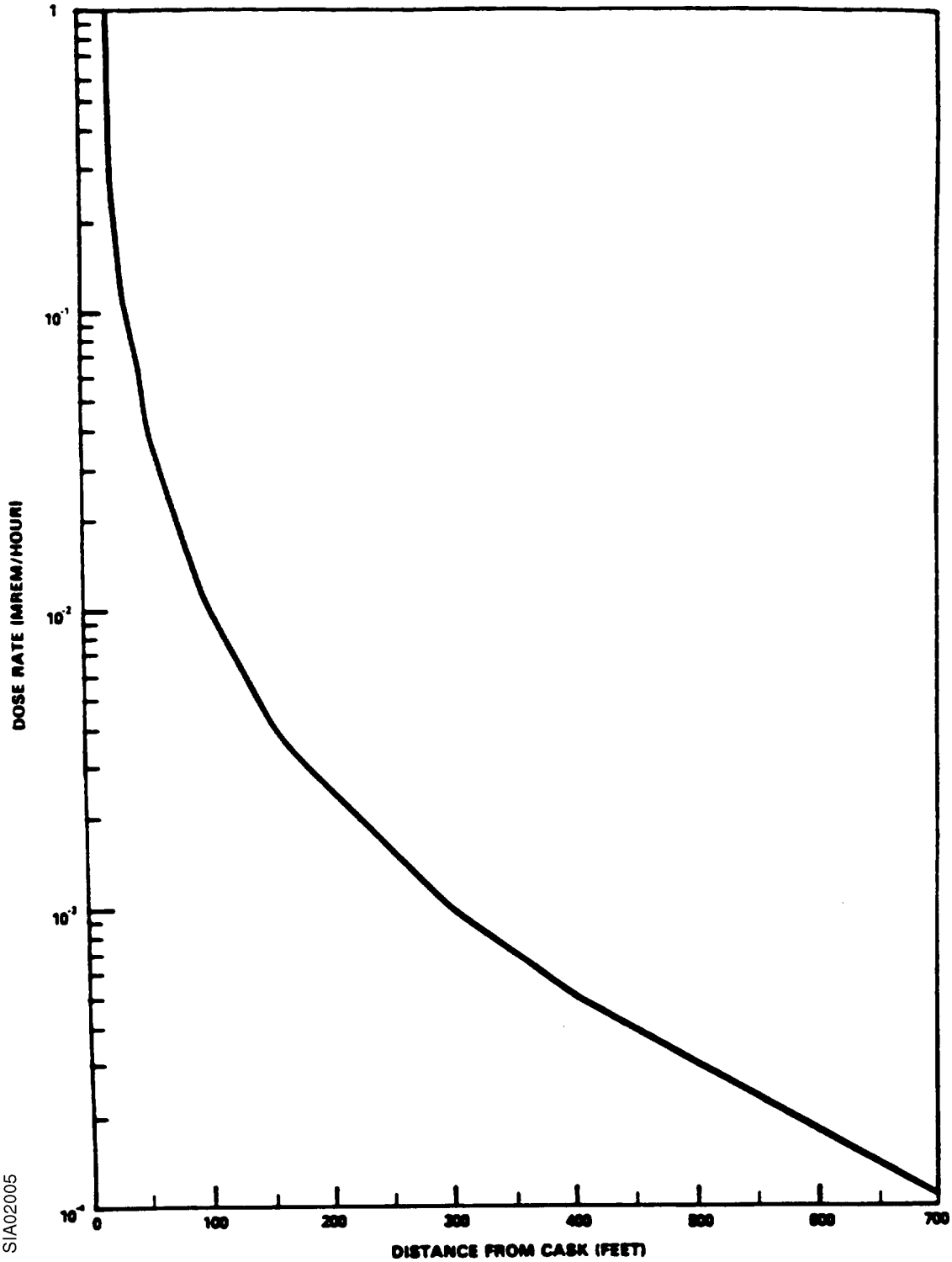


Figure A.2/7.3-5a
WESTINGHOUSE MC-10
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-9000 FEET)

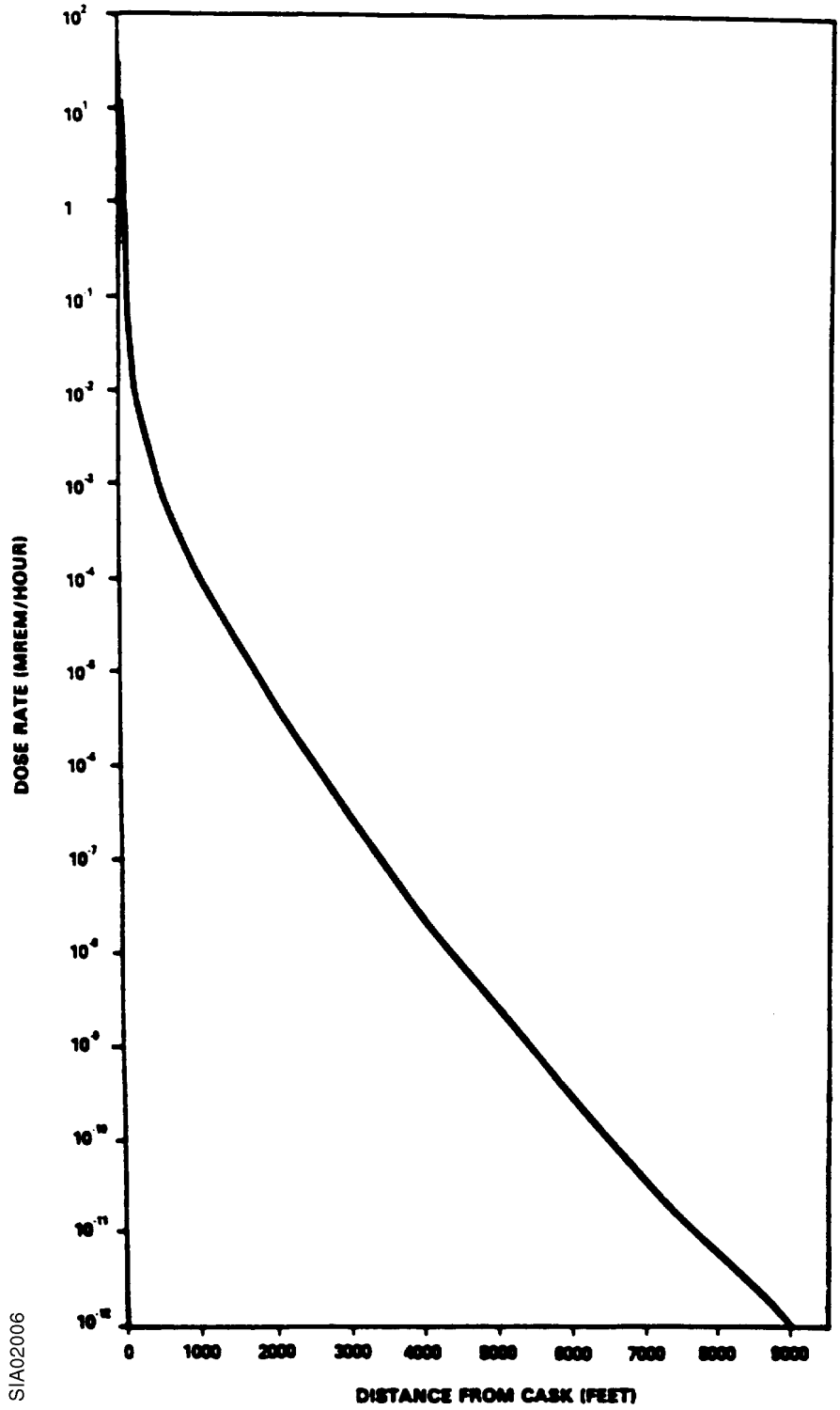


Figure A.2/7.3-5b
WESTINGHOUSE MC-10
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-9000 FEET)

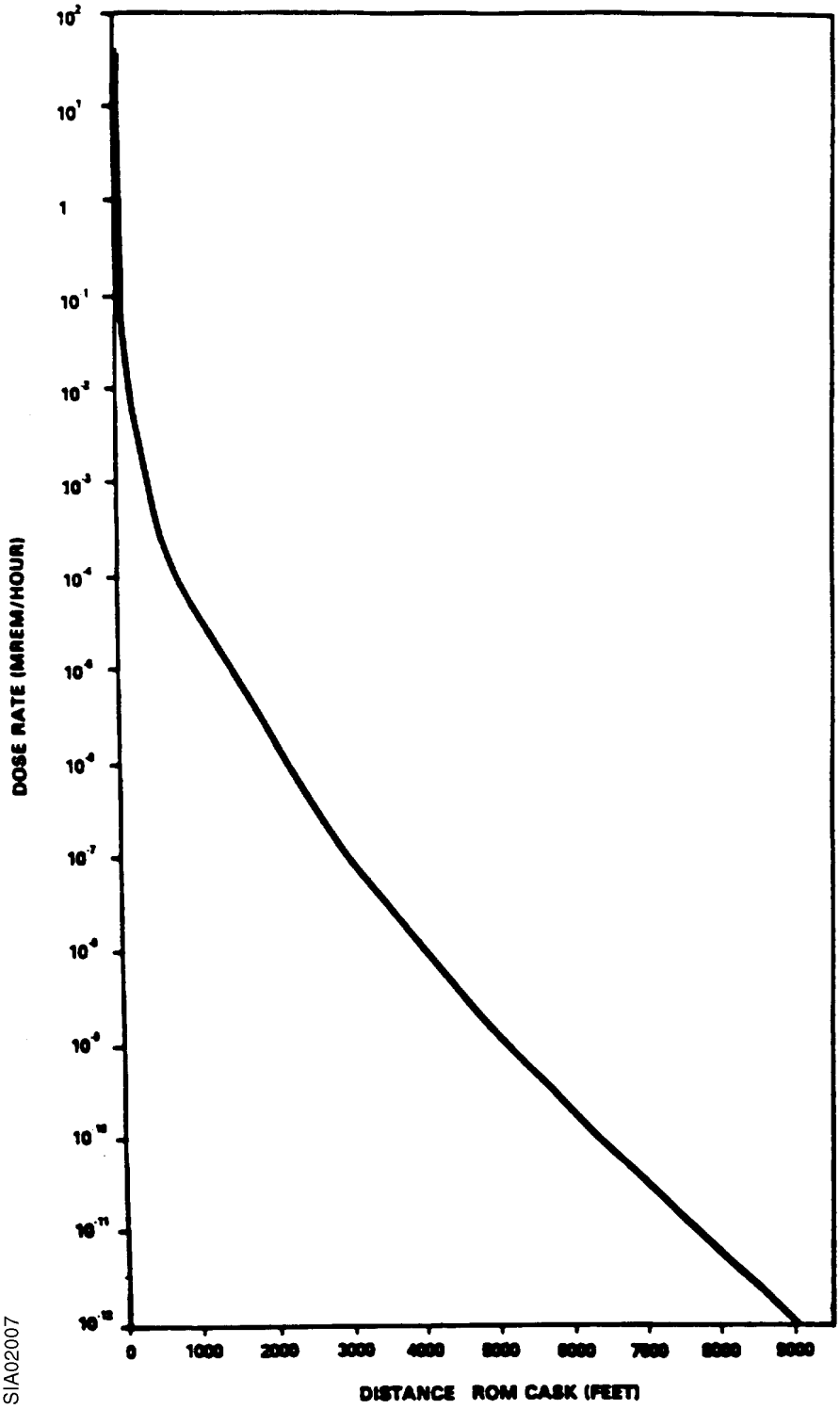
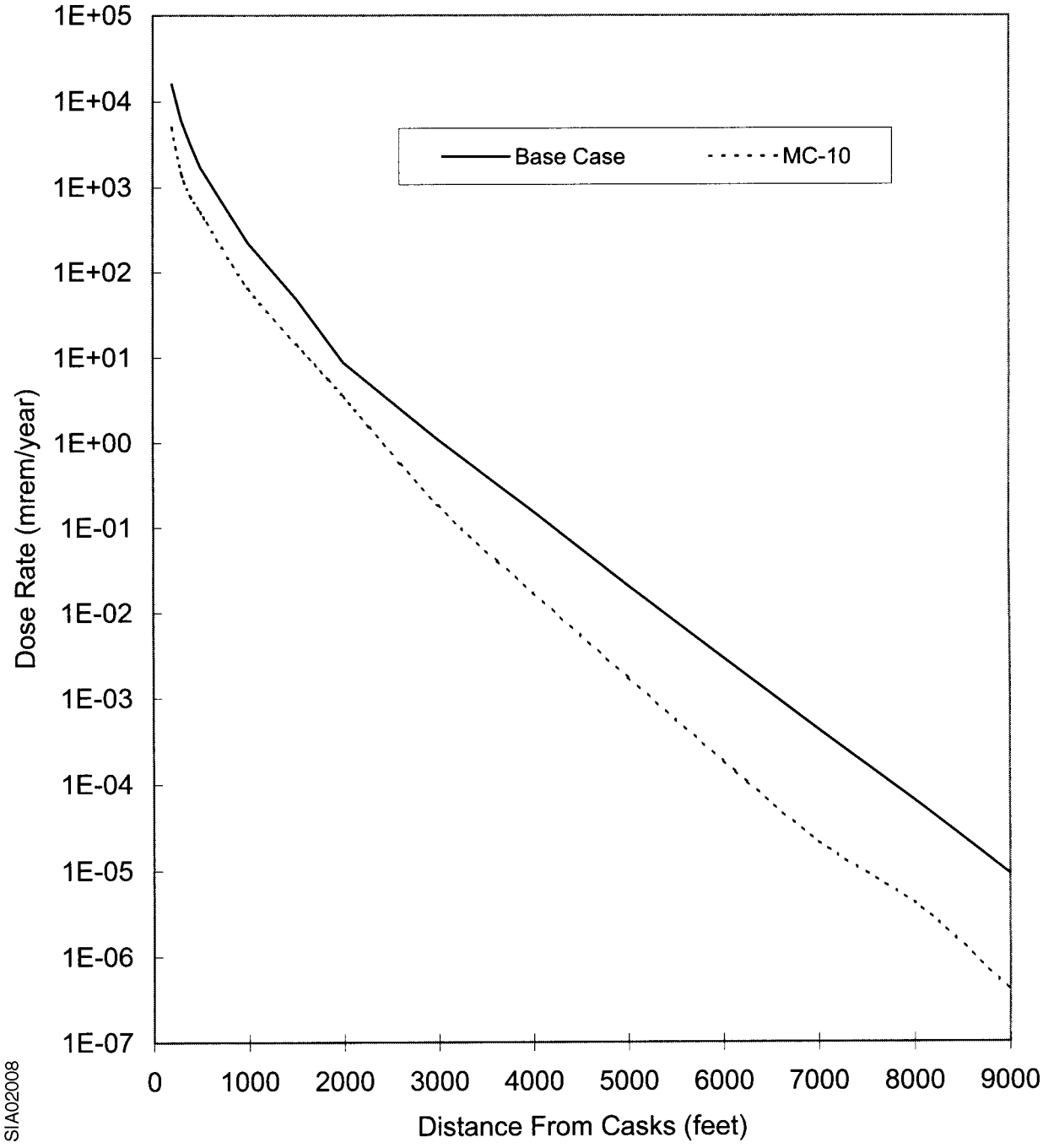


Figure A.2/7.3-6
DOSE RATE FOR 74 MC-10 CASKS VERSUS DISTANCE
COMPARED TO ISFSI DESIGN BASIS BASE CASE VERSUS DISTANCE



A.2/8.2.2 Extreme Wind

The effects and consequences of extreme winds on the Westinghouse cask are presented in Section 8.2.7 of the Westinghouse Topical Report. For a 360 mph tornado wind, the Westinghouse analysis concludes that the cask will not topple during the tornado event. If the 360 mph tornado wind is combined with a 3 psi tornado pressure drop, sufficient load will result to topple the cask. The consequences of a postulated cask topple are conservatively bounded by the 5-foot drop accident in Section 8.2.6 of the Westinghouse Topical Report.

A.2/8.2.5 Fire

The ability of the Westinghouse cask to withstand postulated fires is presented in Section 8.2.4 of the Westinghouse Topical Report. As concluded in Surry ISFSI SAR Section 8.2.5, no fires other than small electrical fires are credible at the ISFSI slab. Therefore, consistent with Section 8.2.4.3 of the Westinghouse Topical Report, a total loss of the cask neutron shield due to fire exposure is not a credible event for the Surry ISFSI. See also Section A.2/8.2.8 of this Appendix.

A.2/8.2.8 Loss of Neutron Shield

As discussed in Section 1.3.2 of the Westinghouse Topical Report, the MC-10 cask features an outer shell of neutron absorbing material (BISCO NS-3) which is encapsulated at the cask outer surface between the ribs and at the cask bottom and the top seal cover. The neutron absorbing material also contributes an energy-absorbing feature during a postulated drop accident.

Section 8.2.2 and 8.2.4 of the Westinghouse Topical Report postulate a loss of this outer neutron shielding due to fire. However, no fires other than small electrical fires are credible at the ISFSI slab based on Section 8.2.5 of the Surry ISFSI SAR. Therefore, consistent with the Westinghouse evaluation of this event, a total loss of the cask neutron shield due to fire exposure is not a credible event for the Surry ISFSI.

Should the outer neutron shield be damaged from a postulated fire, cask tip-over, or cask drop event, temporary shielding could be placed external to the cask (e.g., high temperature polyethylene sheets or concrete blocks) until the cask shielding could be repaired. Depending on the extent of damage, Section 8.2.10 of the Surry ISFSI SAR outlines the steps that would be taken to return the cask to the spent fuel pool to facilitate the repair or replacement of the portion of the BISCO NS-3 that was damaged. See also the discussion in Section 8.2.2.3 of the Westinghouse Topical Report.

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Appendix A.3
NAC INTACT 28 S/T CASK

GENERAL DESCRIPTION

The NAC-I28 S/T cask is a smooth right circular cylinder of multiwall construction with a 1.5 inch thick inner shell and a 2.63 inch thick outer shell of austenitic stainless steel separated by 3.2 inches of lead gamma shielding. The inner and outer shells are connected to each other at the ends by an austenitic stainless steel ring and plate. The upper end of the cask is sealed by an austenitic stainless steel bolted closure lid which is 6.5 inches thick in the edge flange region and has a 1-inch inner closure plate and a 5.5-inch outer closure plate. The closure plates are separated by two inches of lead gamma shielding. The closure lid utilizes a double barrier seal system with two metallic o-rings forming the seals. The lower end of the cask is 6 inch thick austenitic stainless steel with a 1 inch outer closure plate. The bottom end closure plates are separated by 1.80 inches of lead gamma shielding. The cask body is approximately 181 inches long and 94 inches in diameter. Neutron emissions from the stored fuel are attenuated by an integral neutron shield located outside the outer shell which contains a 7-inch thickness of borated solid neutron shield material. Neutron emissions from the top of the cask are attenuated during storage by a 3-inch thick solid neutron shield cap encased in stainless steel.

The cask contains a basket assembly which consists of 28 storage locations. The aluminum basket structure provides nuclear criticality control, structural integrity, and heat transfer to the cask cavity wall.

A tipover impact limiter is attached to the top of the cask after the cask is placed at the ISFSI. This impact limiter consists of an annular ring of aluminum honeycomb material enclosed in a thin stainless steel shell with a backing ring, web plates and a bearing ring providing structural support. The impact limiter is bolted to the cask body through eight tabs welded to the top of the bearing ring.

A.3/3.1.1 Materials to be Stored

The structural evaluations of the NAC-I28 S/T are provided in Chapters 4 and 8 of the Topical Report. These evaluations used a fuel weight of 1440 lb, but the possible combinations of Surry Units 1 and 2 fuel assemblies containing a burnable poison rod assembly (BPRA) or thimble plugging device (TPD) could weigh up to 1525 lb. However, this cask design is also approved for the storage of consolidated fuel canisters weighing up to 2988 lb. Therefore, the use of combined fuel assembly and BPRA or TPD weights of up to 1525 lb is acceptable for the NAC-I28 S/T.

An evaluation has also been performed on the effect to the cask surface dose rates as a result of placing BPRAs or TPDs in the fuel stored in the NAC-I28 S/T. This evaluation confirmed that the calculated surface dose rates for the NAC-I28 S/T remained less than the design basis dose rates used to calculate doses at the ISFSI perimeter and to the nearest resident.

An evaluation has been performed on the effect on criticality control from the storage of BPRAs or TPDs in the fuel stored in the NAC-I28 S/T. BPRA rods will displace water (a moderator) in the fuel assembly thimble tubes, therefore, even the use of depleted BPRAs will reduce reactivity in a cask. TPDs are short and do not displace water in the thimble tubes, therefore, their use will not affect reactivity.

The NAC-I28 S/T is designed for a maximum internal pressure under accident conditions, and helium buildup or pre-pressurization in BPRAs will affect this analysis. The confinement analysis for the NAC-I28 S/T has been reanalyzed for twenty-eight 20-finger BPRAs, and this reanalysis shows that the maximum pressure under accident conditions would be 116.5 psia, when the design basis for this cask is 150 psia. The impact of TPDs on the confinement analysis is bounded by the impact of BPRAs.

To account for the additional decay heat from BPRAs and TPDs, fuel assembly decay heat estimates must include an estimate for the decay heat from the actual component in each fuel assembly. Therefore, the combined decay heat from the fuel assembly and its component must be less than the limit for a fuel assembly in the NAC-I28 S/T.

Based on these evaluations, the storage of fuel assemblies with BPRAs or TPDs is acceptable for the NAC-I28 S/T.

A.3/7.3.2.1 Cask Surface Dose Rates

The NAC-I28 S/T cask is evaluated for fuel with an initial enrichment of 1.9 wt.% U-235 and burnup of 22,000 MWD/MTU.

The NAC-I28 S/T cask surface dose rates and energy spectra are provided in a supplement (Reference 11) to the NAC Topical Report (Reference 1).

Neutron and gamma source terms for the stored spent fuel were generated using OREST (ORIGEN II). Typical results from these runs are shown in Surry ISFSI SAR Tables 7.2-1, 7.2-2, 7.2-3 and 7.2-4. XSDRNPM-S (Reference 10) was used by NAC to calculate the cask surface fluxes. The NAC-I28 S/T cask average surface dose rates for 10-year-old fuel are 0.30 mrem/hour neutron and 7.88 mrem/hour gamma for the side and 3.56 mrem/hour neutron and 32.91 mrem/hour gamma for the top. When these dose rates are combined, the side and top average surface dose rates are 8.18 mrem/hour and 36.47 mrem/hour, respectively. These dose rates are bounded by the total average surface dose rates of 224 mrem/hour for the side and 76 mrem/hour for the top reported in the Surry ISFSI SAR, Section 7.3.2.1.

Figure A.3/7.3-2 shows the normalized surface dose rates on NAC-I28 S/T cask versus age of spent fuel for both gamma and neutron radiation.

A.3/7.3.2.2 Dose Rate Versus Distance

The cask surface dose rates discussed in Section A.3/7.3.2.1 result in the dose rates at various distances as shown on Figures A.3/7.3-3a through A.3/7.3-6. The neutron transport results

shown on these figures were generated using a series of adjoint (References 2 & 3) ANISN (Reference 4) runs. These calculations were performed with a BUGLE-80 (Reference 5) cross-section set for an infinite-air medium. As explained in References 2 and 3, the adjoint method is the preferred analytical technique when more than one set of sources must be evaluated at a given detector location for a response of interest. For the adjoint analyses reported here, the adjoint source is the flux-to-dose conversion factor reported in Reference 9. Four separate ANISN analyses were performed at distances of 50, 460, 1500, and 2460 meters. The resulting adjoint fluxes are presented in Table A.1/7.3-3. These adjoint fluxes were then folded with the cask surface leakage spectra supplied by NAC over the area of the cask's top and side. Cask surface neutron leakage data are provided in Table A.3/7.3-2.

The resultant neutron dose rates were then used to construct the dose rate versus distance curves presented on Figures A.3/7.3-3a, A.3/7.3-4a, and A.3/7.3-5a.

For the gamma-ray transport, simple point kernel calculations using infinite medium dose rate buildup factors in dry air were performed. Using a point source model and References 6 and 7, air-to-void correction factors were developed and applied to the gamma dose rates in void based on Reference 8. The gamma dose rates for the casks are shown on Figures A.3/7.3-3b, A.3/7.3-4b, and A.3/7.3-5b.

For Figure A.3/7.3-6, decay factors have been used assuming that 3 NAC-I28 S/T casks are placed in the ISFSI each year for 21 years and each new group of 3 casks has a minimum of 10 years decay of the fuel. As shown on Figure A.3/7.3-6, the design basis dose rate for the ISFSI bounds the dose rate for the ISFSI filled to capacity with NAC-I28 S/T casks.

A.3/7.3.5 References

1. *Topical Safety Analysis Report for the NAC Storage/Transport Cask Containing 28 Intact Fuel Assemblies for use at an Independent Spent Fuel Storage Installation,* Nuclear Assurance Corporation, November 1988.

2. V. R. Cain, The Use of Discrete Ordinates Adjoint Calculations, *A Review of the Discrete Ordinates 5 Method for Radiation Transport Calculations,* ORNL-RSIC-19, March 1968, pp. 85-94.

3. G. I. Bell, S. Glasstone, *Nuclear Reactor Theory,* Chapter 6.1 - The Adjoint Function and Its Applications, Van Nostrand Reinhold Company, New York, 1970.

4. W. W. Engle, Jr., *A User's Manual for ANISN, A One-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering,* K-1643, Union Carbide Corporation, Nuclear Division, June 1973.

5. *BUGLE-80, Coupled 47-Neutron, 20-Gamma-Ray, P3, Cross-Section Library for LWR Shielding Calculations,* DLC-75, R. W. Roussin, ORNL, June 1980.

6. Warkentin, J. K., *Polynominal Coefficients for Dose Buildup in Air,* Radiation Research Associates, Inc., August 15, 1975, RRA-N7511.

7. Hubbell, L. H., *Photon Cross-Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 KeV to 100 GeV,* National Bureau of Standards, August 1969, NSRDS-NBS29.

8. Spacetran II, *Dose Calculations at Detectors at Various Distances from the Surface of a Cylinder,* Neutron Physics Division of Oak Ridge National Laboratory, September 1973, ORNL-TM-2592.

9. ANSI/ANS-6.1.1-1977, *American National Standard - Neutron and Gamma Ray Flux to Dose Rate Factors,* American Nuclear Society, March 17, 1977.

10. NUREG/CR-0200, Vol. 2, *XSDRNPM-S: A One-Dimensional Discrete-Ordinates Code for Transport Analysis,* ORNL/NUREG/CSD-2/V2/Rl, N. M. Green & L. M. Petrie, ORNL Computer Sciences Division, Oak Ridge, Tennessee, 1983.

11. Letter from Alan H. Wells (NAC) to John P. Roberts (NRC), Docket No. M-54, March 1, 1989.

Table A.3/7.3-2
NAC-I28 S/T SURFACE NEUTRON LEAKAGES

Neutron Group	Upper[a] Energy (ev)	Cask Surface Leakage Spectra (n/cm^2 - sec)	
		Side	Top
1	1.7E+7	4.55E-04	9.21E-05
2	1.4E+7	1.59E-03	3.77E-04
3	1.2E+7	5.84E-03	1.69E-03
4	1.0E+7	1.07E-02	3.74E-03
5	8.6E+6	1.85E-02	7.43E-03
6	7.4E+6	3.94E-02	1.88E-02
7	6.1E+6	5.33E-02	2.71E-02
8	5.0E+6	9.74E-02	5.10E-02
9	3.7E+6	8.10E-02	4.90E-02
10	3.0E+6	5.04E-02	3.79E-02
11	2.7E+6	5.68E-02	4.91E-02
12	2.5E+6	2.96E-02	2.69E-02
13	2.4E+6	6.60E-03	7.67E-03
14	2.3E+6	3.66E-02	4.02E-02
15	2.2E+6	1.12E-01	1.18E-01
16	1.9E+6	1.23E-01	1.50E-01
17	1.6E+6	1.78E-01	2.41E-01
18	1.4E+6	3.12E-01	5.81E-01
19	1.0E+6	1.99E-01	4.71E-01
20	8.2E+5	9.46E-02	2.25E-01
21	7.4E+5	1.94E-01	6.92E-01
22	6.1E+5	1.85E-01	8.69E-01
23	5.0E+5	2.25E-01	1.05E+00
24	3.7E+5	1.56E-01	9.29E-01
25	3.0E+5	2.58E-01	1.56E+00
26	1.8E+5	2.13E-01	1.43E+00
27	1.1E+5	1.58E-01	1.11E+00
28	6.7E+4	1.34E-01	1.05E+00
29	5.0E+4	5.15E-02	4.08E-01
30	3.2E+4	2.41E-02	2.07E-01
31	2.6E+4	3.80E-02	2.90E-01
32	2.4E+4	2.96E-02	2.09E-01
33	2.2E+4	7.54E-02	6.12E-01
34	1.5E+4	1.62E-01	1.38E+00
35	7.1E+3	1.32E-01	1.27E+00

Table A.3/7.3-2
NAC-I28 S/T SURFACE NEUTRON LEAKAGES

Neutron Group	Upper[a] Energy (ev)	Cask Surface Leakage Spectra (n/cm^2 - sec)	
		Side	Top
36	3.4E+3	1.41E-01	1.46E+00
37	1.6E+3	2.57E-01	2.76E+00
38	4.5E+2	1.41E-01	1.65E+00
39	2.1E+2	1.49E-01	1.83E+01
40	1.0E+2	2.04E-01	2.63E+01
41	3.7E+1	2.64E-01	3.54E+01
42	1.1E+1	1.62E-01	2.23E+01
43	5.0E+0	1.93E-01	2.69E+01
44	1.8E+0	1.45E-01	2.03E+01
45	8.8E-1	1.36E-01	1.92E+01
46	4.1E-1	2.31E-01	3.29E+01
47	1.0E-1	1.93E-01	2.72E+01

Note: NAC-I28 S/T Cask Surface Area: 274,236 cm^2 (side), 38,133 cm^2 (top).

a.Reference 5.

Figure A.3/7.3-2
NORMALIZED SURFACE DOSE RATE ON
NAC-I28 S/T CASK
VERSUS AGE OF SPENT FUEL

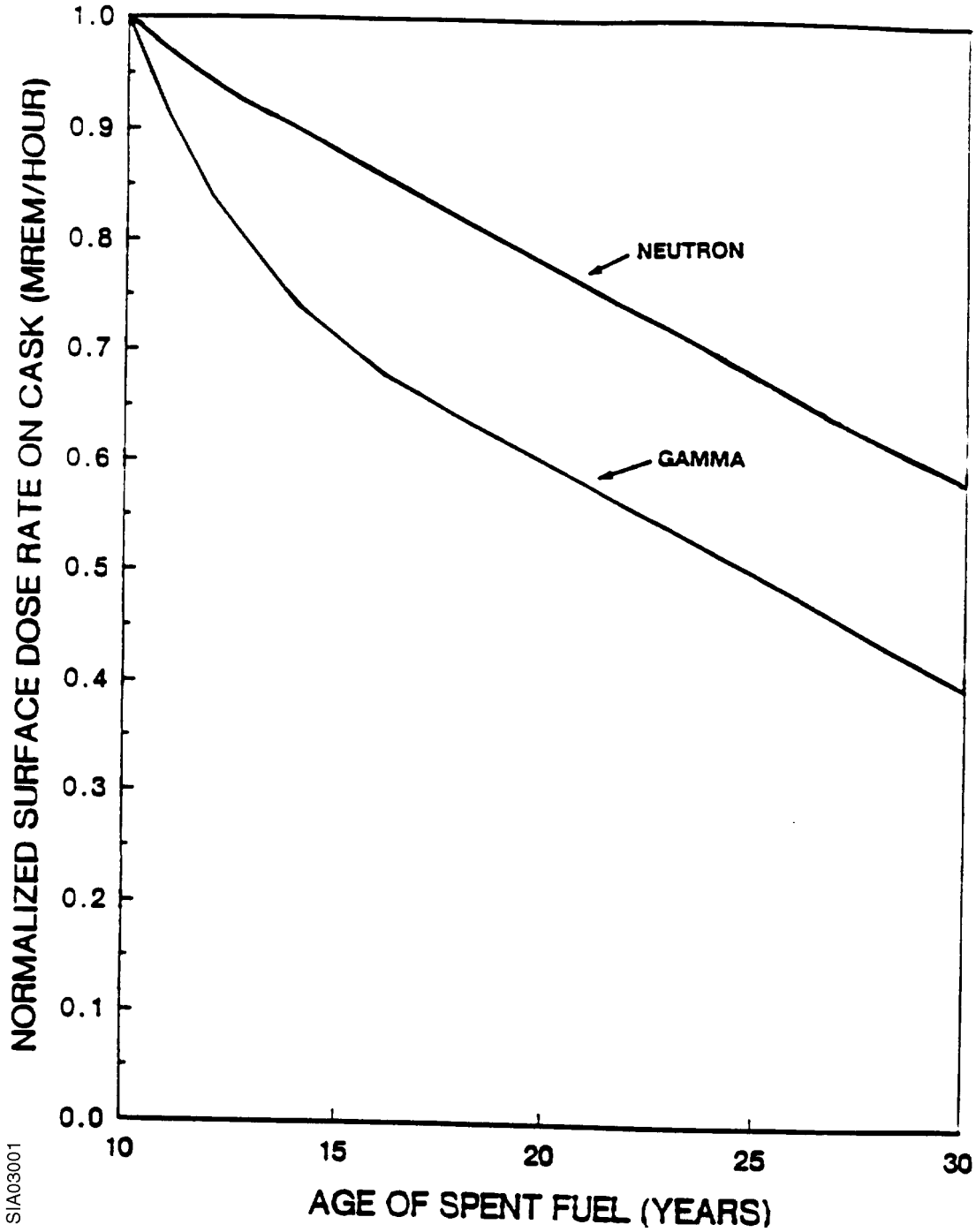


Figure A.3/7.3-3a
NAC-I28 S/T
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-140 FEET)

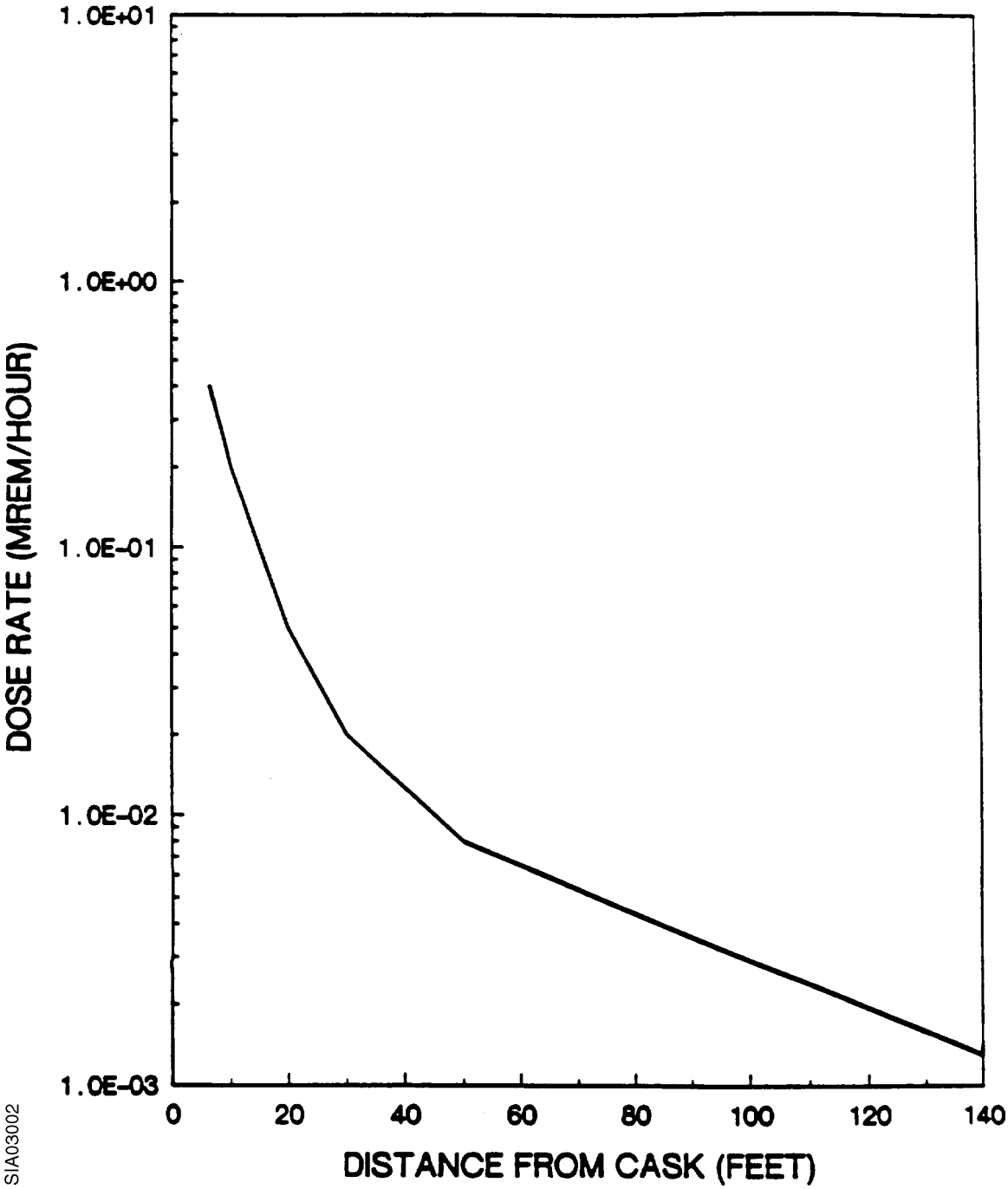


Figure A.3/7.3-3b
NAC-I28 S/T
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-140 FEET)

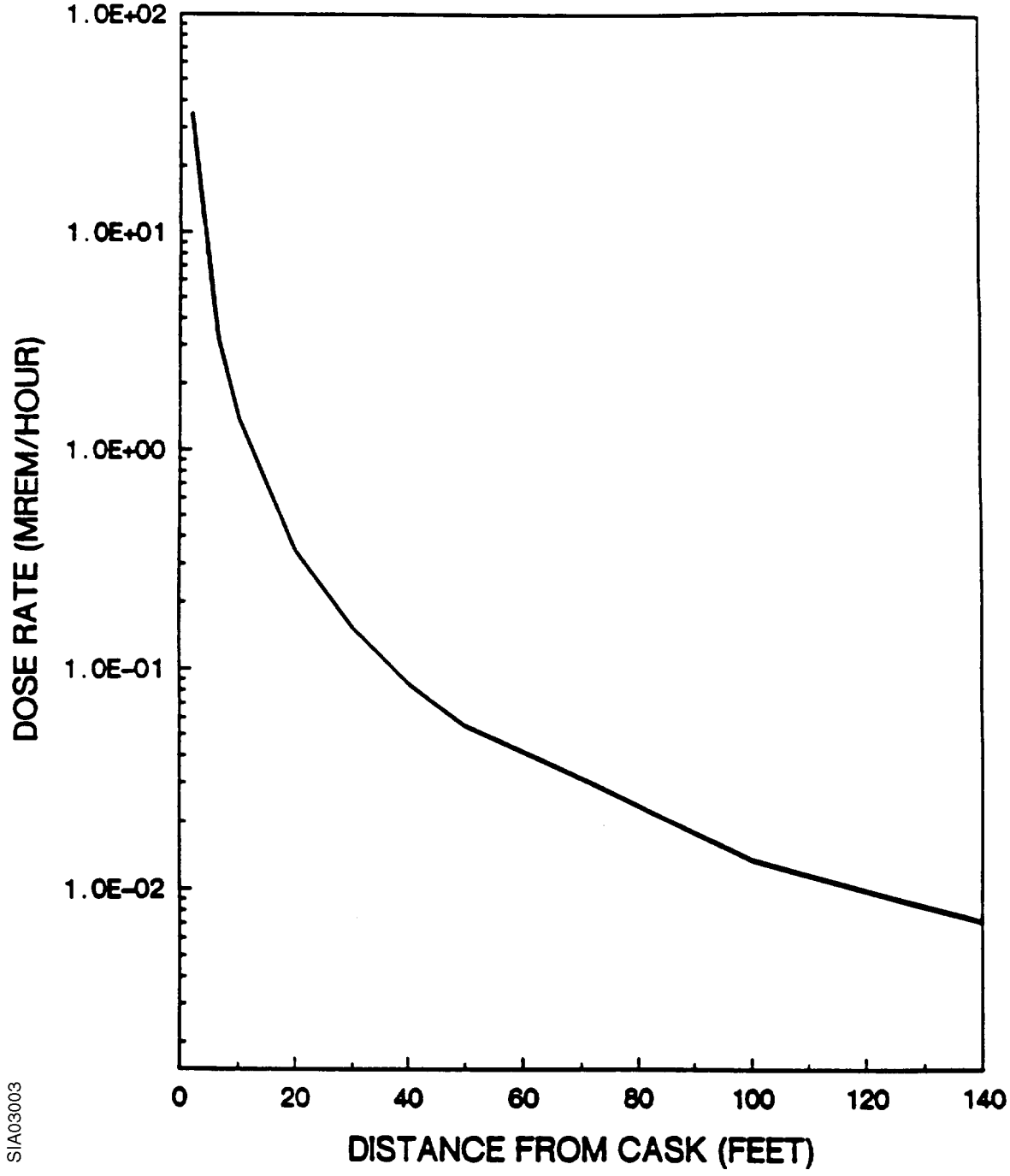


Figure A.3/7.3-4a
NAC-I28 S/T
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-700 FEET)

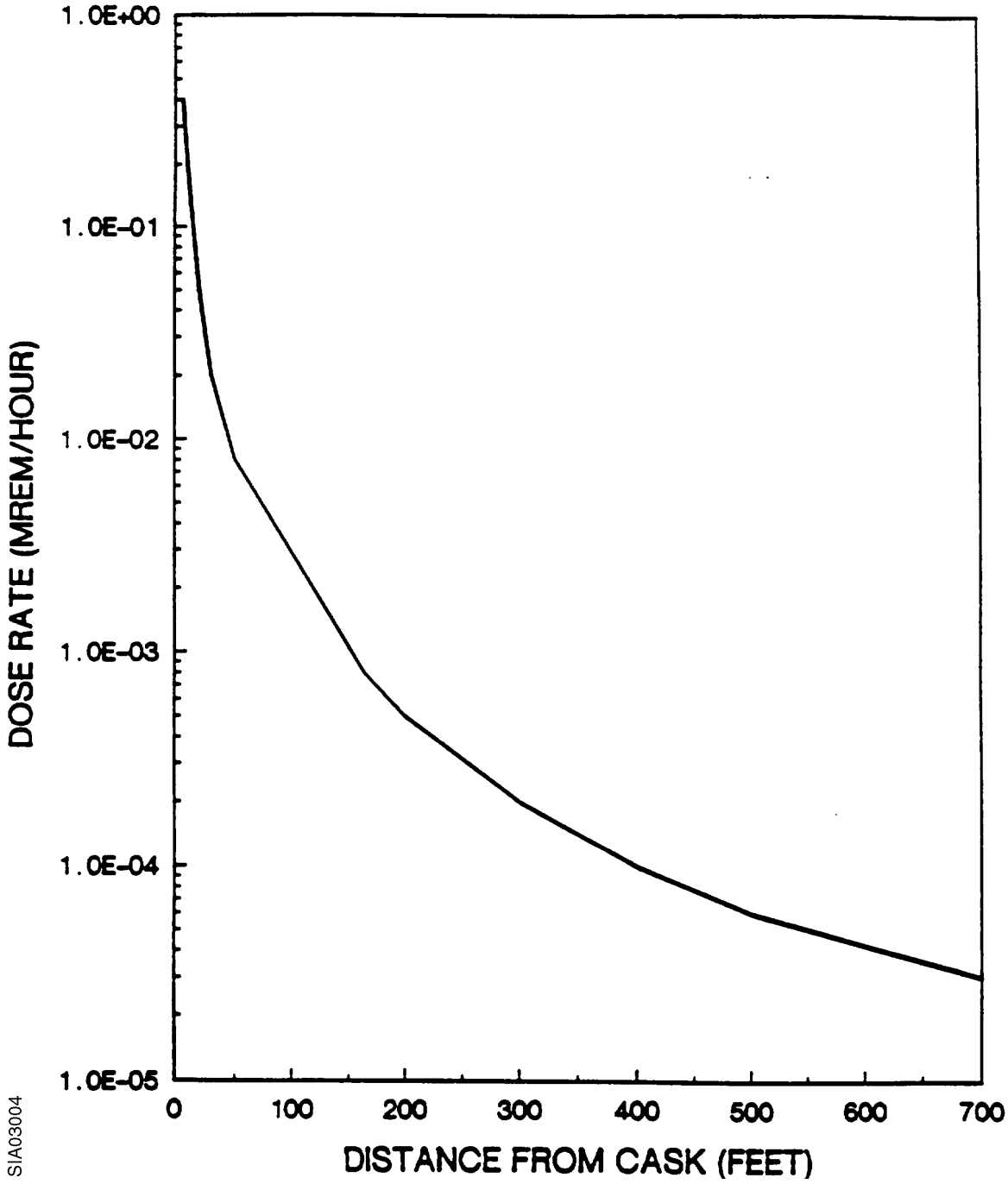


Figure A.3/7.3-4b
NAC-I28 S/T
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-700 FEET)

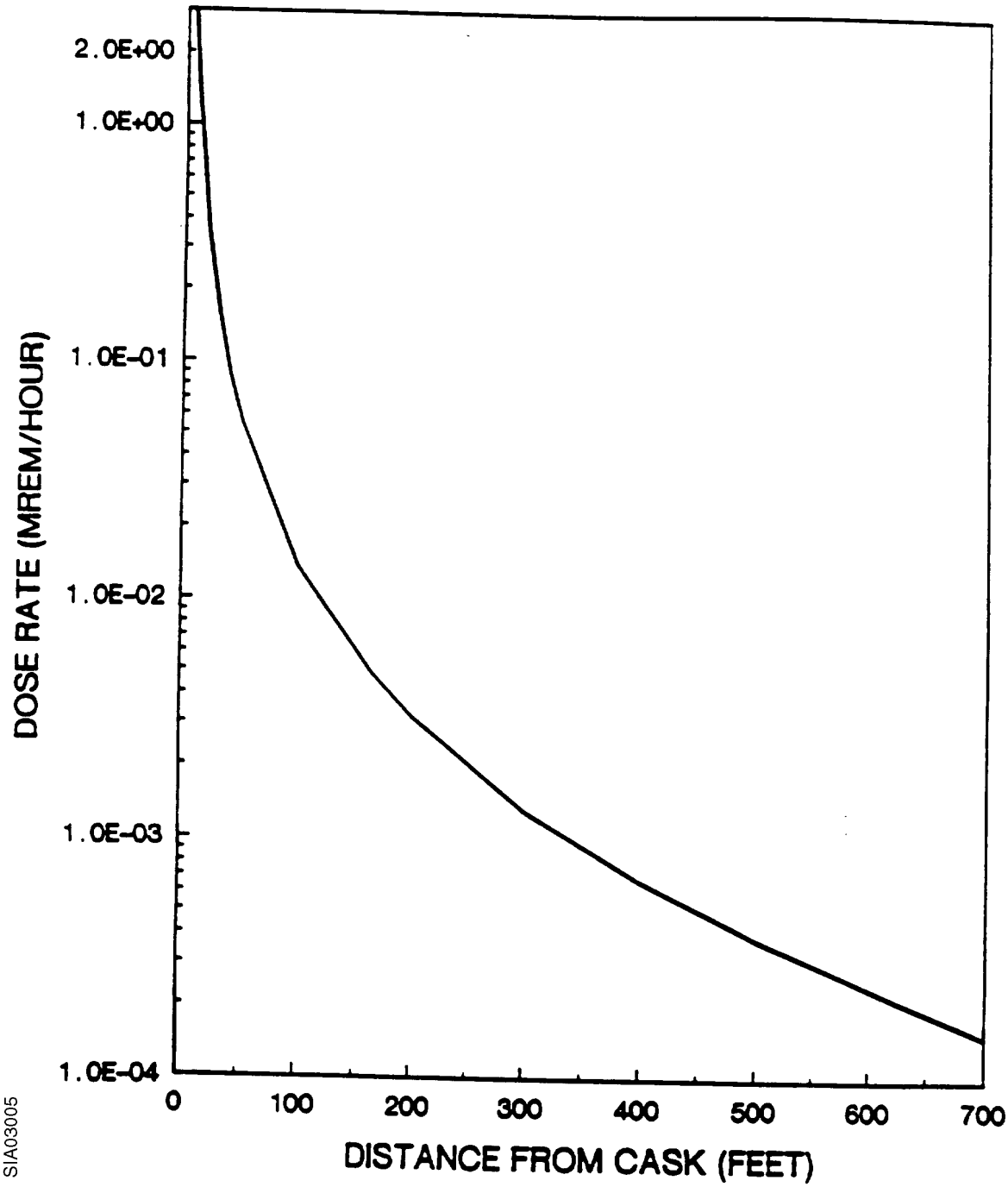


Figure A.3/7.3-5a
NAC-I28 S/T
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-9000 FEET)

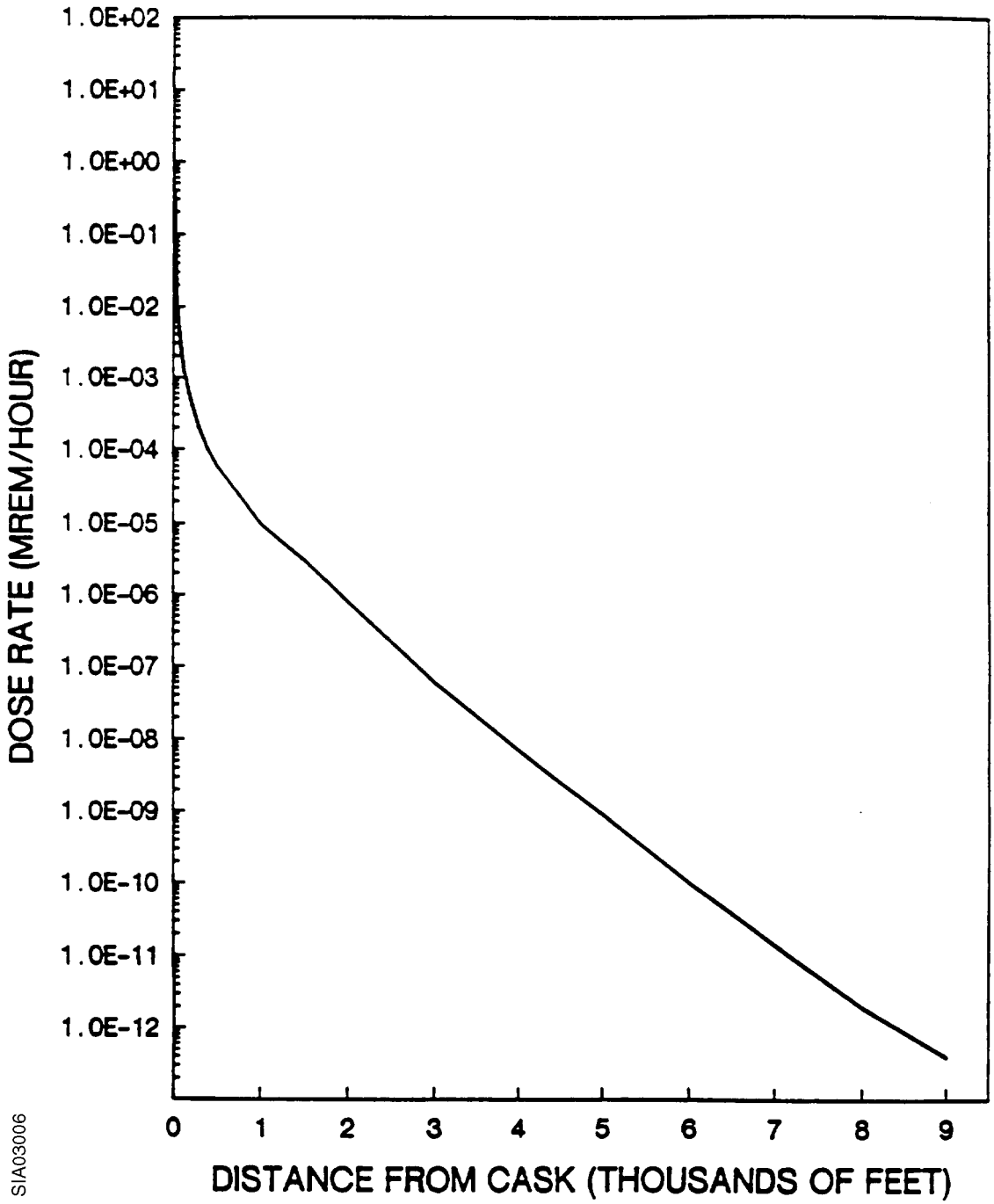


Figure A.3/7.3-5b
NAC-I28 S/T
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-9000 FEET)

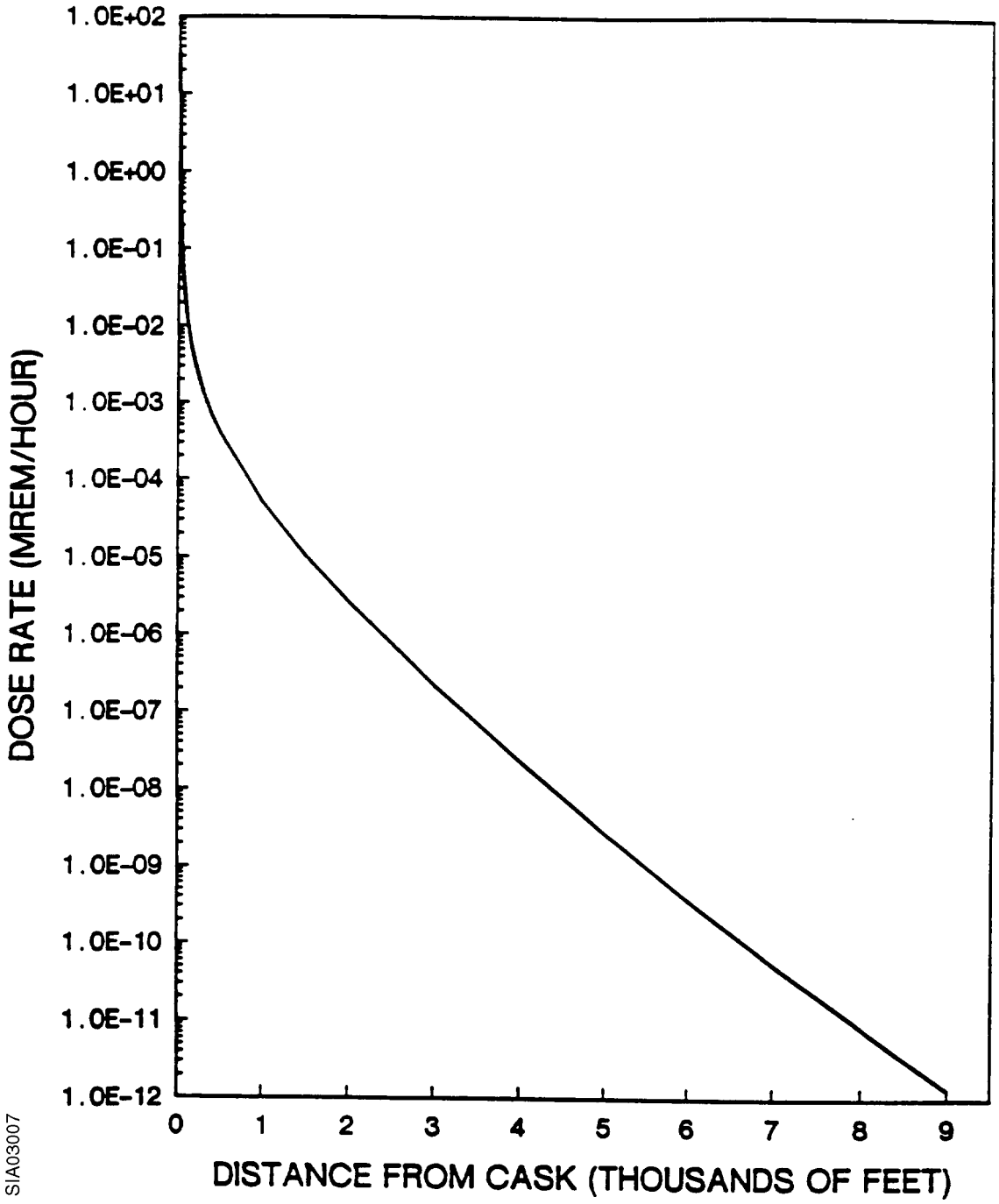
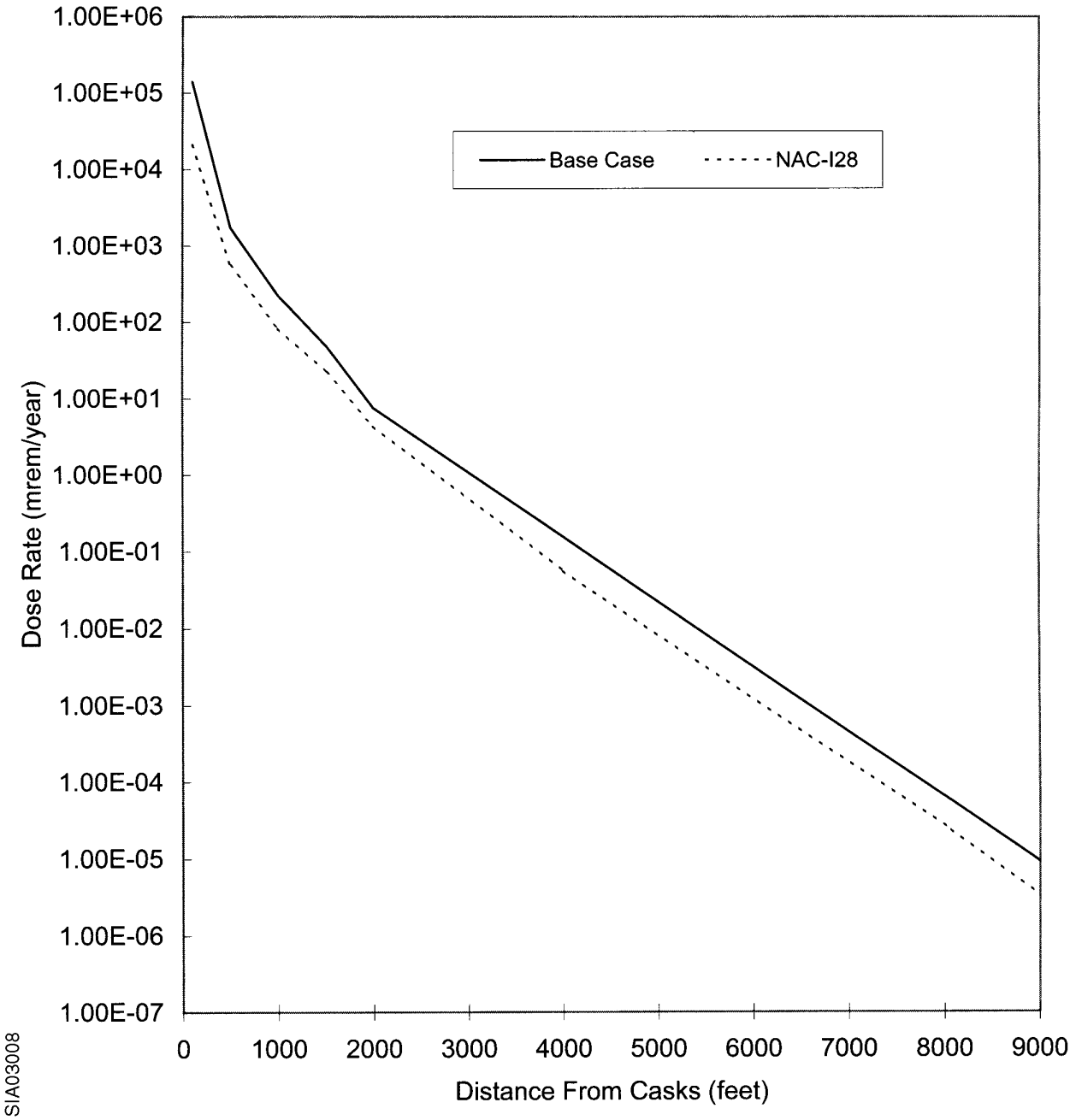


Figure A.3/7.3-6
DOSE RATE FOR 63 NAC-I/28 CASKS
VERSUS DISTANCE COMPARED TO ISFSI DESIGN
BASIS BASE CASE VERSUS DISTANCE



A.3/8.2.2 Extreme Wind

The effects and consequences of extreme winds on the NAC-I28 S/T cask are presented in Section 8.2.7 of the NAC Topical Report. The NAC analysis demonstrates that extreme winds are not capable of overturning their cask nor of producing leakage from it. Since no radioactivity would be released, no resultant doses would occur.

A.3/8.2.5 Fire

The ability of the NAC-I28 S/T cask to withstand postulated fires is presented in Section 8.2.2 of the NAC Topical Report. As concluded in Surry ISFSI SAR Section 8.2.5, no fires other than small electrical fires are credible at the ISFSI slab. Therefore, consistent with Section 8.2.2.2 of the NAC Topical Report, a total loss of the cask neutron shield due to fire exposure is not a credible event for the Surry ISFSI. See also Section A.3/8.2.8 of this Appendix.

A.3/8.2.8 Loss of Neutron Shield

As discussed in Section 1.2.4 of the NAC Topical Report, the NAC-I28 S/T cask features an outer shell which contains a 7-inch thickness of borated solid shield material. Sections 8.2.1 and 8.2.2 of the NAC Topical Report postulate a loss of this outer neutron shielding due to fire. However, no fires other than small electrical fires are credible at the ISFSI slab based on Section 8.2.5 of the Surry ISFSI SAR. Therefore, consistent with the NAC evaluation of this event, a total loss of the cask neutron shield due to fire exposure is not a credible event for the Surry ISFSI.

Should the outer neutron shield be damaged from a postulated fire, cask tip-over, or cask drop event, temporary shielding could be placed external to the cask (e.g., high temperature polyethylene sheets or concrete blocks) until the cask shielding could be repaired. Depending on the extent of damage, Section 8.2.10 of the Surry ISFSI SAR outlines the steps that would be taken to return the cask to the spent fuel pool to facilitate the repair of replacement of the portion of the neutron shield that was damaged. See also the discussion in Section 5.1.3.5 of the NAC Topical Report.

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Appendix A.4
CASTOR X/33 CASK

GENERAL DESCRIPTION

The GNSI CASTOR X/33 cask is a thick-walled ductile cast iron cylinder that is approximately 15.8 feet high, 7.8 feet in diameter, and weighs (empty) approximately 94.5 tons. The cask has a cylindrical cavity which holds a fuel basket designed to accommodate 33 PWR fuel assemblies. The loaded weight of the cask is approximately 118.3 tons. Four trunnions are bolted on, two at the head end and two at the bottom end of the body.

The cask is sealed with two stainless steel lids installed one on top of the other and bolted to the cask body. The primary lid is 10.2 inches thick and is secured to the cask body with 44 bolts. The secondary lid is 3.2 inches thick and is secured to the cask body with 70 bolts. Both lids are sealed with multiple seals consisting of metal seals and elastomer o-rings.

For improved neutron shielding, one row of axial holes in the wall of the cask body are filled with polyethylene rods. The cast iron wall of the cask provides gamma radiation shielding.

A tipover impact limiter is attached to the top of the cask after the cask is placed at the ISFSI. This impact limiter consists of an annular ring of aluminum honeycomb material enclosed in a stainless steel shell. The impact limiter is attached to the cask using a trunnion support assembly bolted to the underside of the impact limiter.

A.4/3.1.1 Materials To Be Stored

Due to weight restrictions imposed for handling of the CASTOR X/33 by the 125-ton cask crane, no fuel insert components of any kind may be stored in this cask.

A.4/7.3.2.1 Cask Surface Dose Rates

The assumptions used in calculating the GNSI CASTOR X/33 cask surface dose rates and energy spectra are provided in Sections 3.3.5 and 7.3.2.2 of the GNSI Topical Safety Analysis Report (Reference 1).

Neutron and gamma source terms for the stored spent fuel were generated using OREST (ORIGEN II). Typical results from these runs are shown in Surry ISFSI SAR Tables 7.2-1, 7.2-2, 7.2-3, and 7.2-4. ANISN (Reference 4) and DOT (Reference 10) were used by GNSI to calculate the cask surface fluxes. Flux-to-dose rate conversion factors, as shown in Tables 7.2-2 and 7.2-3 of the GNSI CASTOR X/33 Topical Safety Analysis Report (Reference 1), were then used to obtain the surface dose rates for the cask. The GNSI cask average surface dose rates for 10-year-old fuel are 18.1 mrem/hour neutron and 51.2 mrem/hour gamma for the side and 47.4 mrem/hour neutron and 0.7 mrem/hour gamma for the top. When these dose rates are combined, the side and top average surface dose rates are 69.3 mrem/hour and 48.1 mrem/hour, respectively. These dose rates are bounded by the total average surface dose rates of

224 mrem/hour for the side and 76 mrem/hour for the top reported in the Surry ISFSI SAR, Section 7.3.2.1.

Figure A.4/7.3-2 shows the normalized surface dose rates on the GNSI CASTOR X/33 cask versus age of spent fuel for both gamma and neutron radiation.

A.4/7.3.2.2 Dose Rate Versus Distance

The cask surface dose rates discussed in Section A.4/7.3.2.1 result in the dose rates at various distances as shown on Figures A.4/7.3-3a through A.4/7.3-6. The neutron transport results shown on these figures were generated using a series of adjoint (References 2 & 3) ANISN (Reference 4) runs. These calculations were performed with a BUGLE-80 (Reference 5) cross-section set for an infinite-air medium. As explained in References 2 and 3, the adjoint method is the preferred analytical technique when more than one set of sources must be evaluated at a given detector location for a response of interest. For the adjoint analyses reported here, the adjoint source is the flux-to-dose conversion factor reported in Reference 9. Four separate ANISN analyses were performed at distances of 50, 460, 1500, and 2460 meters. The resulting adjoint fluxes are presented in Table A.1/7.3-3. These adjoint fluxes were then folded with the cask surface leakage spectra supplied by GNSI over the area of the cask's top and side. Cask surface neutron leakage data are provided in Table A.4/7.3-2.

The resultant neutron dose rates were then used to construct the dose rate versus distance curves presented on Figures A.4/7.3-3a, A.4/7.3-4a, and A.4/7.3-5a.

For the gamma-ray transport, simple point kernel calculations using infinite medium dose rate buildup factors in dry air were performed. Using a point source model and References 6 and 7, air-to-void correction factors were developed and applied to the gamma dose rates in void based on Reference 8. The gamma dose rates for the casks are shown on Figures A.4/7.3-3b, A.4/7.3-4b, and A.4/7.3-5b.

For Figure A.4/7.3-6, decay factors have been used assuming that three casks are placed in the ISFSI each year for 18 years and each new group of three casks has a minimum of 10 years decay of the fuel. As shown on Figure A.4/7.3-6, the design basis dose rate for the ISFSI bounds the dose rate for the ISFSI filled to capacity with 54 GNSI CASTOR X/33 casks.

A.4/7.3.5 References

1. *Topical Safety Analysis Report for the GNSI CASTOR X Cask for an Independent Spent Fuel Storage Installation (Dry Storage),* General Nuclear Systems, Inc., June 1988.

2. V. R. Cain, The Use of Discrete Ordinates Adjoint Calculations, *A Review of the Discrete Ordinates 5 Method for Radiation Transport Calculations,* ORNL-RSIC-19, March 1968, pp. 85-94.

3. G. I. Bell, S. Glasstone, *Nuclear Reactor Theory,* Chapter 6.1 - The Adjoint Function and Its Applications, Van Nostrand Reinhold Company, New York, 1970.

4. W. W. Engle, Jr., *A User's Manual for ANISN, A One-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering,* K-1643, Union Carbide Corporation, Nuclear Division, June 1973.

5. *BUGLE-80, Coupled 47-Neutron, 20-Gamma-Ray, P3, Cross-Section Library for LWR Shielding Calculations,* DLC-75, R. W. Roussin, ORNL, June 1980.

6. Warkentin, J. K., *Polynominal Coefficients for Dose Buildup in Air,* Radiation Research Associates, Inc., August 15, 1975, RRA-N7511.

7. Hubbell, L. H., *Photon Cross-Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 KeV to 100 GeV,* National Bureau of Standards, August 1969, NSRDS-NBS29.

8. Spacetran II, *Dose Calculations at Detectors at Various Distances from the Surface of a Cylinder,* Neutron Physics Division of Oak Ridge National Laboratory, September 1973, ORNL-TM-2592.

9. ANSI/ANS-6.1.1-1977, *American National Standard-Neutron and Gamma Ray Flux to Dose Rate Factors,* American Nuclear Society, March 17, 1977.

10. Mynatt, F. R., Rhodes, W. A., et al., *The DOT-II Two Dimensional Discrete Ordinates Transport Code,* ORNL-TM-4280.

Table A.4/7.3-2
CASTOR X/33 CASK SURFACE NEUTRON LEAKAGES

Neutron Group	Upper[a] Energy (ev)	Cask Surface Leakage Spectra (n/cm^2 - sec)	
		Side	Top
1	1.7E+07	2.10E-03	2.41E-04
2	1.4E+07	5.84E-03	6.70E-04
3	1.2E+07	2.85E-02	3.14E-03
4	1.0E+07	5.16E-02	4.98E-03
5	8.6E+06	1.13E-01	9.65E-03
6	7.4E+06	1.19E-01	1.03E-02
7	6.1E+06	2.52E-01	2.26E-02
8	5.0E+06	6.41E-01	3.83E-02
9	3.7E+06	5.44E-01	6.77E-02
10	3.0E+06	6.26E-01	9.58E-02
11	2.7E+06	5.62E-01	8.58E-02
12	2.5E+06	2.43E-01	5.22E-02
13	2.4E+06	5.40E-01	1.16E-02
14	2.3E+06	6.85E-01	1.31E-01
15	2.2E+06	1.77E+00	3.38E-01
16	1.9E+06	1.71E+00	4.51E-01
17	1.6E+06	5.16E+00	1.51E+00
18	1.4E+06	1.13E+01	7.30E+00
19	1.0E+06	1.63E+01	1.71E+01
20	8.2E+05	7.08E+00	7.44E+01
21	7.4E+05	1.23E+01	1.29E+01
22	6.1E+05	2.86E+01	6.16E+01
23	5.0E+05	4.63E+01	1.27E+02
24	3.7E+05	2.58E+01	7.10E+01
25	3.0E+05	4.10E+01	1.13E+02
26	1.8E+05	2.58E+01	7.10E+01
27	1.1E+05	3.94E+01	6.83E+01
28	6.7E+04	2.39E+01	4.15E+01
29	5.0E+04	8.27E+00	1.43E+01
30	3.2E+04	5.16E+00	8.98E+00
31	2.6E+04	1.75E+00	3.04E+00
32	2.4E+04	2.04E+00	3.54E+00
33	2.2E+04	6.23E+00	1.08E+01
34	1.5E+04	7.10E+00	1.23E+01
35	7.1E+03	3.41E+00	5.91E+00

Table A.4/7.3-2
CASTOR X/33 CASK SURFACE NEUTRON LEAKAGES

Neutron Group	Upper[a] Energy (ev)	Cask Surface Leakage Spectra (n/cm^2 - sec)	
		Side	Top
36	3.4E+03	1.39E+01	1.65E+01
37	1.6E+03	1.55E+01	1.63E+01
38	4.5E+02	1.07E+01	9.05E+00
39	2.1E+02	5.14E+00	4.31E+00
40	1.0E+02	1.53E+01	9.38E+00
41	3.7E+01	1.01E+01	5.96E+00
42	1.1E+01	1.33E+01	6.40E+00
43	5.0E+00	6.16E+00	2.30E+00
44	1.8E+00	5.38E+00	1.61E+00
45	8.8E-01	3.01E+00	7.10E-01
46	4.1E-01	8.27E-01	1.33E-02
47	1.0E-01	2.37E-01	3.80E-02

Note: CASTOR X/33 Cask Surface Area: 360,549 cm^2 (side), 44,676 cm^2 (top).

a.Reference 5.

Figure A.4/7.3-2
NORMALIZED SURFACE DOSE RATE ON
GNSI CASTOR X/33 CASK
VERSUS AGE OF SPENT FUEL

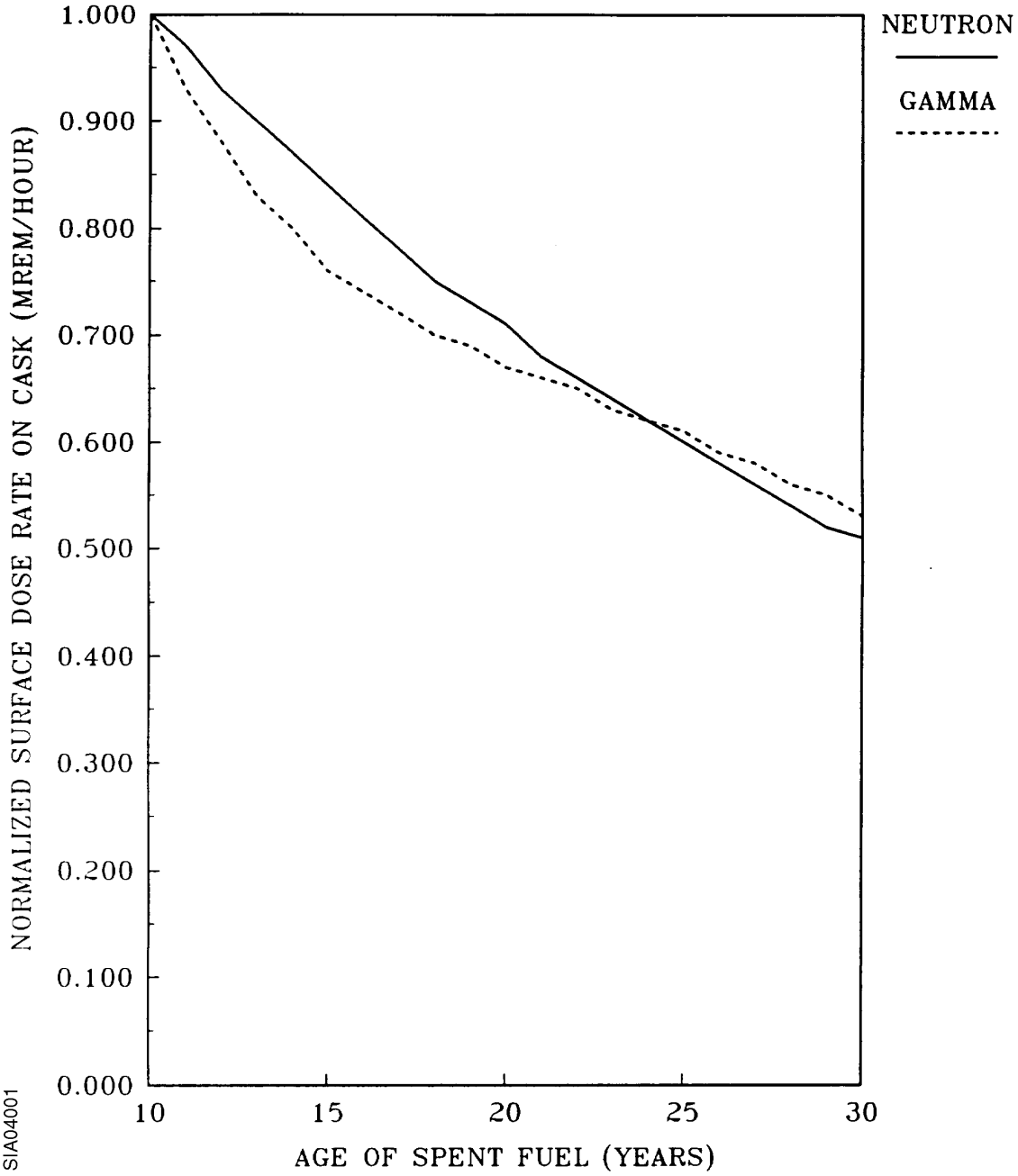


Figure A.4/7.3-3a
GNSI CASTOR X/33
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-140 FEET)

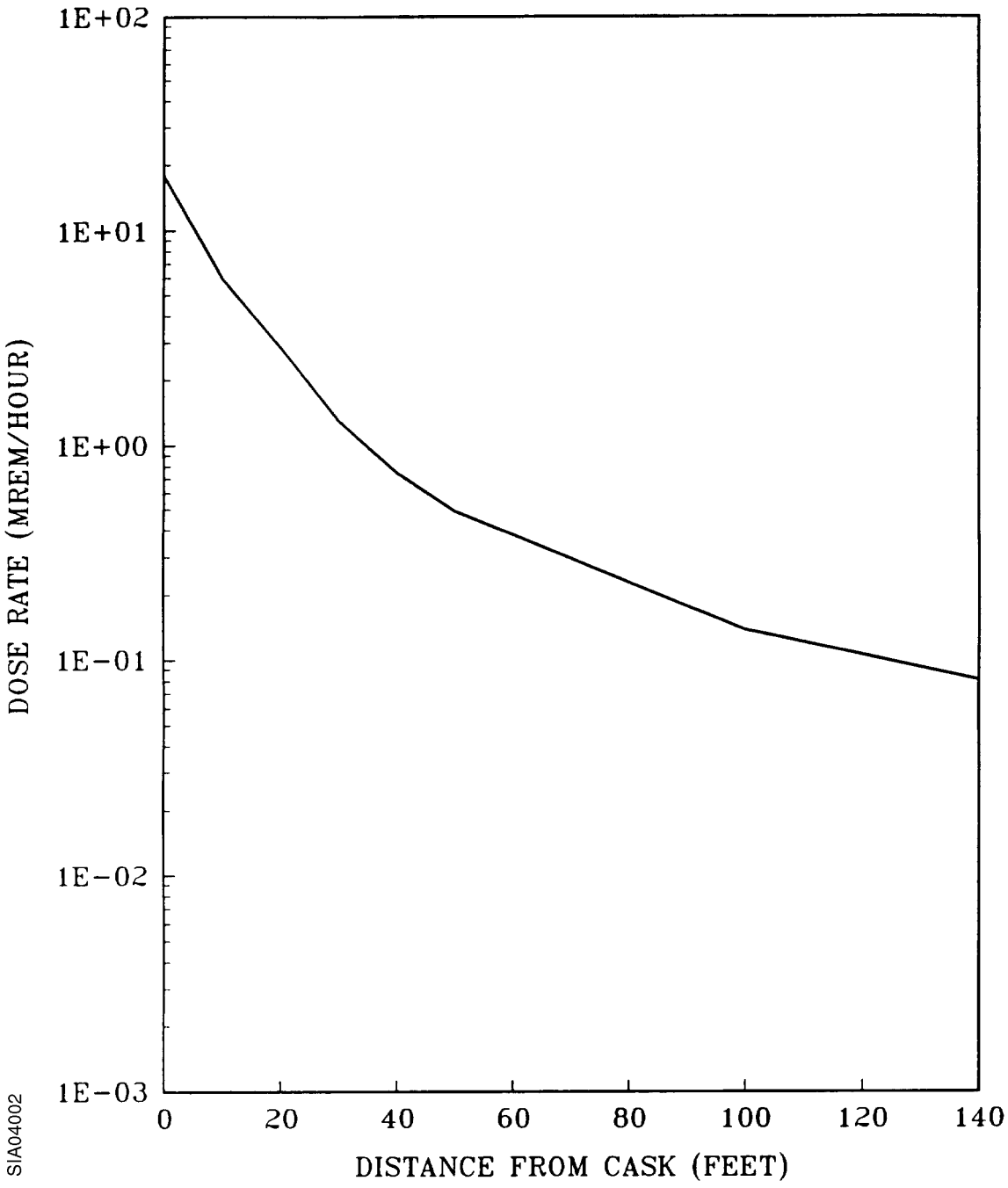


Figure A.4/7.3-3b
GNSI CASTOR X/33
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-140 FEET)

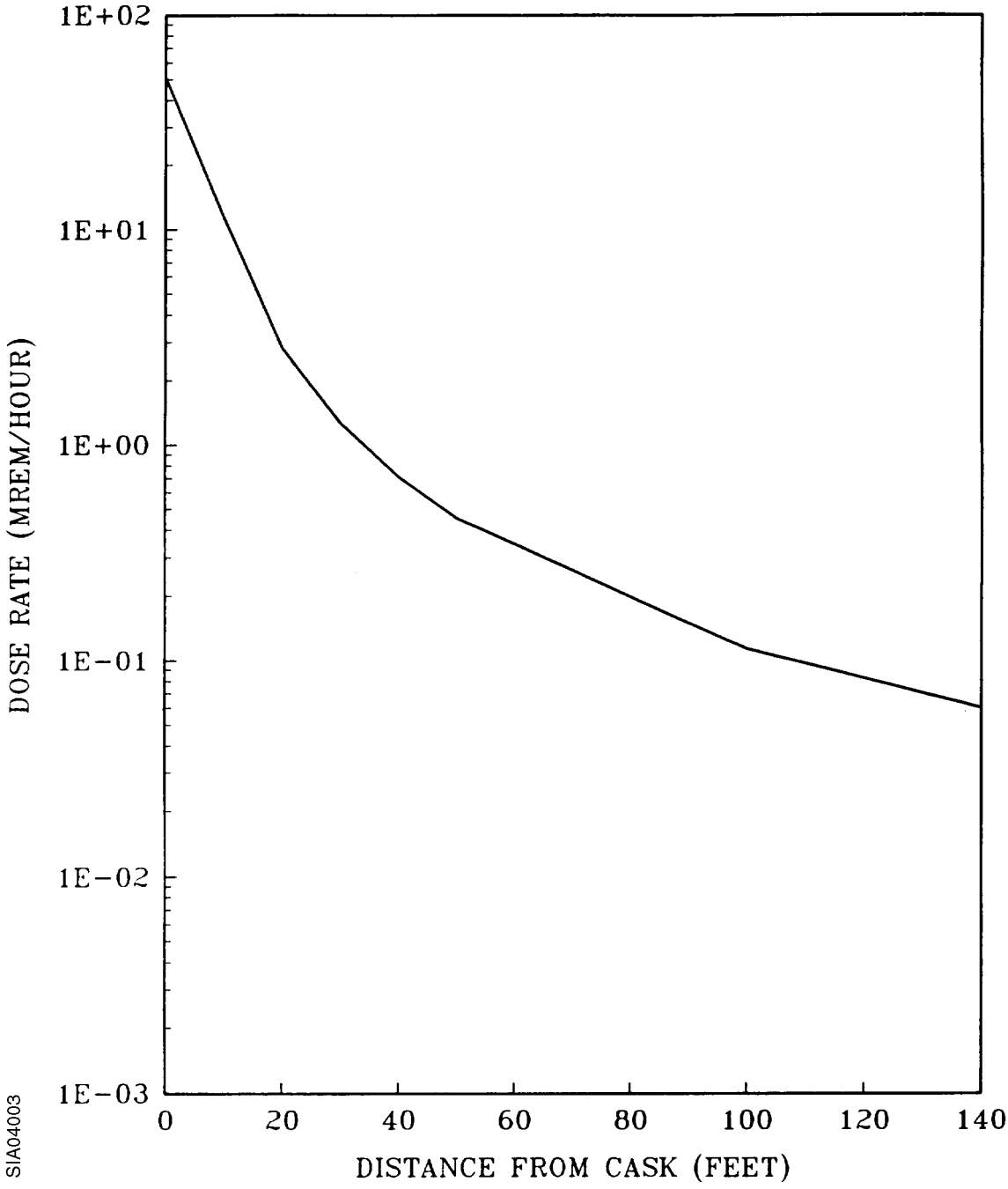


Figure A.4/7.3-4a
GNSI CASTOR X/33
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-700 FEET)

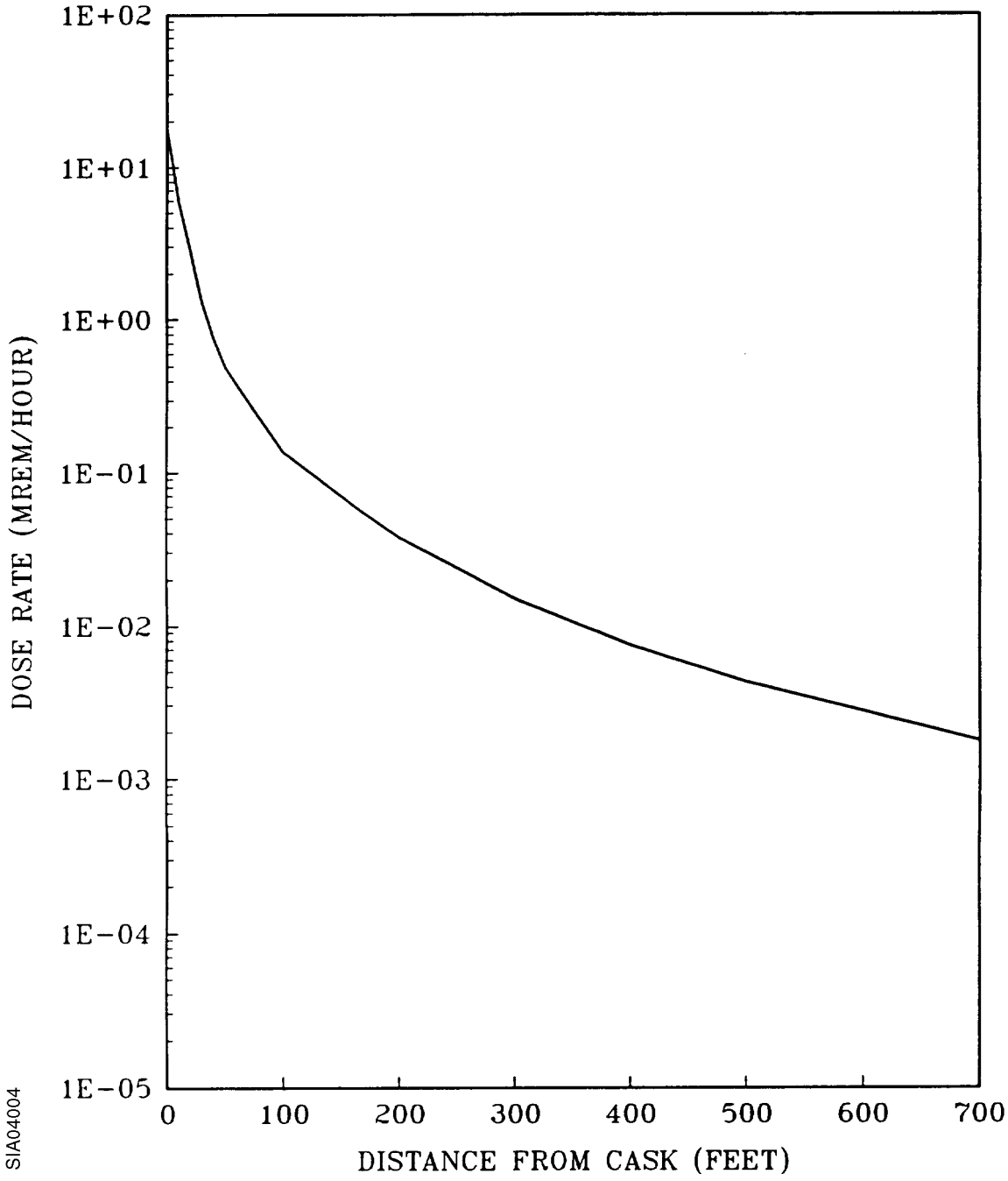


Figure A.4/7.3-4b
GNSI CASTOR X/33
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-700 FEET)

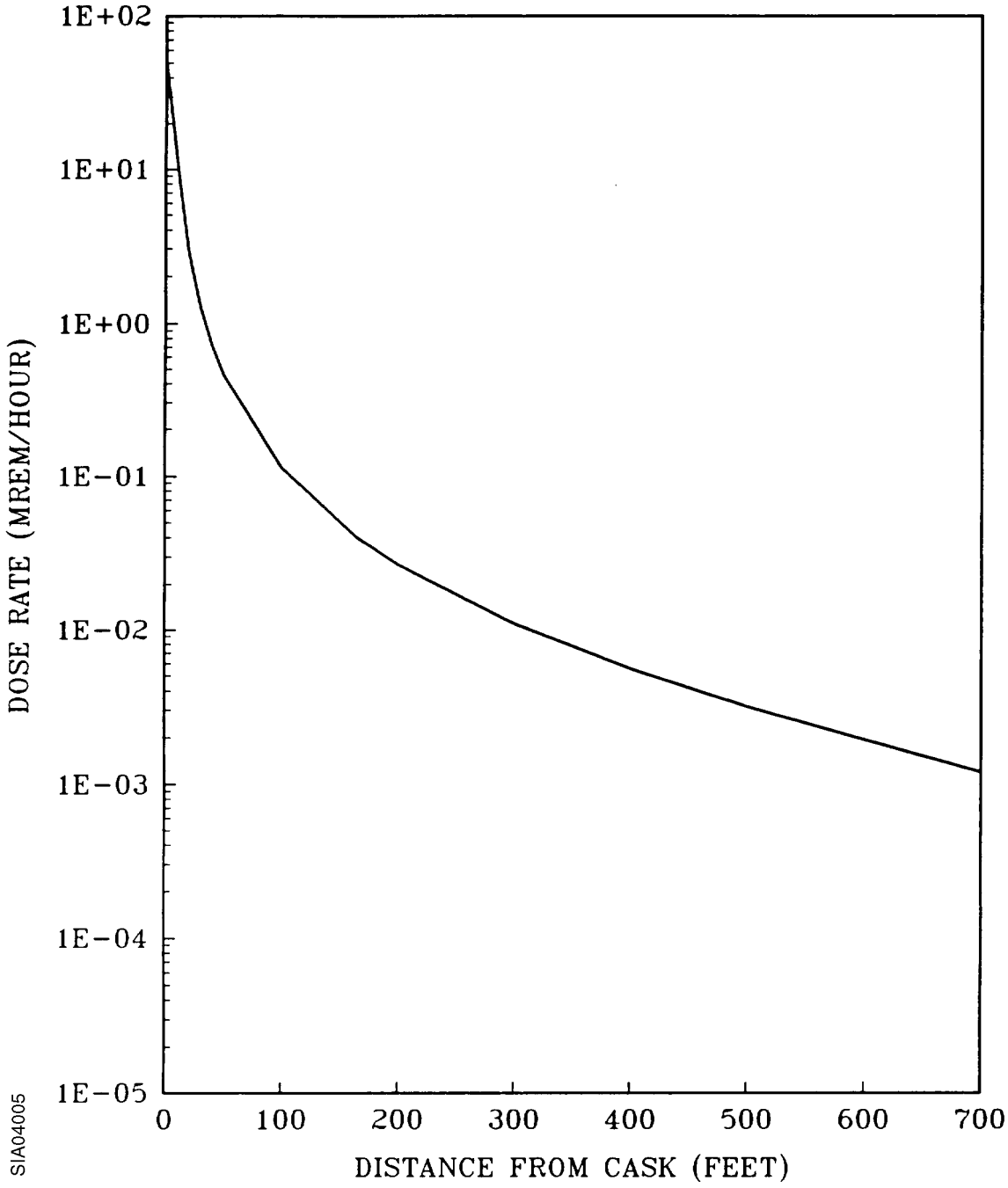


Figure A.4/7.3-5a
GNSI CASTOR X/33
NEUTRON DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-9000 FEET)

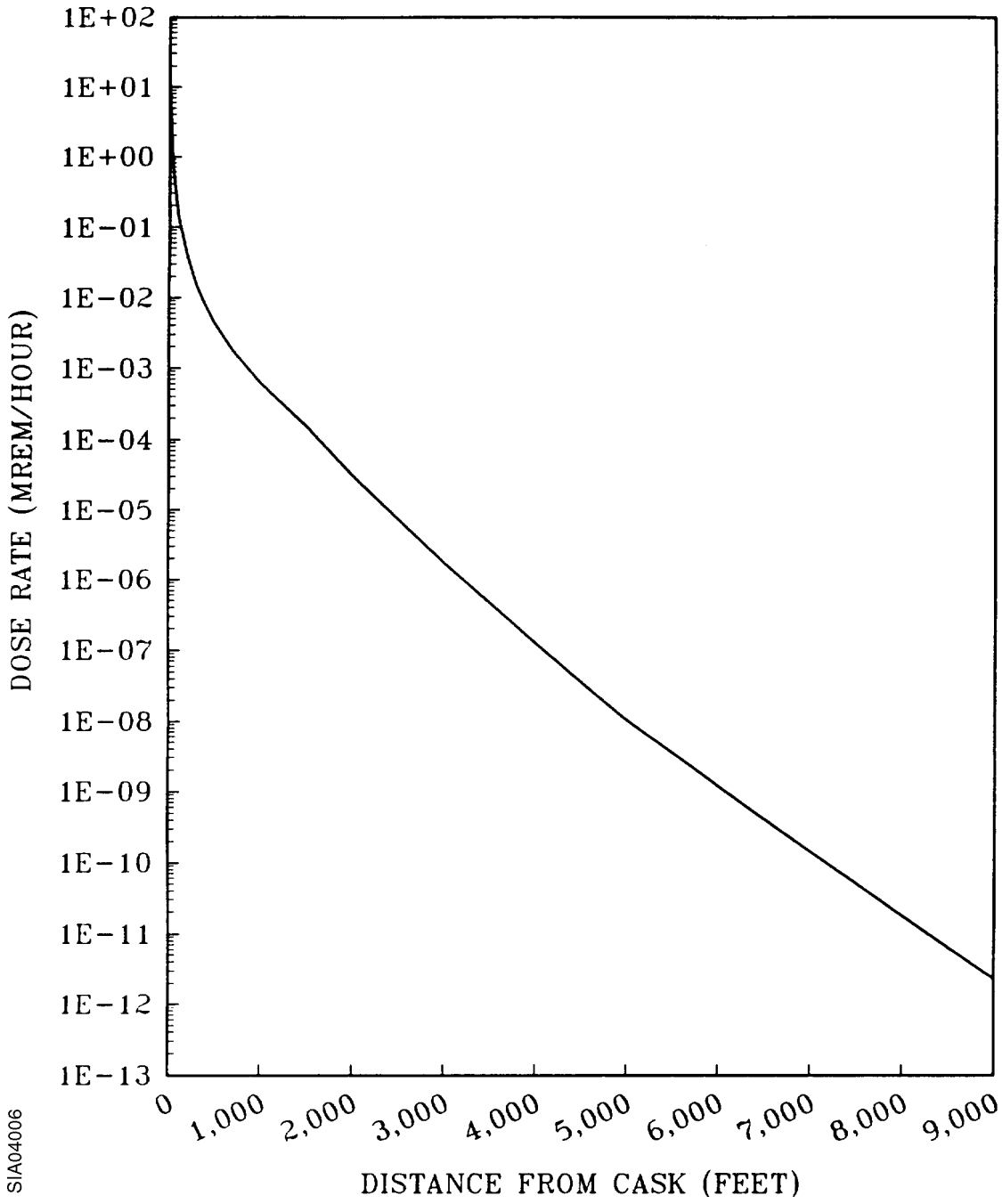


Figure A.4/7.3-5b
GNSI CASTOR X/33
GAMMA DOSE RATE FROM ONE CASK
VERSUS DISTANCE
(0-9000 FEET)

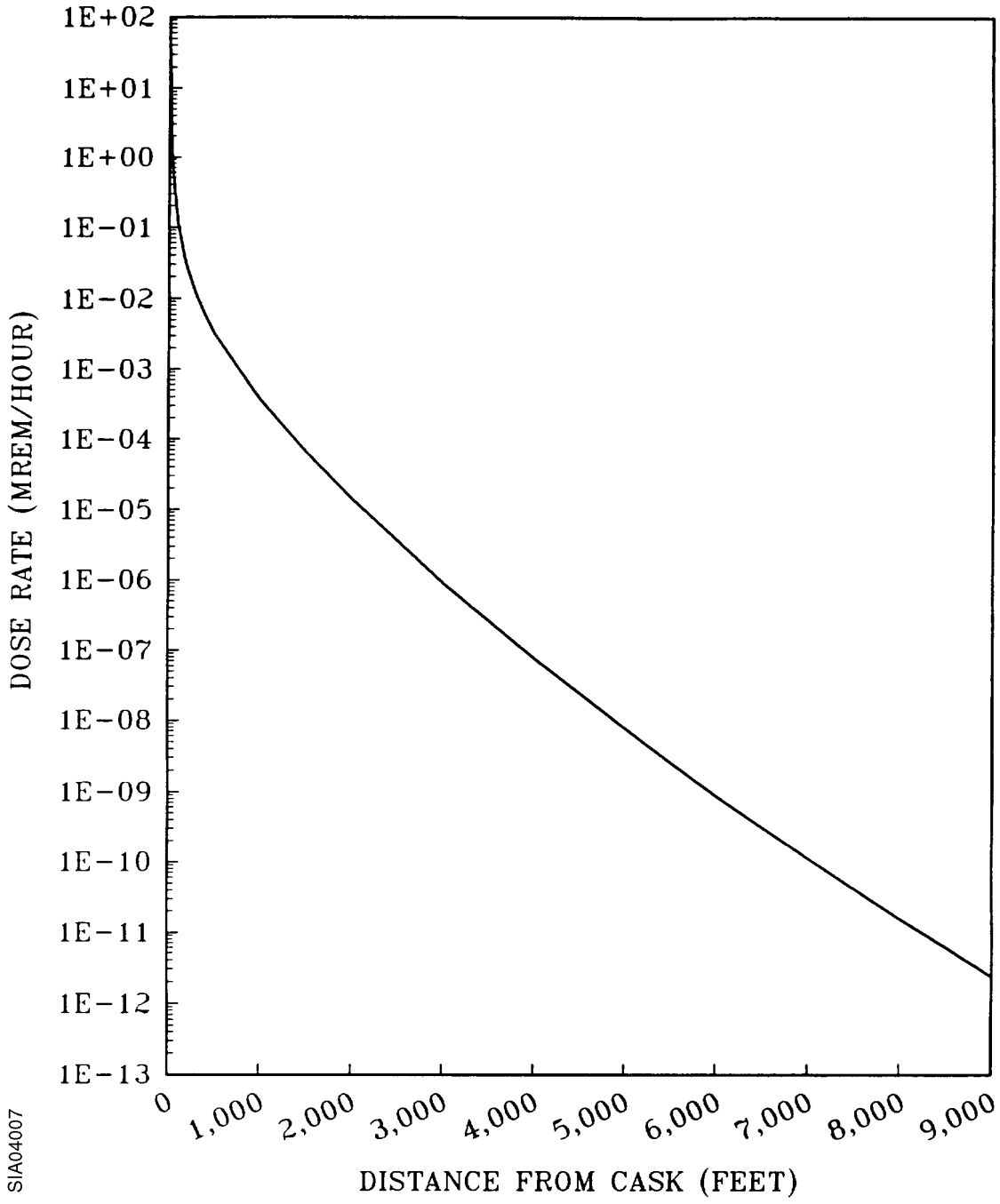
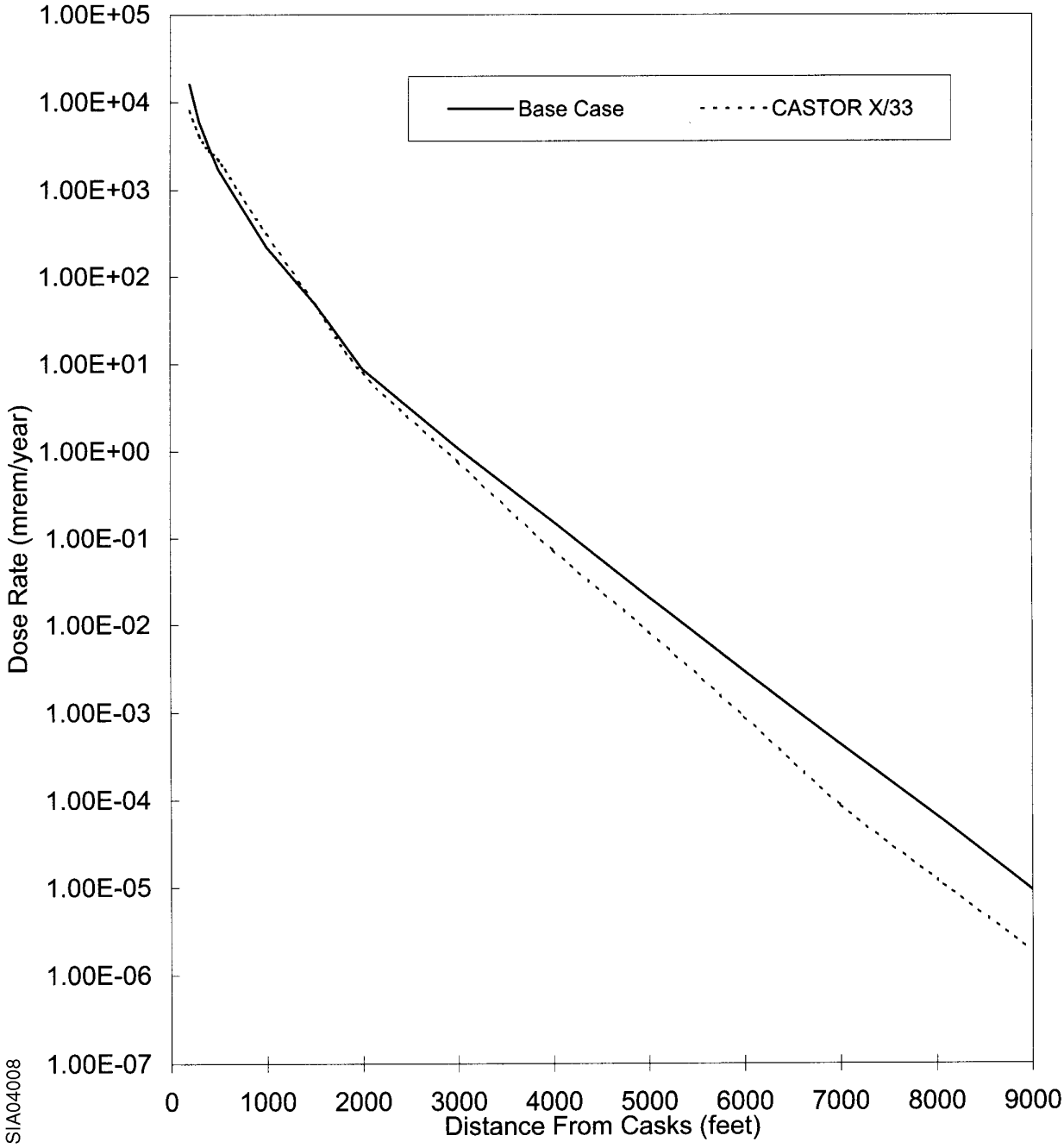


Figure A.4/7.3-6
DOSE RATE FOR 54 CASTOR X/33 CASKS
VERSUS DISTANCE COMPARED TO ISFSI BASE CASE DOSE RATE
VERSUS DISTANCE



A.4/8.2.2 Extreme Wind

The effects and consequences of extreme winds on the GNSI CASTOR X/33 cask are presented in Section 8.2.1.2.1 of the GNSI Topical Safety Analysis Report. The GNSI analysis demonstrates that extreme winds are not capable of overturning their cask nor of producing leakage from it. Since no radioactivity would be released, no resultant doses would occur.

A.4/8.2.5 Fire

The ability of the GNSI CASTOR X/33 cask to withstand postulated fires is presented in Section 8.2.1.2.7 of the GNSI Topical Safety Analysis Report. As concluded in Surry ISFSI SAR Section 8.2.5, no fires other than small electrical fires are credible at the ISFSI slab. Based on the GNSI analyses referenced above, since no radioactivity would be released, no resultant doses would occur.

A.4/8.2.8 Loss of Neutron Shield

As discussed in Section 1.2.4 of the GNSI Topical Safety Analysis Report, the neutron absorbing material for the GNSI CASTOR X/33 cask includes polyethylene rods inserted into the cask wall. Thus, no loss of neutron shield is postulated.

Appendix A.5
TN-32 CASK

GENERAL DESCRIPTION

The TN-32 cask is a smooth right circular cylinder of multi-wall construction that is approximately 16.8 feet high, 8.1 feet in diameter and weighs (empty) approximately 91.0 tons. The cask inner shell and containment vessel is a welded, carbon steel cylinder that is 1.5 inches thick and has a sprayed metallic aluminum coating for corrosion protection. Surrounding the outside of the containment vessel wall is a steel gamma shield with a wall thickness of 8.0 inches. The bottom end of the gamma shield has a thickness of 8.75 inches. The cask has a cylindrical cavity which holds a fuel basket designed to accommodate 32 PWR fuel assemblies. The loaded weight of the cask is approximately 115.5 tons. Four trunnions are welded on, two at the top end and two at the bottom end of the body.

During fabrication of the TN-32 cask, the inner containment vessel and the gamma shielding are fit together by a shrink-fit procedure. The gamma shielding is heated so that the inner containment vessel, with the flange attached, can be inserted into the outer gamma shielding vessel. This allows a close fit between the two cylindrical shells for good heat transfer. During the shrink fit operation, a small circumferential gap between the flange of the inner vessel and the gamma shielding forms as the heated gamma shield cools. Prior to welding the flange to the gamma shield, the gap is filled with shims made of one of the materials specified in the TN-32 TSAR for the gamma shield shell.

The cask is sealed with one carbon steel lid bolted to the top flange of the containment vessel. The lid is 10.5 inches thick and is secured to the cask body with 48 bolts. The lid and lid penetration covers are sealed with metallic o-ring seals.

Neutron shielding is provided by a 4.5-inch thick resin compound enclosed in long aluminum boxes that surround the gamma shield. The neutron shield boxes are enclosed by a painted carbon steel shell that is 0.50 inches thick.

In Chapter 1 of the TN-32 Topical Safety Analysis Report (Rev. 9A, 12/96), drawing 1049-70-2, Rev. 2, includes a view of a cask trunnion (item 6). The back side of the trunnion (weld prep) is shown at a 30 degree angle. This angle should actually be shown as 45 to 50 degrees.

Section 3.1.1, Paragraph 3 of the TN-32 Topical Safety Analysis Report (Rev. 9A, 12/96) states that “Other structural and structural attachment welds are examined by the liquid penetrant or the magnetic particle method in accordance with Section V, Article 6 of the ASME Code. Acceptance standards are in accordance with Section III, Subsection NF, Paragraph NF-5350.” However, Paragraph NF-5350 only pertains to liquid penetrant inspection. Paragraph NF-5340 pertains to magnetic particle inspection. Section 3.1.l, Paragraph 3 of the TN-32 Topical Safety

Analysis Report (Rev. 9A, 12/96) should read “Other structural and structural attachment welds are examined by the liquid penetrant or the magnetic particle method in accordance with Section V, Article 6 of the ASME Code. Acceptance standards are in accordance with Section III, Subsection NF, Paragraphs NF-5340 and NF-5350.”

In Chapter 5 of the TN-32 Topical Safety Analysis Report (Rev. 9A, 12/96), Table 5.1-2 provides a summary of maximum calculated dose rates which are used to estimate personnel exposure from cask loading activities. In order to provide consistency with the NRC SER, the total (neutron plus gamma) side dose rates under normal conditions at the cask surface and at one meter from the cask surface are rounded up from 86.2 mrem/hr to 90 mrem/hr and from 46 mrem/hr to 50 mrem/hr, respectively. In Chapter 10 of the TN-32 TSAR, Table 10.3-1 provides an estimate of occupational exposures for cask loading, transport and emplacement. The dose rate of 46 mrem/hr used in this table is rounded up to 50 mrem/hr, and the total estimated dose is changed from 3.06 man-rem to 3.3 man-rem. These dose rates and estimated doses remain bounded by ISFSI Technical Specification dose limits and dose estimates for cask loading provided in the ISFSI SAR.

The weld between the aluminum plates separating the fuel storage tubes and the outer aluminum plates at twenty-four locations around the periphery of the fuel basket is shown on TN-32 TSAR drawing 1049-70-6, rev. 3 as a 0.25 inch groove weld. In order to provide consistency with as-built conditions, this weld may alternatively be a 0.25 inch fillet weld.

The weld creating the longitudinal seam of the neutron shield outer shell is shown on TN-32 TSAR drawing 1049-70-2, revision 2 as a full penetration weld. In order to provide improved heat transfer between the outer shell and the neutron shield tubes, this weld may alternatively be a partial penetration weld.

TN-32 TSAR Revision 9A drawing 1049-70-5 specifies that the top of borated aluminum plates in the fuel basket be places nominally 11.88 inches from the top of the basket assembly. The TN-32 Final Safety Analysis Report, Rev. 0 (Reference 2), which contains analyses to support loading of fuel with higher burnup and enrichment, specifies that the top of the borated aluminum plates be placed nominally 12.00 inches from the top of the basket assembly. Since Revision 9A is the TN-32 TSAR of record for the Surry ISFSI, the dimensions must be reconciled in order to facilitate future loading of TN-32 casks with Surry fuel of higher burnup and enrichment. Therefore, the nominal dimension may be either 11.88 inches or 12.00 inches without any impact to cask criticality evaluations.

Structural analyses for Missile Types B and C contained in sections 2.2.1.3.1 and 2.2.1.3.3 of the TN-32 TSAR include the protective cover. Transnuclear has revised those analyses and the protective cover is no longer used in the model. The revised TSAR pages are included as Attachment 2 to this appendix. The revised analyses conclude that the code allowable stresses on the lid are not exceeded during a missile impact event. Sections 2.2.1.3.2 and 2.2.1.3.3 in the TN-32 TSAR, Rev. 9A are replaced by the attached sections 2.2.1.3.2 and 2.2.1.3.3.

The lid bolt analysis presented in Appendix 3A.3 of the TN-32 TSAR has been updated to allow for torque in the range of 880 ft-lb to 1230 ft-lb, to incorporate High Purity Loctite N-5000 Antiseize lubricant, and to allow the use of silver-jacketed O-rings. In addition, the summary of bolt stresses presented in Table 3.4-7 of the TN-32 TSAR has been corrected. The updated analysis, figures, and tables are included as Attachment 1 to this appendix. The revised analysis concludes that the code allowable stresses on the bolts are not exceeded for both normal and accident conditions. Pages 3A.3-1 through 3A.3-13, Figures 3A.3-1, 3A.3-2, 3A.3-4, 3A.3-5 and 3A.3-6, and Table 3.4.7 in the TN-32 TSAR Revision 9A are replaced by the attached pages 3A.3-1 through 3A.3-15, Figures 3A.3-1, 3A.3-2, 3A.3-4, 3A.3-5 and 3A.3-6, and Table 3.4.7.

In addition to the sections above, Section 7.1.4 of the TN-32 TSAR, Revision 9A, states that the bolt torque for the main lid bolts is 930 ± 50 ft-lb and for the penetration port covers the torque is 60 ± 10 ft-lb. In accordance with the lid bolt analysis update, the required torque for the main lid bolts is 880 ft-lb to 1230 ft-lb. The required torque for the penetration cover bolts ranges from 60 ft-lb to 100 ft-lb depending on the bolt material supplied by the vendor.

TN-32 TSAR Revision 9A drawing 1049-70-1, drawing 1049-70-4, Figure 1.2-1, and Figure 2.3-1 show that the overpressure system is completely contained under the protective cover. Figure 2.3-1 also shows wiring penetrating the top of the cover and running down the side of the cask. In order to make the pressure switches/transducers more accessible and eliminate the connector at the top of the cover, an alternative design is shown in the revised TSAR pages included as Attachment 3 to this appendix. For this design, the protective cover includes a sealable bolt-on access plate that is both airtight and watertight. The access plate has a through-wall fitting that connects to the OP system on the inside of the protective cover and connects to tubing on the outside of the protective cover. This tubing runs down the side of the cask to an instrumentation box in which the pressure switches/transducers are located. In addition, another connection is located at the access plate which openly communicates to the atmosphere within the protective cover. The external connection to this fitting will connect to tubing that also is mounted along the side of the cask.

Drawings 1049-70-1 and 1049-70-4 of the TN-32 TSAR show the cask with the unmodified protective cover and overpressure switches. The corresponding configuration with modifications is shown in drawing SK-VP-SAR-1 in Attachment 3. Similarly, Figures 1.2-1 and 2.3-1 illustrate the confinement boundary components and pressure monitoring system. The corresponding drawings with modifications are Figures VP1.2-1 and VP2.3-1, respectively, and are contained in Attachment 3. The confinement boundary components shown in Figures 1.2-1 and VP1.2-1 are:

1. Inner shell and bottom closure
2. Flanged and bolted lid
3. Flange

4. Vent cover
5. Drain cover

It should be noted that the confinement boundary components are not changed with the alternative design.

The plastic structural analysis presented in Section 3C.3-1 of the TN-32 TSAR utilizes a value of 0.48" for the gap between center basket rails. The actual gap can range from 0.0" to 1.1326" while maintaining the required opening between opposite rails. Therefore, additional analyses have been performed to demonstrate that the structural integrity of the basket and rails is maintained for the full range of possible gap sizes. The additional analyses are included as Attachment 4 to this appendix.

Table 8.1-1 of the TN-32 TSAR describes the sequence of operations associated with the TN-32 cask. For a modified cask, step 13 for installing the protective cover will be performed prior to step 11 for checking the function of the overpressure system transducers or switches. Also, step 11 will not include instructions to check the function of the transducers or switches before the protective cover is installed.

TN-32 casks used at the Surry ISFSI are fabricated to the requirements of the TN-32 Topical Safety Analysis Report (TSAR), Revision 9A or the TN-32 Final Safety Analysis Report (FSAR), Revision 0. TN-32 casks fabricated to the requirements of the TN-32 FSAR, Revision 0 have been evaluated with respect to the design bases for the TN-32 TSAR, Revision 9A, and have been found to be acceptable. Analyses included in the TN-32 FSAR, Revision 0 may not be credited in the use of TN-32 casks unless they have been added to the ISFSI SAR. The analyses in Chapters 4 and 6 of the TN-32 FSAR, Revision 0 have been added to this Appendix A.5.

The only physical difference between TN-32 TSAR, Rev. 9A casks and TN-32 FSAR, Rev. 0 casks is the design of the non-safety related overpressure system. TN-32 TSAR, Rev. 9A casks use an overpressure system with two pressure switches located under the protective cover and wiring through the protective cover that connects to the facility alarm panel. TN-32 FSAR, Rev. 0 casks use tubing through the protective cover to the pressure switches/transducers in a box on the side of the cask near ground level. An evaluation has shown that either overpressure system configuration is acceptable for use at the Surry ISFSI.

The fabrication of TN-32 FSAR, Rev. 0 casks differs in the following two ways from the fabrication of TN-32 TSAR, Rev. 9A casks.

1. The nil ductility transition temperature (NDTT) required for containment material is minus 80°F. The TN-32 TSAR, Rev. 9A cask containment materials have a specified NDTT of no more than minus 40°F.

2. Progressive PT and MT inspections are required of the bottom to gamma shield weld and the lid to lid shield weld. Progressive inspections were not required in the TN-32 TSAR, Rev. 9A.

These two changes provide additional margin in the structural evaluation performed for the TN-32 FSAR, Rev. 0 cask; however, this evaluation is not approved for use at the Surry ISFSI. The TN-32 FSAR, Rev. 0 cask meets the structural design criteria for casks to be used at the Surry ISFSI. The design and fabrication changes described above will be in effect for TN-32 casks number TN-32.32 and higher.

The US NRC has approved the generic use of TN-32 casks by 10 CFR Part 50 licensees. The TN-32 FSAR, Rev. 0 provides the licensing basis for this use and includes Technical Specifications. The Surry ISFSI Technical Specifications, and the TSAR, Rev. 9A, however, will govern the use of TN-32 Rev. 0 casks at the Surry ISFSI, except to the extent that specific analyses (e.g., criticality or thermal performance) from the FSAR, Rev. 0 have been added to the ISFSI SAR.

A.5/3.1.1 Materials to be Stored

The structural evaluations of the TN-32 cask are provided in Chapters 3 and 11 of the Topical Report. These evaluations used a fuel weight of 1533 lb, which bounds all possible combinations of Surry Units 1 and 2 fuel assemblers containing a burnable poison rod assembly (BPRA) or thimble plugging device (TPD).

An evaluation has also been performed on the effect to the cask surface dose rates as a result of placing BPRAs or TPDs in the fuel stored in the TN-32. This evaluation confirmed that the calculated surface dose rates for the TN-32 remained less than the design basis dose rates used to calculate doses at the ISFSI perimeter and to the nearest resident.

An evaluation has been performed on the effect on criticality control from the storage of BPRAs and/or TPDs in the fuel stored in the TN-32. The criticality control analysis in the TN-32 TSAR assumes that water borated to 2000 ppm is present in the cask cavity. This analysis was redone assuming that the borated water in the fuel assembly thimble tubes was replaced with aluminum rods, which have lower neutron cross sections than a fully depleted BPRA. The results show a slight decrease in reactivity. TPDs are short and do not displace water in the thimble tubes, therefore, their use will not affect reactivity.

The TN-32 is designed for a maximum internal pressure under accident conditions, and helium buildup of pre-pressurization in BPRAs will affect this analysis. The confinement analysis for the TN-32 has been reanalyzed for thirty-two 20-finger BPRAs, and this reanalysis shows that the maximum pressure under accident conditions would be 69.4 psig, when the design basis for this cask is 100 psig. The impact of TPDs on the confinement analysis is bounded by the impact of BPRAs.

To account for the additional decay heat from BPRAs and TPDs, fuel assembly decay heat estimates must include an estimate for the decay heat from the actual component in each fuel assembly. Therefore, the combined decay heat from the fuel assembly and its components must be less than the limit for a fuel assembly in the TN-32.

Based on these evaluations, the storage of fuel assemblies with BPRAs or TPDs is acceptable for the TN-32.

A.5/3.1.2 Thermal Evaluation

Chapter 4 of the TN-32 Final Safety Analysis Report, Revision 0 (Reference 2) includes a thermal evaluation for normal conditions that was based on the following inputs.

1. A maximum heat load of 32.7 kilowatts from 32 fuel assemblies with BPRAs or TPDs, or 1.02 kilowatt/fuel assembly.
2. An ambient temperature range of -30 to 115°F. The temperature range was averaged over 24 hours and a maximum daily averaged ambient temperature of 100°F was used for the maximum cask temperature evaluation.
3. A total solar heat load for a 12-hour period of 1475 Btu/ft^2 for curved surfaces and 2950 Btu/ft^2 for flat surfaces, per 10 CFR 71.71(c). Since the cask has a large thermal inertia, the total insolation was averaged over a 24-hour period.

Using these inputs, the thermal analysis for normal storage concluded that the TN-32 design meets all applicable requirements. The maximum temperature of any confinement structure component was less than 315°F, which has an insignificant effect on the mechanical properties of the confinement materials used. The predicted maximum fuel cladding temperature was 565°F, which is well below the allowable fuel temperature limit of 622°F.

Thermal Evaluation - Loading/Unloading Conditions

All fuel transfer operations occur when the cask is in the spent fuel pool with the cask lid removed. The fuel is always submerged in free-flowing water, permitting heat dissipation. After fuel loading is complete, the cask is removed from the pool, drained and the cavity is dried.

The loading condition evaluated for the TN-32 would be the heatup of the cask before its cavity can be backfilled with helium. This occurs during the vacuum drying operation of the cask cavity. Transient thermal analyses are provided in Reference 2 to predict the heatup time history for the cask components assuming air is in the cask cavity.

The results of the transient thermal analysis for the maximum heat load of 32.7 kw predicted that the fuel cladding reaches a maximum temperature of 935°F, which was well below the loading or unloading temperature limit of 1058°F. Therefore, the duration of the cask drying procedure is not constrained by the fuel cladding temperature limit. However, transient analyses showed that in order to prevent cask component peak temperatures from exceeding their analyzed

temperature range, in particular the basket, the time before backfilling the cask with helium must be limited to less than 36 hours for the new design heat load.

Unloading of a cask would require the flooding of the cask prior to the removal of the fuel. A quench analysis of the fuel is provided in Reference 2, and concluded that the total stress on the fuel cladding was below the cladding material's minimum yield stress. In addition, by limiting the water flow rate into the cask and monitoring the pressure of the air/steam outflow mixture, the buildup of steam pressure in the cavity was limited to less than the cask design pressure.

Thermal Evaluation - Conclusions

The thermal design of the TN-32 cask is in compliance with 10 CFR 72 and the applicable design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the TN-32 will allow the safe storage of spent fuel for 20 years.

The temperatures determined by the evaluation of the cask systems, structures and components important to safety will remain within their operating temperature ranges, and cask internal pressures under normal conditions were acceptable. The TN-32 cask is designed with a heat removal capability having testability and reliability consistent with its importance to safety.

The TN-32 cask provides adequate heat removal capacity without active cooling systems. Spent fuel cladding will be protected against degradation that leads to significant fuel failures by maintaining the clad temperature below maximum allowable limits and by providing an inert environment in the cask cavity.

A.5/3.3.4 Criticality Evaluation

Chapter 6 of Reference 2 includes an evaluation of the storage of the Westinghouse 15 x 15 Standard Fuel design. This evaluation is summarized below.

Criticality control in the TN-32 is provided by the basket structural components, which maintain the relative position of the spent fuel assemblies under normal and accident conditions, by the neutron absorbing plates between the basket compartments, and by dissolved boron in the spent fuel pool water.

The contents of a TN-32 cask at the Surry ISFSI will be limited to the Westinghouse 15 x 15 Standard Fuel and Surry Improved Fuel (SIF) designs with a maximum enrichment of 4.05 weight percent U-235. The SIF design envelope has dimensions identical to the Standard Fuel design, but several structural elements are made of different materials. These material differences do not affect the criticality analyses, however, and so the criticality evaluations for these fuel types were equivalent.

The fuel assemblies were evaluated with and without BPRAs. BPRAs were modeled using aluminum rods containing no boron. This displaces the borated water and bounds the effect of depleted BPRAs. The criticality evaluations did not rely on any special loading patterns or special

orientation of the fuel assemblies. However, a boron concentration of 2300 ppm in the water used in the cask was assumed in the analysis.

The evaluations assumed that each fuel assembly design contained a certain amount of uranium. In the case of the Westinghouse 15 x 15 Standard Fuel design, this content was 467.1 kgU per fuel assembly.

The criticality evaluations were performed by Transnuclear using the CSAS25 sequence from the SCALE4.3 code system with the SCALE 27-group ENDF/B-IV cross section library. Within this sequence, resonance correction based on the fuel pin cell description was provided by NITAWL using the Nordheim Integral method, and k_{eff} was determined by the KENO-Va code. A sufficiently large number of neutron histories were run so that the standard deviation was below 0.0020 for all calculations.

The TN-32 cask was evaluated for a variety of configurations intended to bound normal, off-normal, and accident conditions. The following conditions were evaluated individually.

1. Baseline: Most reactive TN-32 design basis fuel configuration, 100% borated water density. The fuel assemblies are shifted toward the cask vertical axis until the outer pin cells contact the basket compartment wall. This condition bounds all possibilities of fuel assemblies positioned off-center in the compartment.
2. The neutron absorber plates and the active fuel zone are offset by two inches axially. This condition might occur due to fuel design differences in the distance from the bottom of the fuel assembly to the beginning of the active fuel, or due to fuel pins slipping in the spacer grids during handling.
3. The inside dimension of the compartment is increased and decreased by 0.06 inches. All compartments move correspondingly further apart or closer together. This condition bounds the dimensional tolerance on the basket tubes.
4. The width of the neutron poison plate is reduced by 0.06 inches, corresponding to its dimensional tolerance. It is not necessary to evaluate the tolerance in length because it is bounded by the two-inch axial offset condition above.
5. Fresh water is placed in the gap of all fuel rods. Although a fuel rod that develops a cladding breach during reactor operations could be saturated with unborated water at the end of its operating cycle, it is unlikely that the water in the fuel rod would remain unborated after years of storage in borated water.
6. The borated water density is varied, except in the homogenized basket rail/borated water zone, to simulated the reduction in density that might occur during unloading operations.
7. Borated water is drained down to the top of the active fuel, except in the basket rail zone. This was the most reactive configuration expected during loading and unloading operations, because it reduces the boron capture of reflected neutrons.

As expected, reduction of the neutron absorber plate width, reduction of compartment size, borated water drain-down, and inclusion of fresh water in the fuel rod gap all caused a slight increase in k_{eff}. The optimal borated water density was found at about 95%.

These conditions were combined for a worst case normal condition, and the borated water density was again varied from 85% to 100%, resulting in a maximum $k_{eff} = 0.9264 \pm 0.0009$ at 90% borated water density.

To evaluate accident conditions, the worst case normal model was re-run with a single fuel assembly with enrichment of 5 weight percent U-235, and this fuel assembly was placed in one of the four center basket locations. This case demonstrated compliance with the requirement of 10 CFR 72.124 by combining at least two unlikely, independent, and concurrent changes in the conditions essential to nuclear criticality safety: worst case geometry and accidental loading of a fuel assembly outside the design basis. The result was $k_{eff} = 0.9315 \pm 0.0009$.

A.5/3.3.4.1 Neutron Absorber Tests

Effective boron-10 content of the borated aluminum fuel basket neutron absorber sheets is verified by neutron transmission testing of coupons taken from each sheet. The transmission through the coupons is compared with transmission through calibrated standards composed of a homogeneous boron compound without other significant neutron absorbers, for example zirconium diboride or titanium diboride. These standards are paired with aluminum shims sized to match the scattering by aluminum in the neutron absorber sheets. The effective boron-10 content of each coupon, minus 3σ based on the neutron counting statistics for that coupon, must be $\geq$ 10 mg boron-10/cm^2.

In the event that a coupon fails the single neutron transmission measurement, four additional measurements may be made on the coupon, and the average of the 5 measurements, less 3σ based on the counting statistics, must be $\geq$ 10 mg boron-10/cm^2.

Macroscopic uniformity of boron-10 distribution is verified by neutron radioscopy or radiography of the coupons. The acceptance criterion is that there be uniform luminance across the coupon. This inspection shall cover the entire coupon.

Normal sampling of coupons for neutron transmission measurements and radiography/radioscopy shall be 100%. Rejection of a given coupon shall result in rejection of the associated sheet. Reduced sampling (50% - every other coupon) may be introduced based upon acceptance of all coupons in the first 25% of the lot. A rejection during reduced inspection will require a return to 100% inspection of the lot. A lot is defined as all the sheets rolled from a single casting.

Criticality Evaluation - Conclusions

The TN-32 cask is designed to be substantially subcritical under all credible conditions. The criticality design is based on favorable geometry, fixed neutron poisons, and soluble poisons in the

spent fuel pool. An appraisal of the fixed neutron poisons has shown that they will remain effective for the 20-year storage period, and there is no credible way to lose them. The analysis and evaluation of the criticality design and performance have demonstrated that the cask will provide for the safe storage of spent fuel for a minimum of 20 years with an adequate margin of safety.

The criticality design features for the TN-32 are in compliance with 10 CFR 72, and the applicable design and acceptance criteria have been satisfied. The evaluation of the criticality design provides reasonable assurance that the TN-32 will allow the safe storage of spent fuel.

A.5/4.2.1 Structural Specifications

As noted in Section 4.2.1, the concrete pads used to support the casks stored at the Surry ISFSI are approximately three feet thick and are constructed with reinforced concrete with a nominal design concrete compressive strength of 3000 psi at 28 days. In the Safety Evaluation Report for the TN-32, the NRC stated that it had evaluated the cask drop and tipover analyses in the TN-32 Topical Report and that "cask confinement and spent fuel retrievability from the basket will be assured if the concrete storage pad 1) is not more than 3 feet thick, 2) the concrete strength is not greater than 4000 psi, and 3) the soil modulus of elasticity is not greater than 40 ksi." The as-built conditions for the second pad at the Surry ISFSI meet these requirements. The 3000 psi nominal design strength for the Surry ISFSI is less than the 4000 psi nominal compressive strength limit. The average measured 28-day climate controlled compressive strength for the second pad is within the range expected for concrete construction in accordance with applicable American Concrete Institute codes and standards for a 4000 psi nominal concrete strength. Therefore, the as-built conditions of the second pad at the Surry ISFSI are acceptable for storage of TN-32 casks.

A.5/4.2.3.3 Codes and Standards

The TN-32 cask is designed and fabricated in accordance with Section III of the 1992 edition of the ASME Code. Exceptions to the Code are listed in Table A.5/4.2-1.

Changes to Table A.5/4.2-1 or ASME Code exceptions not included in the Table shall be reviewed in accordance with 10 CFR 72.48. This review should demonstrate that:

1. The changes or exceptions would provide an acceptable level of quality and safety, or
2. Compliance with the specified requirements of Section III of the 1992 edition of the ASME Code would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Table A.5/4.2-1
TN-32 ASME CODE EXCEPTIONS

List of ASME Code Exceptions for TN-32 Dry Storage Cask Confinement Boundary/Gamma Shielding/Basket

The cask confinement boundary is designed in accordance with the 1992 edition of the ASME Code, Section III, Subsection NB. The basket was designed in accordance with the 1992 edition of the ASME Code, Section III, Subsection NF. The gamma shielding, which is primarily for shielding, but also provides structural support to the confinement boundary during drop accidents, was analyzed in accordance with Subsection NB. Inspections of the gamma shielding are performed in accordance with the 1992 edition of the ASME Code as delineated in the TN-32 Topical Safety Analysis Report, Rev. 9A, December 1996 (the TSAR).

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
TN-32 Cask	NB-1100	Stamping and preparation of reports by Certificate Holder	The TN-32 cask is not N stamped, nor is there a code design specification generated. A design criteria document was generated in accordance with TN's QA Program and the design and analysis is provided in the TSAR.
TN-32 Cask	NCA-3800	Quality Assurance Requirements	The Quality assurance requirements of NQA-1 or 10 CFR 72 Subpart G are imposed in lieu of NCA-3800 requirements.
Lid Bolts	NB-3232.3	Fatigue analysis of bolts	A fatigue analysis of the bolts is not performed for storage, since the bolts are not subject to significant cyclical loads.
Gamma Shielding	NB-1132.2	Non-pressure retaining structural attachments shall conform to Subsection NF	The primary function of the gamma shield is shielding, although credit is taken for the gamma shielding in the structural analysis. A surface examination of the welds is performed in accordance with the requirements of Subsection NF.
Pressure test of the confinement boundary	NB-6110	All pressure retaining components shall be pressure tested	The TN-32 cask is not pressure limited. All confinement welds are fully radiographed. In addition, the gamma shielding supports the confinement boundary under all conditions, so a pressure test of the confinement vessel separately will not simulate actual loading conditions. If the pressure test is performed with the confinement vessel inside the gamma shield, the confinement boundary welds cannot be examined.

Table A.5/4.2-1
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Confinement Vessel Material	NB-2120	Requirement materials to be ASME Class 1 material	Standard Review Plan, NUREG-1536 has accepted the use of either Subsection NB (Class 1) or NC (Class 2 or 3) of the Code for the confinement. SA-203 Gr. D is similar to SA-203 Gr. E, which is a Class 1 material. The chemical content of the two grades are identical, except that Gr. E restricts the carbon to 0.20 max., while Gr. D further restricts the carbon content to 0.17 max. Gr. D is acceptable as a Class 2 material up to 500°F. SA-350, Gr. LF3 is the same material as the SA-203, Gr. D, except in a forged condition. SA-350, Gr. LF3 is a Class 1 material in the 1995 edition of the ASME Code, and a Class 2 material in the 1992 Code. Gr. D was selected because of its ductility, since the higher strength is not required. SA-203 Gr. D has better elongation than Gr. E and due to its lower strength is more likely to have the good fracture toughness at low temperatures. In selecting materials for storage and transport casks, one of the major selection criteria is fracture toughness at low temperatures. SA-203, Gr. D and SA-350 Gr. LF3 were selected on this basis. There is no similar requirement for pressure vessels, as they are used at much higher temperatures. For the SA-203 Gr. D and SA-350, Gr. LF3 materials, the allowable stress was based on S, the allowable stress for Class 2 components. This is conservative, since NB is based on S_m, which is 1/3 the tensile strength, while S is 1/4 the tensile strength. Thus there is additional margin over and above the margin required by the code for Class 1 materials.

Table A.5/4.2-1
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Weld of Lid Shield Plate to Lid	NB-4335	Impact testing of weld and heat affected zone of lid to shield plate	If two different materials are joined, the fracture toughness requirements of either may be used for the weld metal. There are no fracture toughness requirements on the shield plate, and therefore none are performed on the base metal or the heat affected zones. This weld is not subject to low temperatures, as it is inside the cask cavity.
Gamma Shielding	NB-2190	Material in the component support load path and not performing a pressure retaining function welded to pressure retaining material shall meet the requirements of NF-2000	The gamma shielding materials were procured to ASTM or ASME material specifications. Material testing is performed in accordance with the applicable specification. Impact testing is not performed on the gamma shielding materials (including welding materials).
Confinement Vessel	NB-7000	Vessels are required to have overpressure protection	No overpressure protection is provided. Function of confinement vessel is to contain radioactive contents under normal, off normal, and accident conditions of storage. Confinement vessel is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.
Confinement Vessel	NB-8000	States requirements for nameplates, stamping and reports per NCA-8000	TN-32 cask to be marked and identified in accordance with 10 CFR 72 requirements. Code stamping is not required. QA data package to be in accordance with Transnuclear approved QA program.
Confinement Vessel material	NB-2000	Requires materials to be supplied by ASME approved material supplier; Quality assurance to meet NCA requirements	Material will be supplied by Transnuclear approved suppliers with Certified Material Test reports (CMTR) in accordance with NB-2000 requirements. The cask is not code stamped. The quality assurance requirements of NQA-1 or 10 CFR 72 Subpart G may be imposed in lieu of the requirements of NCA-3800.

Table A.5/4.2-1
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Corner weld between bottom inner plate to inner shell	NB-5231	Full penetration corner welded joints require the fusion zone and the parent metal beneath the attachment surface to be UT inspected after welding	In lieu of the UT inspection, the joint will be examined by RT and either PT or MT methods in accordance with ASME Subsection NB requirements.
Boundary of Jurisdiction	NB-1131	The design specification shall define the boundary of a component to which another component is attached	A code design specification was not prepared for the TN-32 cask. A TN design criteria was prepared in accordance with TN's QA program. The containment boundary is specified in Chapter 1 of the TSAR.
PT/MT inspection of plates	NB-5130	Weld preparations in plates 2 inches and over are required to be surface examined by PT or MT	The final thickness of the shell is 1.5 inches, and therefore this requirement was not imposed. However, the confinement shells may be made from shells with original thickness greater than 1.5 inches. We interpret the code to mean the final thickness of the pressure vessel. The weld prep on one side of the wall is performed by back gouging after the opposite side is welded. An MT examination of this back gouged surface before welding is performed. A UT examination is performed on the plate material when purchased. This examination is intended to discover indications, both laminar and nonlaminar imperfections. Therefore the UT examination of the plate prior to welding can be expected to reveal any indications or imperfections that exist in the plate.

Table A.5/4.2-1
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Surface examination after machining	NB-4121.3	If more than 1/8 inch of material is removed, a surface examination is required of components which have been previously surface examined	The containment flanges and the lids are procured with both a UT and MT examination. More than 1/8 inch of material may be removed during processing, and no additional surface examinations are performed.
Aluminum basket plate and rail, neutron absorber plates	NF-2120	Materials to be ASME Class 1 material	The aluminum plate strength is not used for structural analysis under normal operating loads nor the 50g accident end drop load. The aluminum plate strength is only assumed to be effective for the short duration dynamic loading from a tipover accident and for secondary thermal stress calculations. 6061-T6 is ASME code material (Class 2 or 3). The strength of the neutron absorber plates are not considered in any analysis.
Basket	NF-4000/ NF-5000	Welding/NDE Inspections	Basket welding procedures are qualified in accordance with ASME Section IX. Due to this unique nature of these welds, special inspections and tests were developed for these welds.
Components other than the containment boundary and basket	Subsection NB		The code does not apply to components other than the containment boundary and basket. The gamma shielding has been analyzed and inspected in accordance with Subsection NB as defined at the beginning of this table.

Table A.5/4.2-1
TN-32 ASME CODE EXCEPTIONS

Component	Reference ASME Code/Section	Code Requirement	Exception, Justification & Compensatory Measures
Basket	NF-3000	Allowable Stresses	The ASME Code gives stress values up to 400°F. Stress values above 400°F are taken from "Aluminum Standards and Data," 1990. The allowable stresses used for the aluminum basket plate and rail are based on S, the allowable stress for a Class 2 or 3 component. This is conservative, since the analyses of the basket and rail are performed in accordance with the rules of Subsection NF. Subsection NF allowables are based on S_m which is 1/3 the ultimate strength, while S is 1/4 the ultimate strength. Thus there is additional margin built into the analysis of the basket and rail over and above the margin required by Subsection NF for Class 1 materials.

A.5/7.3.2.1 Cask Surface Dose Rates

The TN-32 shielding and dose analyses were based on spent fuel with an initial enrichment of 3.5 weight percent U-235, burnup of 45,000 MWD/MTU and cooling time of 7 years (Reference 2). Using an enrichment lower than the 4.05 weight percent U-235 approved for the TN-32 yields a bounding isotope inventory, and is in accordance with NUREG-1536 and NRC Interim Staff Guidance.

Source terms for the fuel were calculated using the SAS2H/ORIGEN-S module of SCALE4.3 as described in Section 5.1 of Reference 2. These source terms are then passed through a SAS2H cask shield model for a 1-dimensional dose assessment. Section 5.2 (Reference 2) describes the source specification and Section 5.3 (Reference 2) describes the shielding analyses performed for the TN-32 cask.

In addition to the spent fuel, the TN-32 is capable of storing BPRAs and TPAs. BPRAs and TPAs with combinations of cumulative exposures and cooling times are permissible for storage in the TN-32 cask. The source evaluation of the BPRAs and TPAs is described in Section 5.2 (Reference 2).

Virginia Power conducted an independent analysis of the TN-32 surface dose rate. This analysis was used to form the basis for the cask surface dose rate limit in the ISFSI Technical Specifications. The surface dose rates calculated for the TN-32 base case cask were 224 mrem/hr (neutron and gamma) for the side surface and 76 mrem/hr (neutron and gamma) for the top surface.

The average side surface dose rate will be determined by averaging dose rate measurements separately, above the radial neutron shield, along the radial neutron shield, and below the neutron shield. Area weighting will be applied in the proportions of 10% for both the average above and below the neutron shield, and 80% for the average along the neutron shield. The average side surface dose rate limit was calculated as follows:

Location	Gamma (mrem/hr)	Neutron (mrem/hr)	Total (mrem/hr)	Weight Factor	Total*Factor (mrem/hr)
Above Neutron Shield	352	140	492	0.1	49.2
Along Neutron Shield	149	20	169	0.8	135.2
Below Neutron Shield	191	200	391	0.1	39.1
				Total	224

Surface gamma and neutron dose rates will be measured separately and separate limits for the average side surface gamma and neutron dose rates were calculated as follows:

Location	Gamma (mrem/hr)	Weight Factor	Gamma*Factor (mrem/hr)
Above Neutron Shield	352	0.1	35.2
Along Neutron Shield	149	0.8	119.2
Below Neutron Shield	191	0.1	19.1
		Total	174

Location	Neutron (mrem/hr)	Weight Factor	Neutron*Factor (mrem/hr)
Above Neutron Shield	140	0.1	14.0
Along Neutron Shield	20	0.8	16.0
Below Neutron Shield	200	0.1	20.0
		Total	50

The average side gamma dose rate limit (174 mrem/hr) or the average side neutron dose rate limit (50 mrem/hr) may be exceeded as long as the total average side dose rate limit (224 mrem/hr) is not exceeded.

The average top surface dose rate will be determined by averaging nine dose rate measurements from the protective cover. One measurement will be made at the center of the cover, four midway between the center and edge of the cover, and four along the edge of the cover. An area-weighted average will not be used for the top surface dose rate, and separate gamma and neutron surface dose rate limits are not used.

A.5/7.3.2.1.1 Cask Surface Dose Rate Measurement

Beginning with the issuance of the license amendment to permit the storage of fuel assemblies having an initial enrichment of 4.05 weight percent U-235 and an average fuel assembly burnup of 45,000 MWD/MTU, the following method will be used to determine the average surface dose rates of TN-32 casks to compare with Technical Specifications limits.

Side Surface Dose Rate

The surface dose rates shall be measured at approximately the following points (see also Figure A.5/7.3-7). Obtain separate measurements for gamma and neutron dose rates.

a. Above the Radial Neutron Shield (Map location A)

   Obtain four measurements, equally spaced circumferentially, midway between the top of the cask body flange and the top of the radial neutron shield. Do not obtain measurements over or in the immediate vicinity of the cask trunnions.

Add the measurements together and divide by the number of measurements obtained in this area. The result is the average dose rate above the neutron shield.

b. Sides of Radial Neutron Shield (Map locations B, C, and D)

Obtain four measurements, equally spaced circumferentially, at each of the following approximate elevations: one sixth, one half and five sixths along the axial span of the radial neutron shield. Do not obtain measurements over or in the immediate vicinity of the cask trunnions.

Add the measurements together and divide by the number of measurements obtained over the neutron shield. The result is the average dose rate over the radial neutron shield.

c. Below Radial Neutron Shield (Map location E)

Obtain four measurements, equally spaced circumferentially, midway between the bottom of the radial neutron shield and the bottom of the cask. Do not obtain measurements over or in the immediate vicinity of the cask trunnions. Also, it may not be possible for a neutron dose rate meter to access the surface at location E. If so, the neutron dose rate meter may be located as much as one foot away from the cask surface to obtain measurements.

Add the measurements together and divide by the number of measurements obtained in this area. The result is the average dose rate below the neutron shield.

Top Surface Dose Rate

d. Top of Cask (Map locations F, G, and H)

Obtain one measurement at the center of the protective cover (F). Obtain four measurements equally spaced circumferentially half way between the center and the knuckle (G). Obtain four measurements equally spaced circumferentially at the knuckle (H).

Add the measurements together and divide by the number of measurements obtained over the protective cover. The result is the average dose rate over the top surface of the cask.

Final Average Surface Dose Rate

The average surface gamma and neutron dose rates shall be determined by the following formulae. Note that A, B, C, and D refer to the average values obtained in steps A, B, C, and D above, respectively. The 0.1 and 0.8 multipliers are area weighting factors.

$$\text{Average Side Surface Gamma Dose Rate} = (0.1 \times A_\gamma) + (0.8 \times B_\gamma) + (0.1 \times C_\gamma)$$

$$\text{Average Side Surface Neutron Dose Rate} = (0.1 \times A_n) + (0.8 \times B_n) + (0.1 \times C_n)$$

$$\text{Average Top Surface Gamma Dose Rate} = D_\gamma$$

Average Top Surface Neutron Dose Rate = D_n

A.5/7.3.2.2 Dose Rate Versus Distance

Analyses were completed to determine dose rates at the ISFSI perimeter fence, the site boundary and the nearest permanent resident. These analyses were performed using the MCNP Monte Carlo transport code and the following conservative inputs.

1. Isotope inventories were based on 32 fuel assemblies with enrichment of 3.5 weight percent U-235, burnup of 45,000 MWD/MTU and seven years decay.
2. The three storage pads were filled with 84 base case TN-32 casks, each pad having 28 casks. This input is conservative, since the first storage pad is filled with CASTOR V/21, CASTOR X/33, MC-10 and NAC-I28 storage casks, all of which have maximum surface dose rates that are lower than the base case TN-32. In addition, using 84 TN-32 casks results in an amount of fuel stored on the pads which exceeds the current licensed limit of 811.44 TeU, providing additional conservatism to the analysis.
3. The analyses assume no decrease in the gamma and neutron emission rates as a result of decay beyond the initial seven-year requirement. That is, all 84 casks were assumed to be placed simultaneously at the ISFSI.
4. The effects of irradiated insert components were included in the MCNP analyses. Each cask was assumed to contain 32 irradiated insert components with the source spectrum and source strength identified in Reference 1.

The MCNP analysis of the dose rate at the ISFSI perimeter fence using base case TN-32 casks resulted in peak dose rates that range from 2.9 to 12.2 mrem/hr when all three pads were full. Dose rate measurements at the ISFSI perimeter fence will be used to ensure that the requirements of 10 CFR 20 are met.

The MCNP analysis for the nearest site boundary indicated that the maximum dose rate at this location was less than 100 mrem/yr, which meets the requirements of 10 CFR 20.1301.

The licensing basis for the annual dose to the nearest permanent resident was based on 84 GNSI CASTOR V/21 casks, adjusted for decay, and air and distance attenuation of neutron and gamma rays. The annual dose to the nearest permanent resident (1.53 miles away) for this case was 6.0E-05 mrem, based on Section 2.3 of the NRC's Safety Evaluation Report for the Surry Dry Cask Independent Spent Fuel Storage Installation and Section 6.2 of the NRC's Environmental Assessment Related to the Construction and Operation of the Surry Dry Cask Independent Spent Fuel Storage Installation. The MCNP analysis using 84 base case TN-32 casks resulted in an annual dose to the nearest permanent resident from normal ISFSI operation that is bounded by the ISFSI licensing basis.

A.5/7.3.5 References

1. *TN-32 Dry Storage Cask Safety Analysis Report,* Revision 9A, Transnuclear Inc., December 1996.

2. *TN-32 Final Safety Analysis Report,* Revision 0, Transnuclear Inc., January 2000.

3. SCALE4.3, *A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers,* CCC-545, Oak Ridge National Laboratory.

4. MCNP Version P01.3, *Monte Carlo N-Particle Transport Code System,* CCC-660, Los Alamos National Laboratory.

Figure A.5/7.3-6
DOSE RATE FOR 84 BASE CASE TN-32 CASKS VERSUS DISTANCE

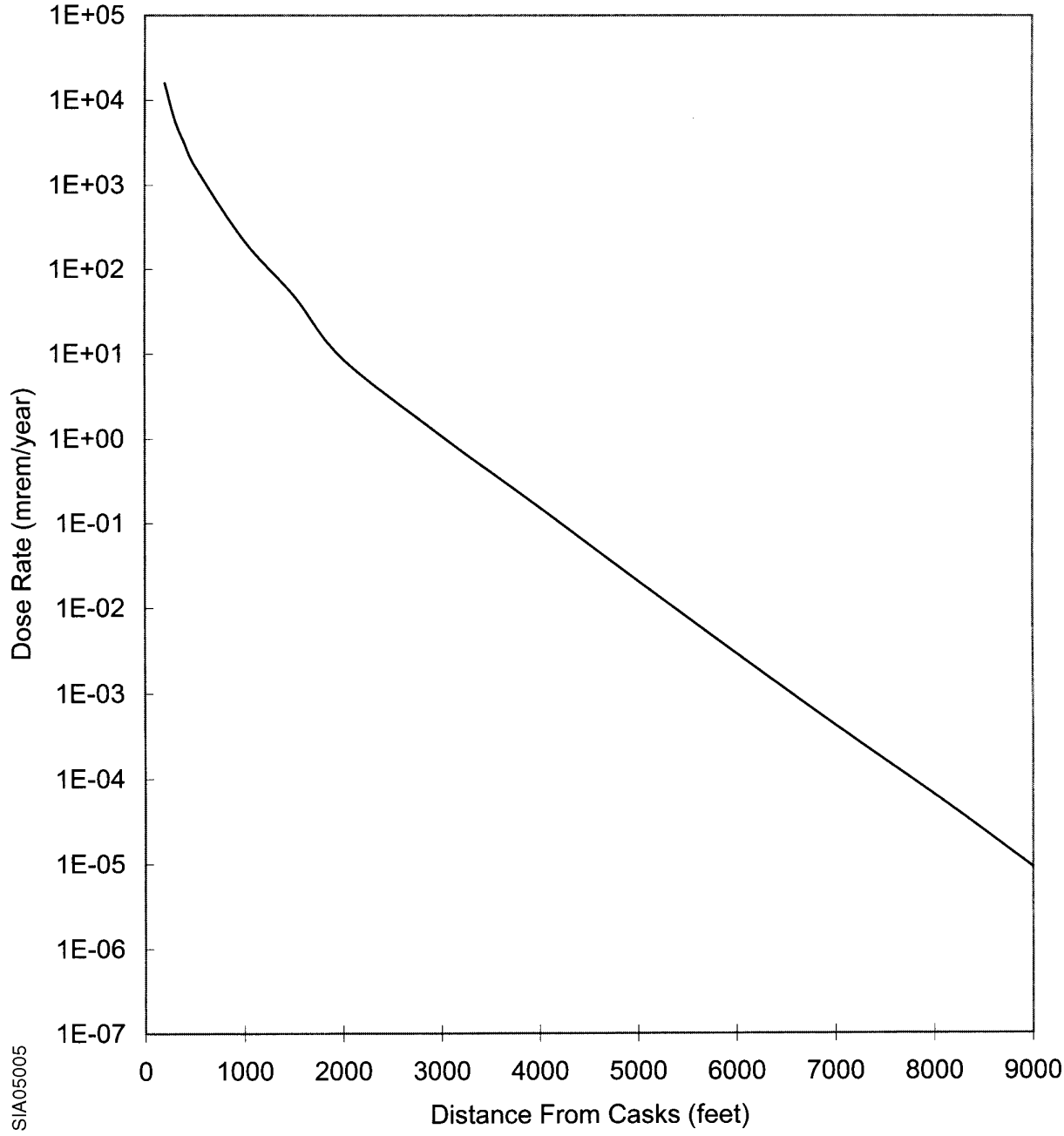
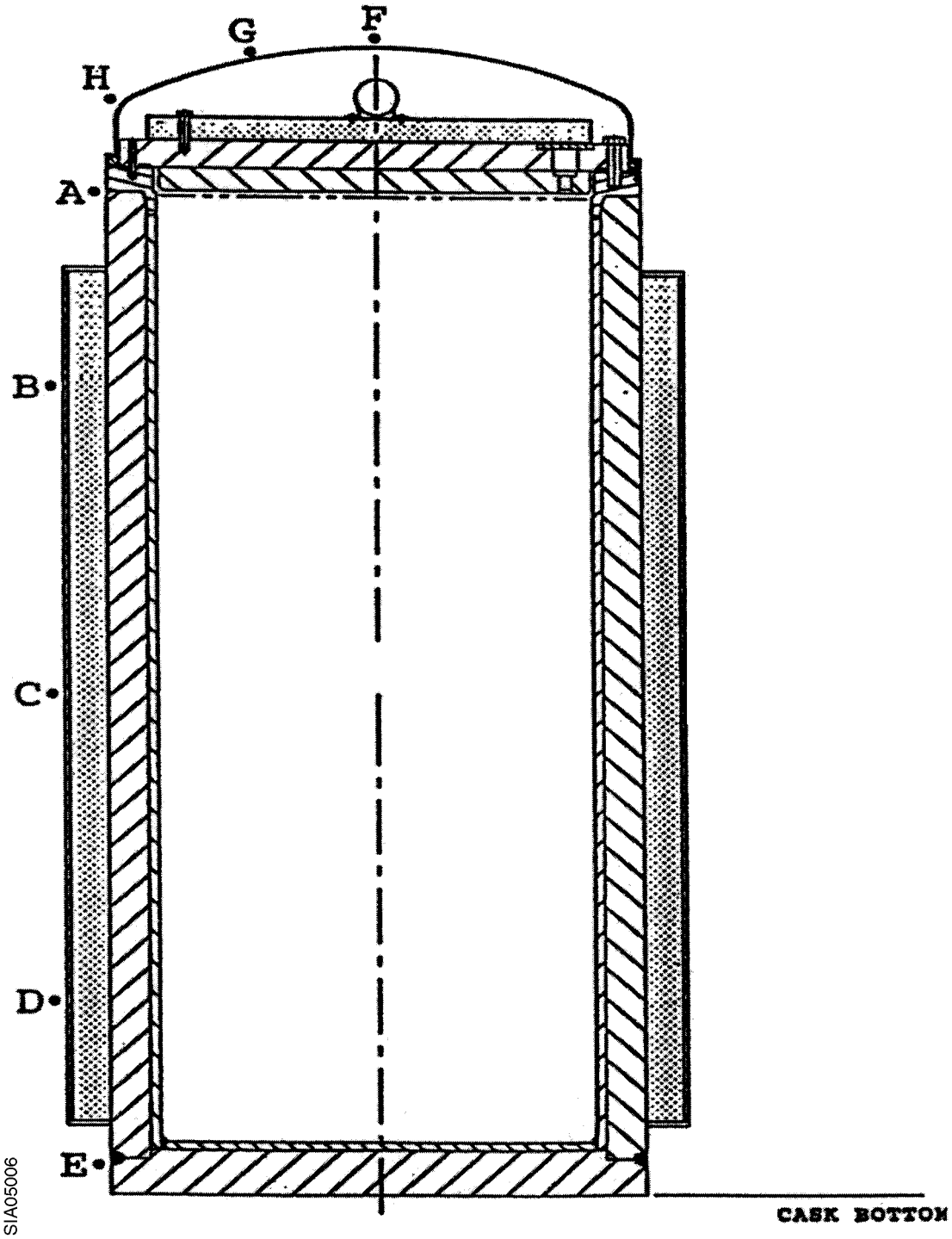


Figure A.5/7.3-7
TN-32 SURFACE DOSE RATE MEASUREMENT LOCATIONS



A.5/8.2.2 Extreme Wind

The effects and consequences of extreme winds on the TN-32 cask are presented in Section 2.2.1 of the TN-32 Topical Report. The Transnuclear analysis demonstrates that extreme winds are not capable of overturning the TN-32 cask nor of producing leakage from it. Since no radioactive material would be released, no resultant doses would occur.

A.5/8.2.5 Fire

The ability of the TN-32 cask to withstand postulated fires is presented in Section 11.2.5 of the TN-32 Topical Report. As concluded in Surry ISFSI SAR Section 8.2.5, no fires other than small electrical fires are credible at the ISFSI slab. Consistent with the Transnuclear analyses referenced above, a total loss of the cask neutron shield due to fire exposure is not a credible event for the Surry ISFSI, nor would radioactive material be released. See Section A.5/8.2.8 below.

A.5/8.2.8 Loss of Neutron Shield

As discussed in Section 1.2 of the TN-32 Topical Report, the TN-32 cask features an outer shell which contains a 4.5-inch thickness of resin material. Section 11.2.5 of the TN-32 Topical Report postulates a loss of this outer neutron shielding due to fire. However, no fires other than small electrical fires are credible at the ISFSI slab, based on Section 8.2.5 of the Surry ISFSI SAR. Therefore, consistent with the Transnuclear evaluation of this event, a total loss of the cask neutron shield due to fire exposure is not a credible event for the Surry ISFSI.

Should the neutron shield be damaged from a postulated fire, cask tipover, or cask drop event, temporary shielding could be placed external to the cask (e.g. high temperature polyethylene sheets or concrete blocks) until the cask shield could be repaired. Depending on the extent of the damage, Section 8.2.10 of the Surry ISFSI SAR outlines the steps that would be taken to return a cask to the spent fuel pool to repair or replace the damaged portion of the neutron shield.

A.5/8.2.9 Cask Seal Leakage

An accident analysis using a TN-32 cask with the fuel limits in Reference 2 was performed based on the requirements of NUREG-1536, NRC Interim Staff Guidance, and the following inputs:

1. Isotope inventories were based on 32 fuel assemblies with an enrichment of 3.3 weight percent U-235, burnup of 45,000 MWD/MTU and seven years decay. This enrichment was selected after reviewing the enrichment and burnup of all Surry spent fuel to ensure that this enrichment is bounding. Using a lower enrichment than that approved for the cask yielded a bounding isotope inventory, and is in accordance with NRC Interim Staff Guidance.
2. The Co-60 source was calculated based on the surface area of a 17 x 17 fuel assembly and a seven-year decay time from discharge. This was a conservative assumption for Surry as a 17 x 17 fuel assembly has a larger surface area than a 15 x 15 fuel assembly does.

3. A cask seal leak rate was calculated in the Reference 2, however, the analysis assumed a leak rate 1.5 times greater to provide additional conservatism.
4. A conservative 500-meter dispersion factor (χ/Q) for accident conditions was used in the analysis.
5. The breathing rate identified in Reference 2 was used in the analysis.
6. The bounding dose conversion factors in EPA Guidance Report No. 11 were used to calculate the whole body, critical organ, and thyroid dose from inhalation.
7. The bounding dose conversion factors in EPA Guidance Report No. 12 were used to calculate the whole body, critical organ, thyroid, and skin dose from immersion.

The isotopes used in the analysis were based on the selection criteria in the NRC Interim Staff Guidance, and included Co-60 in the fuel rod crud, iodine-129, tritium, metastable tellurium-125, fission products that contributed greater than 0.1% of activity, and actinides that contributed greater than 0.01% of activity. The isotope concentrations were used with the release fractions, the free volume in the cavity of the TN-32 cask (5.39 cubic meters), and the cask seal leak rate to calculate the isotope release rate (μCi/sec) from the cask. The isotope release rate was used over a 30-day period to calculate a release inventory in curies.

Using this release inventory, the bounding dose conversion factors from EPA Guidance Report No. 11, a 500 meter dispersion factor (χ/Q), and the breathing rate, the site boundary inhalation dose for each isotope was calculated. Similarly, using this release inventory, the bounding dose conversion factors from EPA Guidance Report No. 12, and a conservative 500-meter dispersion factor (χ/Q), the site boundary immersion dose for each isotope was calculated.

This accident evaluation resulted in a deep dose plus committed dose equivalent to the worst organ (bone marrow) that is less than the licensing basis of 84 mrem identified in Section 8.2.

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Appendix A.5

Attachment 1

Revision of Lid Bolt Analysis
Supplants the Analyses in TN-32 TSAR, Revision 9A, Section 3A.3
and TN-32 FSAR, Revision 0, Section 3A.3

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3A.3 Lid Bolt Analyses

The lid bolt analysis presented below is performed using the weight of the TN-32A lid (including top neutron shield) since it is slightly heavier than the standard TN-32 lid assembly (with top neutron shield). The use of either aluminum or silver metallic o-ring seals is discussed in the analysis below. Both are acceptable for use in a TN-32 cask lid system. O-ring parameters from either an aluminum or silver o-ring are used interchangeably in the following analyses, depending on which of the parameters from a particular o-ring provides the more limiting result.

3A.3.1 Normal Conditions

3A.3.1.1 Bolt Preload

The lid is secured to the cask body by forty-eight 1.5-in. diameter bolts. The selected bolt preload is such that the metallic confinement seals are properly compressed and the lid is seated against the flange with sufficient force to resist the maximum cavity internal pressure and any dead weight loads acting to unseat the lid. The maximum corresponding tensile preload stress in the bolts at temperature is 51,930 psi (corresponding to a maximum applied torque during cask loading of 1230 ft-lb. with lubrication) which is less than the stress allowable for the bolt material for Normal (Level A) Conditions. The minimum tensile preload stress in the bolts at temperature is 37,150 psi (corresponding to a minimum applied torque of 880 ft-lb. with lubrication) The load per bolt is:

Maximum: $F_B = A_B \times 51,930$
$= 1.492 \times 51,930 = 77,480$ lb./bolt

Minimum: $F_B = A_B \times 37,150$
$= 1.492 \times 39,260 = 55,430$ lb./bolt

Since we have 48 bolts, the maximum total seating force of all 48 bolts is 48 F_B = 3,719,000 lb. and the minimum total seating force is 2,661,000 lb.

The force required to seat the metallic O-rings (also referred to as seals), from Reference 1, is a line load of 1399 pounds per inch of seal circumference for aluminum seals, or 2284 pounds per inch of seal circumference for silver seals. The diameter of the outer seal is 72.65 in. and the diameter of the inner seal 71.05 in. The seal seating force is then:

$$F_{seating} = 1399\ \pi(72.65 + 71.05) = 631,570 \text{ lb. (aluminum)}$$

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$F_{seating}$ = 2284 π(72.65 + 71.05) = 1,031,000 lb. (silver)

The maximum cask cavity internal pressure is the Design Pressure of 100 psi. The force required to react the pressure load (conservatively assuming the pressure is applied over the outer seal diameter) is:

$$F_{Pressure} = 100\left(\frac{\pi}{4}\right)(72.65)^2 = 414{,}500 \text{ lbs.}$$

The TN-32 cask is always oriented vertical during loading, during transfer to the ISFSI and during storage on the pad. Dead weight of the lid and cask contents does not actually load the lid bolts. In fact the lid weight (and external pressure) helps to seat the lid. However, it is conservative to require that the bolt preload maintain lid seating in any cask orientation. The weights of the lid, fuel and basket are:

Lid Assembly Weight	=	14,480 lb.
Fuel Weight	=	49,060 lb.
Basket Weight	=	16,900 lb.
W_{Total}		80,440 lb.

The total of the seal seating force (conservatively assuming silver seals are used), pressure load and dead weight loads is:

$F_{seating}$	=	1,031,000 lb.
$F_{pressure}$	=	414,500
W_{total}	=	80,440
		1,525,940 lb.

This force is less than the preload stresses achieved for the torque value range of 880 to 1230 ft-lbs. and shows that ample lid seating force is provided under Normal Conditions. Furthermore, the range of preload stresses is well below the limiting value of $2S_m$ (63,800 psi) for the bolt material at 300°F.

3A.3.1.2 Differential Thermal Expansion

The 48 lid bolts preload the outer rim of the closure lid against the cask body flange. The 1.5 in. diameter bolts are installed through 1.56 in. diameter clearance holes in the 4.50 in. thick lid periphery. Preloading of the bolts against the lid is accomplished by tightening the bolts so that the shank

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portions of the bolts within the clearance holes are stretched elastically. The bolt loads will therefore change from the initial installed values if any thermal expansion differences should occur between the lid (through thickness direction) and the bolts.

The bolt material is SA 320 Grade L43 (1 3/4 Ni 3/4 Cr 1/4 Mo). The lid and body flange are both SA 350 Grade LF3 (3 1/2 Ni). The Section III Code Appendices specify the same coefficient of thermal expansion for these materials. The bolts are in intimate contact with the lid and flange and will therefore operate at the same temperature as these components. Therefore there will be no thermal expansion differences between the lid and bolts, and the assembly preload will be maintained under all temperatures.

3A.3.1.3 Bolt Torsion

The torque required to preload the bolt is:

$T = K D_N F_B$ (Reference 2)

Where

T_{max} = 0.127(1.5)(77,480)=14,760 in-lb. = 1,230 ft-lb.
T_{min} = 0.127(1.5)(55,430)=10,560 in-lb. = 880 ft-lb.
K = Nut Factor = 0.127 for N-5000 lubricant (as determined experimentally on a TN-32 cask)
A_B = Bolt stress area = 1.492 $in.^2$
D_N = Bolt nominal diameter = 1.5 in.
F_{Bmax} = 51,930 psi preload stress x A_B = 77,480 lb.
F_{Bmin} = 37,150 psi preload stress x A_B = 55,130 lb.

The maximum residual torque in the bolt corresponds to the maximum applied torque and is:

$T_R = 0.5625T = 0.5625 \times 14,760 = 8,303$ in-lb.

The minimum residual torque in the bolt corresponds to the minimum applied torque and is:

$T_R = 0.5625T = 0.5625 \times 10,560 = 5,940$ in-lb.

The shear stress in the bolt due to the residual torque from the maximum preload given by Reference 3:

$$\tau_{torsion} = \frac{T_R \, r}{J}$$

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where r and J are based on the bolt effective radius for the above stress area.

r = 0.689 in. effective bolt radius

J = torsional moment of inertia of threaded bolt

$$J = \frac{\pi r^4}{2} = 0.354 \text{ inch}^4$$

$\tau_{torsion}$ = 8,303(0.689)/0.354 = 16,160 psi (Torsional Shear Maximum)

$\tau_{torsion}$ = 5,940(0.689)/0.354 = 11,560 psi (Torsional Shear Minimum)

3A.3.1.4 Bolt Bending

It is assumed that bolt bending does not occur during seating of the lid against the cask body during assembly. The bolts are rotated as they are torqued so any slight relative movements between lid and body flange during preloading will not result in a net offset between the bolt head and tapped flange holes. In addition, since the lid, flange and bolt materials have the same coefficient of thermal expansion and will operate at essentially the same temperature, differential expansion between components will not produce bolt bending.

As internal pressure is applied to the cask cavity, the lid will bulge slightly and its edge will rotate. In addition, the body cylinder radius will increase slightly due to the internal pressure resulting in outward radial movement of the tapped bolt holes in the body flange. Since no net membrane stress is developed in the lid, the lid bolt holes (at the mid surface) will remain at the original location. Rotation of the edge of the lid will, however, produce radial movement of the outer surface of the lid at the bolt head location.

The hoop stress in the cask body cylinder is:

$$S_{hoop} = \frac{P R_i}{t}$$

Where P = 100 psi Design Pressure
R_i = 34.375 in. inside radius
T = 9.5 in. thickness

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$$S_{hoop} = \frac{100 \times 34.375}{9.5} = 361.8 \text{ psi}$$

The radial deflection at the bolt circle is:

$$\delta_{b.c.} = R_{bc} \times \frac{S_{hoop}}{E}$$

R_{bc} = 38.03 in. bolt circle radius

$$\delta_{b.c.} = \frac{38.03 \times 361.8}{28 \times 10^6} = 0.0004914 \text{ inches outward}$$

When pressure is applied to the lid, the edge rotation can be calculated assuming the lid is simply supported. From Reference 4, Table 24 case 10:

$$\theta = \frac{3W(1-\nu)R^3}{2\,E\,t^3}$$

Where
- θ = edge rotation, radians
- W = total applied load = 100 psi
- ν = Poisson's ratio = 0.3
- R = 36.35 in. outer seal radius
- T = 4.5 in. lid thickness
- E = Young's modulus = 28 x 10^6

$$\theta = \frac{3 \times 100 \times (1-0.3) \times (36.35)^3}{2 \times 28 \times 10^6 \times (4.5)^3} = 0.00198 \text{ radians}$$

Figure 3A.3-1 shows the net movement of the threaded hole and the Point on the lid under the bolt head.

If it is assumed that the bolt head doesn't slide on the lid surface, the head will be forced from position a to a' as the lid deflects. Point a' under the bolt head moves outward 0.00445 in. while the threaded hole moves only 0.0004914 in. outward. The bolt head will be bent laterally by 0.00445 - 0.0004914 in. or 0.00396 in. from the threaded end.

The bending model of the bolt is shown in Figure 3A.3-2. The moment on the bolt is calculated assuming the bolt is

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subjected to affect bending with the head and threaded end prevented from rotating. For a cantilevered bolt free to rotate at the head, the bending moment would be reduced by one half. Therefore the assumption of fixed ends is the most conservative and results in the highest stress.

The shear force, P, and bending moment, M, for a beam subjected to offset bending with ends prevented from rotating are:

$$P = \frac{12EI\ \delta}{L^3}$$

$$M = \frac{6EI\ \delta}{L^2}$$

Where

P = lateral load to deflect the bolt distance δ, lb.
δ = lateral displacement
= 0.00396 in.
E = Young's modulus, 28 x 10^6 psi @300°F
L = bolt length in bending
= 4.625 in. (including tapped hole chamfer)
I = $\pi r^4/4$
= 0.177 in.^{4} (r=0.689 in. based on stress area of 1.492 in.^{2})

Therefore

$$M_B = \frac{6 \times 28 \times 10^6 \times 0.177 \times 0.00396}{4.625^2}$$

$$= 5{,}500 \text{ in - lb.}$$

$$P = \frac{12 \times 28 \times 10^6 \times 0.177 \times 0.00396}{4.625^3}$$

$$= 2{,}380 \text{ lb.}$$

The bending stress in the bolt is

$$\sigma_b = \frac{Mr}{I} = \frac{5{,}500 \times .689}{0.177}$$

$$= 21{,}430 \text{ psi}$$

The shear stress due to the lateral force is

X10026

$\tau_p = P/A = 2,380/1.492 = 1,595$ psi

3A.3.1.5 Combined Stresses

The total shear stress for the maximum preload stress (51,930 psi corresponding to a torque of 1230 ft-lbs.)is then equal to the residual torsional shear stress plus that due to force P.

$\tau_{total} = \tau_{torsion} + \tau_p$

$= 16,160 + 1,595$
$= 17,755$ psi

The total shear stress for the minimum preload (torque of 880 ft-lbs.) equals:

$\tau_{total} = 11,560 + 1,595 = 13,155$

The average tensile stress is the bolt preload stress:

$\sigma_{average} = 51,930$ psi

The maximum tensile stress at two locations in the bolt is the preload stress plus the bending stress.

$\sigma_{max} = 51,930 + 21,430 = 73,360$ psi

Therefore, the average combined stress intensity is:

$SI_{average} = (\sigma_{average}^2 + 4\ (\tau_{total})^2)^{1/2}$

$= (51,930^2 + 4 \times 17,755^2)^{1/2}$

$= 62,910$ psi (62.9 ksi) $< 2S_m = 63.8$ ksi

The maximum combined stress intensity is:

$SI_{max.} = (\sigma_{max}^2 + 4\ (\tau_{total})^2)^{1/2}$

$= (73,360^2 + 4 \times 17,755^2)^{1/2}$

$= 81,500$ psi $= 81.5$ ksi $< 3S_m = 95.7$ ksi

For Level A conditions, the average bolt stress is limited to 2 S_m or 2 x 31.9 = 63.8 ksi. The maximum bolt stress is limited to 3 S_m or 95.7 ksi. The analyzed stresses are within

X10027

these limits as well as the yield strength of the bolt material (also 95.7 ksi).

3A.3.2 Accident Conditions

The lid bolts are analyzed in this section under the loadings selected to bound those for the hypothetical bottom end drop and tipover onto the concrete storage pad.

3A.3.2.1 Bottom End Drop

The bottom end drop from a height of 5 feet onto the concrete storage pad is analyzed in Section 3A.2.3.2. That section indicates that the cask deceleration may reach 42 g. This analysis conservatively examines the effects (if any) of a 50 g quasistatic loading on the lid bolts.

During a bottom end drop, the rim of the lid is forced against the flange of the cask body. The lid is initially seated against the flange by preloading (torquing) the bolts. The bolt preload will not be affected if compressive yielding of the contact bearing area does not occur.

The contact force on the bearing area, conservatively neglecting internal pressure, is the bolt preload force less the seal compression force plus the 50 g inertial force of the lid system. The maximum preload force, from Section 3A.3.1, is 3,719,000 lb. The seal seating force is 631,570 lb. for the aluminum seal and 1,031,000 for the silver seal. The weight of the lid system (weight of lid plus weight of top neutron shield assembly, 11560 + 2960 = 14,480 lbs., the highest weight among TN-32, TN-32A and TN-32B casks) is 14,480 lb.

Therefore, during a 50 g deceleration in the axial direction, and conservatively assuming an aluminum seal is used (i.e., an aluminum seal has a lower seating force compared to the silver seal thus resulting in a greater contact force), the contact force between lid and cask body is:

$$F_{contact} = F_{Bolt\ Preload} - F_{seal\ seating} + 50\ (W_{lid\ system})$$

$$= 3{,}719{,}000 - 631{,}570 + 50(14{,}480)$$

$$= 3{,}811{,}000 \text{ lb.}$$

Figure 3A.3-3 illustrates the bearing interface between lid edge and body flange. The bearing area equals the area within the diameter of the lid raised section (74.0 in.) less the outside of the body chamber (70.22 in.) less the area of the seal groove.

$$A_{Bearing} = \frac{\pi}{4}(74^2 - 72.95^2 + 70.75^2 - 70.22^2) = 180\,\text{in}^2$$

XI0028

The bearing stress during impact is then equal to:

$S_{bearing}$ = 3,811,000 /180 = 21,170 psi (21.2 ksi)

This contact stress is below the 33.2 ksi yield strength of the lid and flange material at 300°F. The bolt preload will not be affected by the bottom drop. Therefore, this hypothetical accident case will not affect the bolt stresses.

3A.3.2.2 Tipover

The tipover onto the concrete storage pad is analyzed in Appendix 3A.2.3.2 of Revision 9A of the TN-32 TSAR and Appendix 3D.2.5 of Revision 0 of the TN-32 FSAR. The tipover scenario is summarized in Figure 3A.3-4. The peak deceleration occurs at the top of the cask. The deceleration is much less at the center of gravity and essentially zero at the bottom corner pivot point. For this analysis the lateral deceleration at the lid end of the body is conservatively taken as 67g and that at the pivot point is zero.

There are two dynamic loadings acting on the lid tending to push or throw it off of the cask body (i.e. producing tensile forces in the lid bolts). There is a small axial (parallel to cask longitudinal axis) centrifugal inertia load due to the internals acting on the lid and the lid weight itself while the cask is rotating.

For the evaluation of the lid bolts it is assumed herein that the cask impacts on the corner at the lid end. There is no accident condition postulated that would cause greater load on the lid bolts. The cask orientation for the analysis is shown in Figure 3A.3-5. The axis of the cask is 30° from horizontal with the lid down. Note that this orientation is well beyond that predicted in the tipover analyses. If the lateral load, G_L, is 67g, then the axial load used is 67 x tan 30° or 38.7g.

The loads acting on the cask are shown in Figure 3A.3-5. The loads acting on the lid are shown in Figure 3A.3-6. Also shown is the reaction load at the cask interface and the pivot point, O, for analysis of lid rotation. Figure 3A.3-7 shows the lid bolt loads resisting rotation of the lid about pivot point O. The increase in bolt load beyond the preload varies uniformly from pivot point, O, to the bolt farthest from O.

X10029

The moment acting on the lid about pivot point, O, due to the inertia load is calculated as follows:

$M_I = W_I \times 38.7 \times R_T + W_L \times 38.7 \times R_T + W_L \times 67 \times a + P_A \times R_T$

Where M_I = Total moment about pivot point, in-lb.

W_I = Weight of internals

= 16,900 + 49,060 = 65,960 lb.

W_L = Weight of lid system (including shield plate and resin disk), 14,480 lb.

P_A = Internal pressure load

= 414,500 lb.

R_T = Distance from center of lid to pivot point

= 39.75 in.

a = Moment arm of lid inertia load, W_L, in.

= 2.25 in. (very conservative since shield weight effect moves CG toward 0)

Therefore:

$M_I = (65,960 \times 38.7 \times 39.75) + (14,480 \times 38.7 \times 39.75)$

$+ (14,480 \times 67 \times 2.25) + (414,500 \times 39.75)$

$= 142.4 \times 10^6$ in-lb.

This moment is resisted by the effect of the preload on the lid bolts. The moment due to preload is calculated as follows:

$M_p = N \times F_B \times R_T$

Where

M_p = moment due to bolt preload, in-lb.
N = number of bolts, 48
F_B = preload per bolt
= A_B x preload stress
= stress area bolt x preload stress

= 1.492 in.^{2} x 51,930 psi = 77,480 lb. with 1230 ft-lbs. torque

XI0030

= 1.492 in.^{2} x 37,150 psi = 55,430 lb. with 880 ft-lbs. torque

R_T = distance from center of lid to pivot point, 39.75 in.

Therefore:

Torque = 1230 ft-lbs.:
M_p = 48 x 77,480 x 39.75
= 147.8 x 10^6 in-lb. > 142.4 x 10^6 in-lb.

Torque = 880 ft-lbs.:
M_p = 48 x 55,430 x 39.75
= 105.8 x 10^6 in-lb. < 142.4 x 10^6 in-lb.

Since the bolt preload moment, M_p, corresponding to the maximum torque value is higher than the moment due to inertial load, M_T, there will not be any additional load due to a tipover accident. However, the bolt preload moment corresponding to the minimum torque value is less than the moment due to inertial load. In this case, the inertial moment is partially resisted by the effect of the preload on the bolts. The increase in bolt load beyond the preload due to the inertia g loads created by the difference between M_I and M_p which is:

$M_T = M_I - M_p$
$M_T = 142.4 \times 10^6 - 105.8 \times 10^6$
$M_T = 36.6 \times 10^6$ in-lbs.

The lid bolts resist the above moment which tends to unseat the lid. The increase in lid bolt load (ΔF_{BO}) beyond the preload is proportional to the distance from the pivot point O. The additional resisting moment, M_R, applied by the bolts about point O is obtained from the following expressions. Refer to Figure 3A.3-8 of Revision 9A of the TN-32 TSAR for terminology.

$$\Delta \text{BoltForce} = \Delta F_{BO} \times \frac{[R + R\cos(n\Theta) + B]}{2R + B}$$

$$\Delta \text{Moment for a given bolt} = \Delta \text{Bolt Force} \times [R + R\cos(n\Theta) + B]$$

Therefore, the additional moment, M_R, can be expressed in general terms as follows:

X10031

$$M_R = \frac{\Delta F_{BO}\left[(2R+B)^2 + B^2 + 2\sum_{n=1}^{n=23}(R + R\cos(n\Theta) + B)^2\right]}{(2R+B)}$$

R = 39.75 in.
B = 1.72 in.
Θ = 7.5°

Substituting yields:

M_R = 1421.7 x ΔF_{B0}

Therefore, ΔF_{B0} = 36.6 x 10^6 / 1421.7 = 25,740 lb.

The increase in tensile stress in the bolt beyond the preload is

ΔF_{B0} / A_B where:

A_B = bolt area, 1.492 $in.^2$

The increased stress is then:

ΔF_{B0} / A_B = 25,740 / 1.492 = 17,250 psi.

The total tensile stress in Bolt 0 is 37,150 + 17,250 = 54,440 psi. Therefore, the total tensile stress for a bolt subjected to cask tipover is greater for a bolt torqued to 880 ft-lbs. than for a bolt torqued to 1230 ft-lbs. The remainder of this tipover analysis will evaluate both the 880 ft-lbs. torque and the 1230 ft-lbs. torque scenarios.

When the tensile stress is combined with the bolt bending stress due to the lid edge rotation under internal pressure calculated in Section 3A.3.1, the maximum tensile plus bending stress is 54,450 psi plus 21,430 psi (bending) = 75,830 psi and the minimum is 51,930 psi + 21,430 psi = 73,360 psi. The total shear stress due to torquing and lid deformation from Section 3A.3.1.5 is 17,755 psi for the 1230 ft-lbs. case and 13,155 psi for 880 ft-lbs. The combined stress intensity is then:

The average combined stress intensity is:

$SI_{average} = (\sigma_{average}^2 + 4(\tau_{total})^2)^{1/2}$

1230 ft-lbs. torque: $SI_{average} = (51{,}930^2 + 4 \times 17{,}755^2)^{1/2}$

XI0032

$SI_{average}$ = 62,910 psi < S_y = 95,700 psi

880 ft-lbs. torque: $SI_{average} = (54{,}400^2 + 4 \times 13{,}155^2)^{1/2}$

$SI_{average}$ = 60,430 psi < S_y = 95,700 psi

The maximum combined stress intensity is:

$SI_{max} = (\sigma_{max}^2 + 4(\tau_{total})^2)^{1/2}$

1230 ft-lbs. torque: $SI_{max} = (73{,}360^2 + 4 \times 17{,}755^2)^{1/2}$

SI_{max} = 81,500 psi < S_u = 113,930 psi

880 ft-lbs. torque: $SI_{max} = (75{,}830^2 + 4 \times 13{,}155^2)^{1/2}$

SI_{max} = 80,260 psi < S_u = 113,930 psi

In addition to the above calculations, the lid bolts are evaluated based on the interaction formula from Appendix F of the ASME Code (Reference 5) for tension and shear:

$$\frac{(f_t)^2}{(F_{tb})^2} + \frac{(f_v)^2}{(F_{vb})^2} \leq 1$$

Where:

f_t and f_v are the applied tensile and shear stresses

F_{tb} = allowable tensile stress, smaller of $(0.7S_u)$ or S_y(TSAR Table 3.1-3)= 0.7 x 113,930 = 79,750 psi

F_{vb} = allowable shear stress, smaller of $(0.42S_u)$ or $0.6S_y$(SAR Table 3.1-3)= 0.42 x 113,930 = 47,850 psi

1230 ft-lbs. torque:

$$\frac{51{,}930^2}{79{,}750^2} + \frac{17{,}755^2}{47{,}850^2} = 0.56 < 1$$

880 ft-lbs. torque:

$$\frac{54{,}400^2}{79{,}750^2} + \frac{13{,}155^2}{47{,}850^2} = 0.54 < 1$$

3A.3.3 Conclusions

X10033

Based on the above evaluation, it is concluded that:

1. The maximum normal and accident condition stresses in the lid bolts are acceptable.

2. A positive (compressive) load is maintained on seals during normal and accident condition loads as bolt preload is higher than the applied loads.

XI0034

References

1. Resilient Metal Seals and Gaskets, Helicoflex Catalog H.001.002, Helicoflex Co., Boonton, N.J., 1983 pp.5-7.

2. NUREG/CR-6007, Stress Analysis of Closure Bolts for Shipping Casks, April 1992.

3. Hopper, A.G. and Thompson, G.V. "Stress in Preloaded Bolts," Product Engineering, 1964.

4. Roark, R.J.: "Formulas for Stress & Strain", 6th Edition, McGraw-Hill Book Co.

5. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Appendix F, 1992.

XI0035

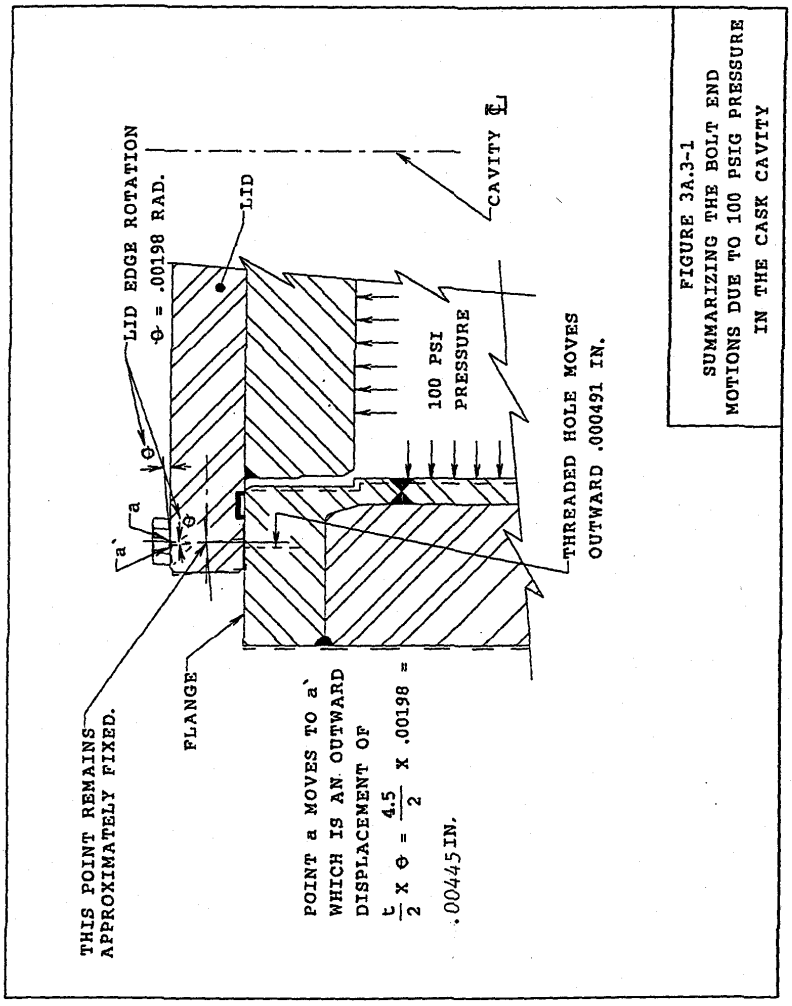

FIGURE 3A.3-1
SUMMARIZING THE BOLT END
MOTIONS DUE TO 100 PSIG PRESSURE
IN THE CASK CAVITY

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X10036

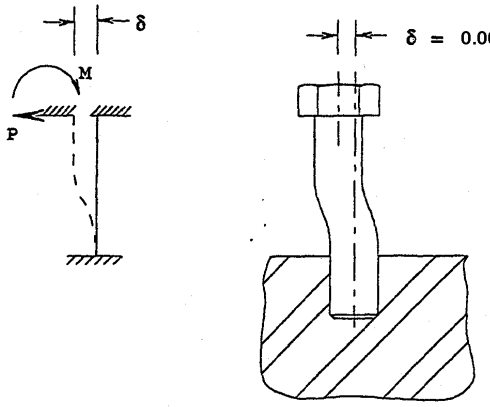

FIGURE 3A.3-2
LID BOLT BENDING DUE TO LID EDGE ROTATION UNDER INTERNAL PRESSURE

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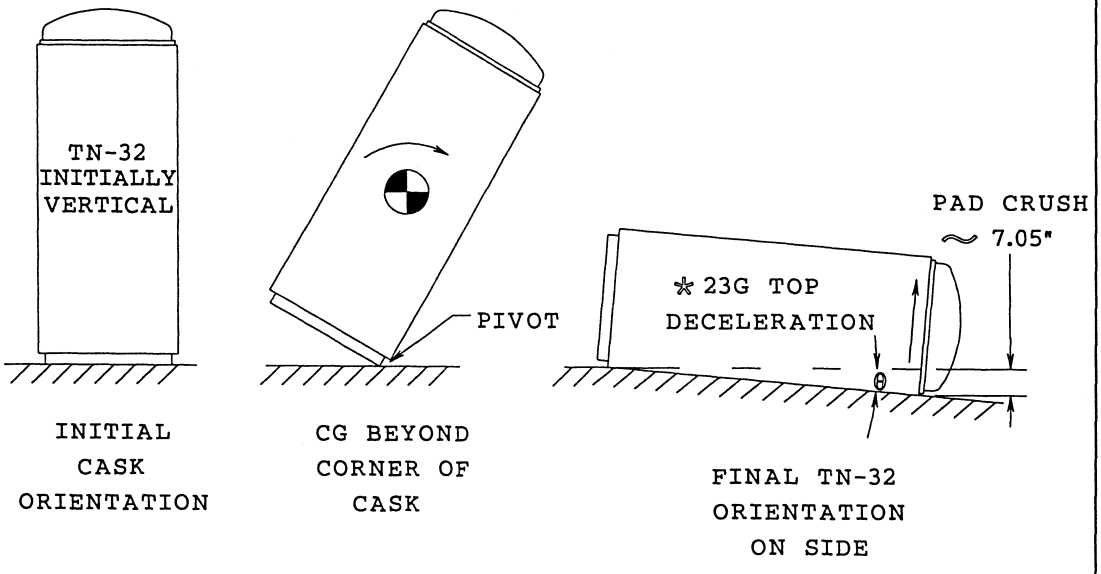
XI0037

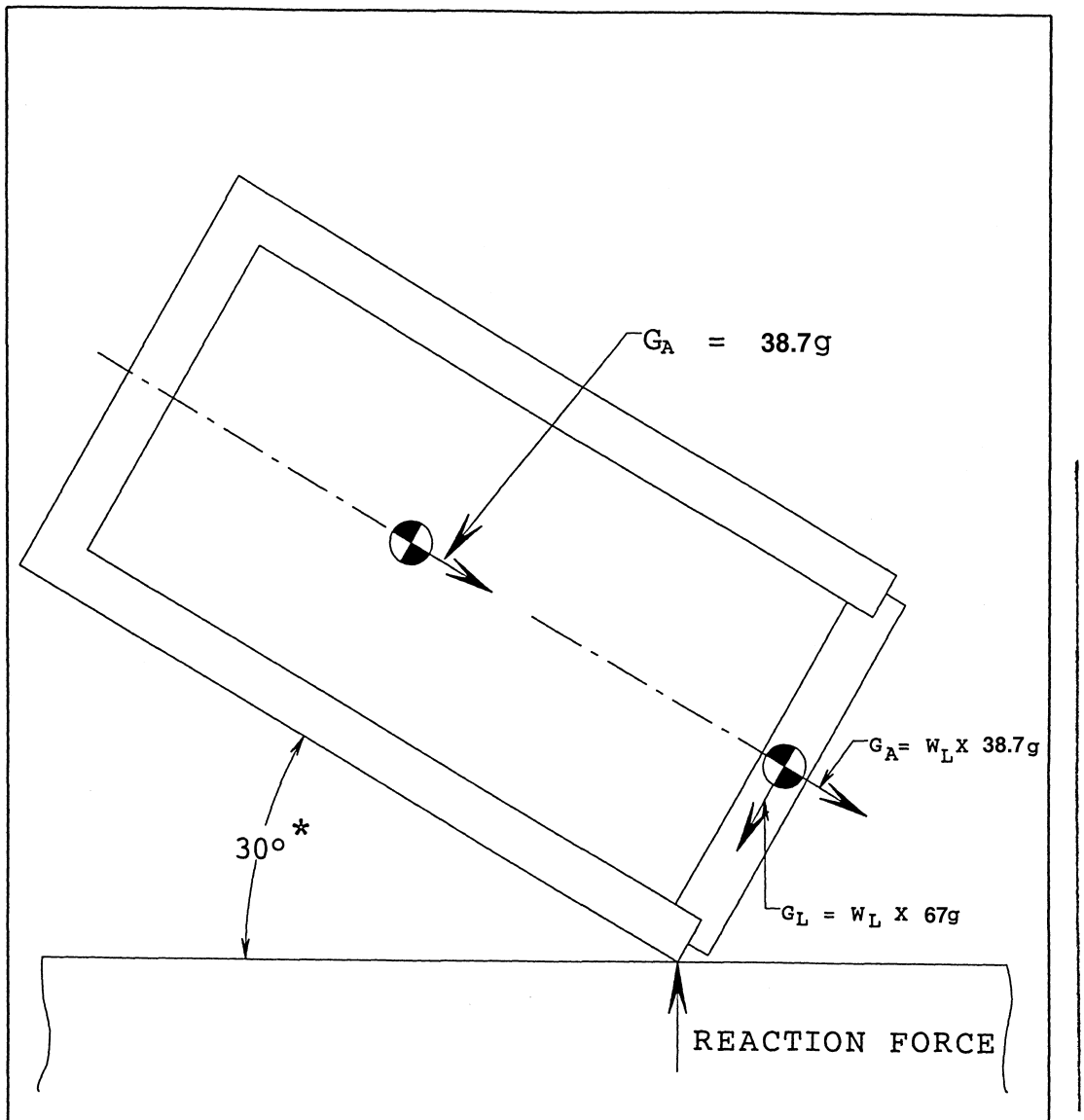


$$\theta = \sin^{-1}\frac{7.05"}{184} \approx 2.2^{\circ}$$

* 67g IS CONSERVATIVELY USED FOR LID BOLT ANALYSIS

FIGURE 3A.3-4
TIPOVER ONTO CONCRETE
STORAGE PAD

XI0014



* 30° WAS CONSERVATIVELY USED
INSTEAD OF CALCULATED 2.2°

FIGURE 3A.3-5
SYSTEM OF INERTIA LOADS
APPLIED ON CASK

XI0015

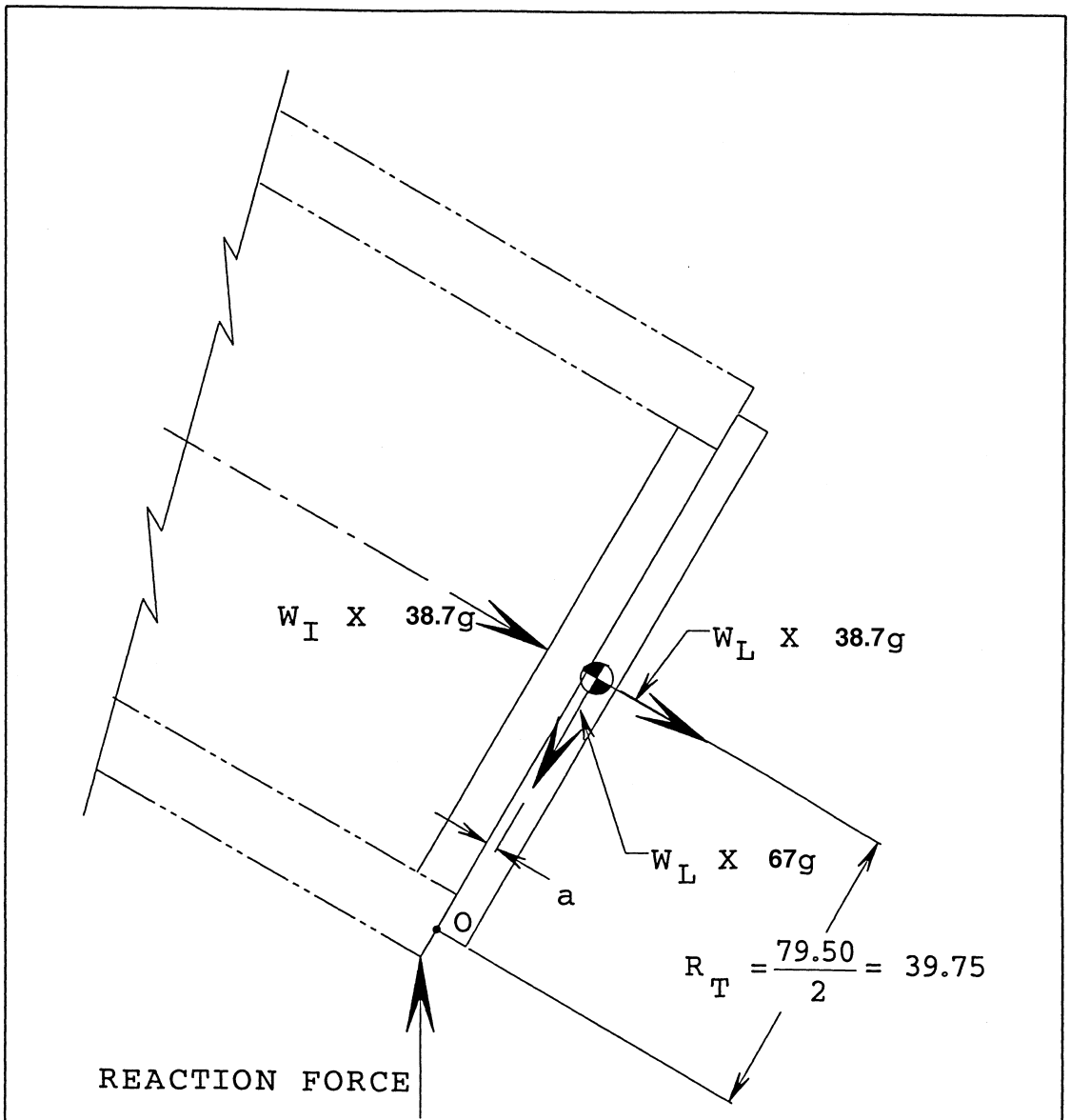


FIGURE 3A.3-6
INERTIA LOADS APPLIED ON LID

X10016

Table 3.4-7
Summary of Maximum Stress Intensity and Allowable Stress Limits for Lid Bolts

STRESS CATEGORY	SERVICE CONDITION	MAXIMUM CALCULATED STRESS (psi)	ALLOWABLE STRESS (psi)	SAFETY FACTOR
Tensile	Level A	51,930	63,800 ($2S_m$)	0.23
	Level D	54,440	79,750 (0.7 S_u)	0.46
Tensile + Bending	Level A	73,360	95,700 (3 S_m)	0.30
	Level D	75,830	113,930 (S_u)	0.50
Shear	Level A	17,755	38,280 (0.4 S_y)	1.16
	Level D	17,755	45,572 (0.4 S_u)	1.57
Combined S.I.	Level A	62,910	95,700 (3 S_m)	0.52
	Level D	81,500	113,930 (S_u)	0.40

XI0038

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Appendix A.5

Attachment 2

Revision of Tornado Missile Analysis
Excerpt from TN-32 TSAR (Rev. 9A, 12/96)

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2.2.1.3.2 Missile B

Missile B (rigid) partially penetrates the cask wall. The loss in kinetic energy is dissipated as strain energy in the cask wall. The force F_b developed by an 8 in. diameter missile penetrating the cask body is calculated below. With a yield strength of 31,900 psi at 300°F, used for the gamma shield material:

$$F_b = S_y(\frac{\pi}{4})(8)^2 = 1.603 \times 10^6 \ lbs.$$

From conservation of energy:

$$F_b x = \frac{1}{2} m_b v_o^2$$

For a given puncture force F_b:

$$x = \frac{m_b v_o^2}{2 F_b}$$

where x is the penetration distance.

The penetration distance is found to be 1.10 in. for a perpendicular impact of the missile.

When the impact angle is not 90 degrees, the missile will rotate during the impact limiting the energy available for penetration (conservatively neglected), since part of the energy will be transformed into rotational kinetic energy.

When hitting the weather protective cover, Missile B deforms the dished head before penetration begins. This will decrease the penetration distance from the above value.

If the missile were to impact the top of the cask in the vertical orientation, the missile velocity would be 88.2 mph (70% of the horizontal impact velocity of 126 mph). The kinetic energy would be:

KE = 0.5 x (276 lbs/32.2ft/sec^2) x (88.2 mph x 5280ft/mi/3600 sec/hr)^2 x 12 in/ft
= 860,440 in lbs.

Ignoring the effect of the protective cover and the top neutron shield, the lid bending stresses under a top impact are evaluated. Reference 20 is used to evaluate the stresses for two boundary conditions:

1. Modeling the lid as a simply supported plate.
2. Modeling the lid as a plate with the edges fixed.

XI0018

For edges simply supported, Table X, Case 2 of Reference 20 is used. The maximum stresses occur at the center, where the plate thickness is t = 10.5 in. The impact force, $F_b = 1.603 \times 10^6$ lbs.

The maximum stress at the center is calculated below:

$$S_r = S_t = 3W/(2\pi mt^2) \times [m + (m+1)\ln(a/r_o) - (m-1)r_o^2/4a^2]$$

Where r_o = uniform load radius = missile radius = 4 inches
m = 3.33
t = 10.5 inches
a = 38.03 inches(effective radius for a simply supported lid at the bolt circle)
$W = F_b = 1.603 \times 10^6$ lbs.

Therefore, $S_r = S_t \approx 28.5$ ksi

This is well below the Level D allowable stress of 63,000 psi.

For the second case, with the lid edges fixed, Table X, case 7 of Reference 20 is used.

The maximum stress occurs at the edge, where the plate thickness, t = 4.5 inches.

$$S_r = 3W/(2\pi t^2)\,(1 - r_o^2/2a^2)$$

Where $W = F_b = 1.603 \times 10^6$ lbs.
r_o = uniform load radius = missile radius = 4 inches
t = 4.5 inches
a = 38.03 inches

$S_r \approx 37.0$ ksi.

This is also well below the allowable Level D stress of 63,000 psi.

2.2.1.3.3 Missile C (steel sphere 1" diameter)

The impact of the steel sphere can result in a local dent by penetrating into the cask surface at the yield strength, S_y, for a penetration depth, d. The contact area on the cask surface is:

$$A = \pi(2Rd - d^2)$$

Where:

R is the radius of the sphere, 0.5 inches,
and d is the penetration depth

The kinetic energy of the steel sphere is dissipated by displacing the cask surface material:

$$KE = \tfrac{1}{2}(m_c v_o^2) = S_y \int_o^d \pi(2Rd-d^2)\partial_d$$

Where m_c = sphere mass

$KE = 0.5(4/3)(\pi)(0.5)^3(0.28)(1/32.2)(126 \times 5280/3600)^2 = 933$ in-lbs

$S_y \int_o^d \pi(2Rd-d^2)\partial_d = S_y\pi(Rd^2 - d^3/3) = KE = 933$ in-lbs

For a yield strength of 31,900 psi, by trial and error:

d = 0.14 in.

XI0019

The area, A, is therefore 0.38 sq. inches. A maximum impact force of 12.1 x 10^3 lb. (A x S_y) will be developed. It can be concluded that only local denting of the cask will result.

If the impact is at the top of the cask (ignoring the protective cover and the neutron shielding), Reference 20, Table X, Case 4 is used to determine the stresses. The impact force is assumed to act at the center of the lid, where p = 0, r_o = 0.353 in. and a = 38.03 inches.

The maximum stress is:

$$S_r = S_t = 3W/(2\pi mt^2) \times [m + (m+1)\ln(a/r_o) - (m-1)r_o^2/4a^2] \approx 1.1 \text{ ksi.}$$

Since all penetrations are covered, the steel sphere will have a negligible effect on the cask.

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Appendix A.5

Attachment 3

Drawing SK-VP-SAR-1, and Figures VP1.2-1 and VP2.3-1
Showing the Modifications to the TN-32 Protective Cover

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Figure Withheld Under 10 CFR 2.390

TRANSNUCLEAR INC.

TN-32 DRY STORAGE CASK
GENERAL ARRANGEMENT
FOR VIRGINIA POWER SAR

NONE SCALE	B SIZE	SK-VP-SAR-1 DWG. NO.	REV.

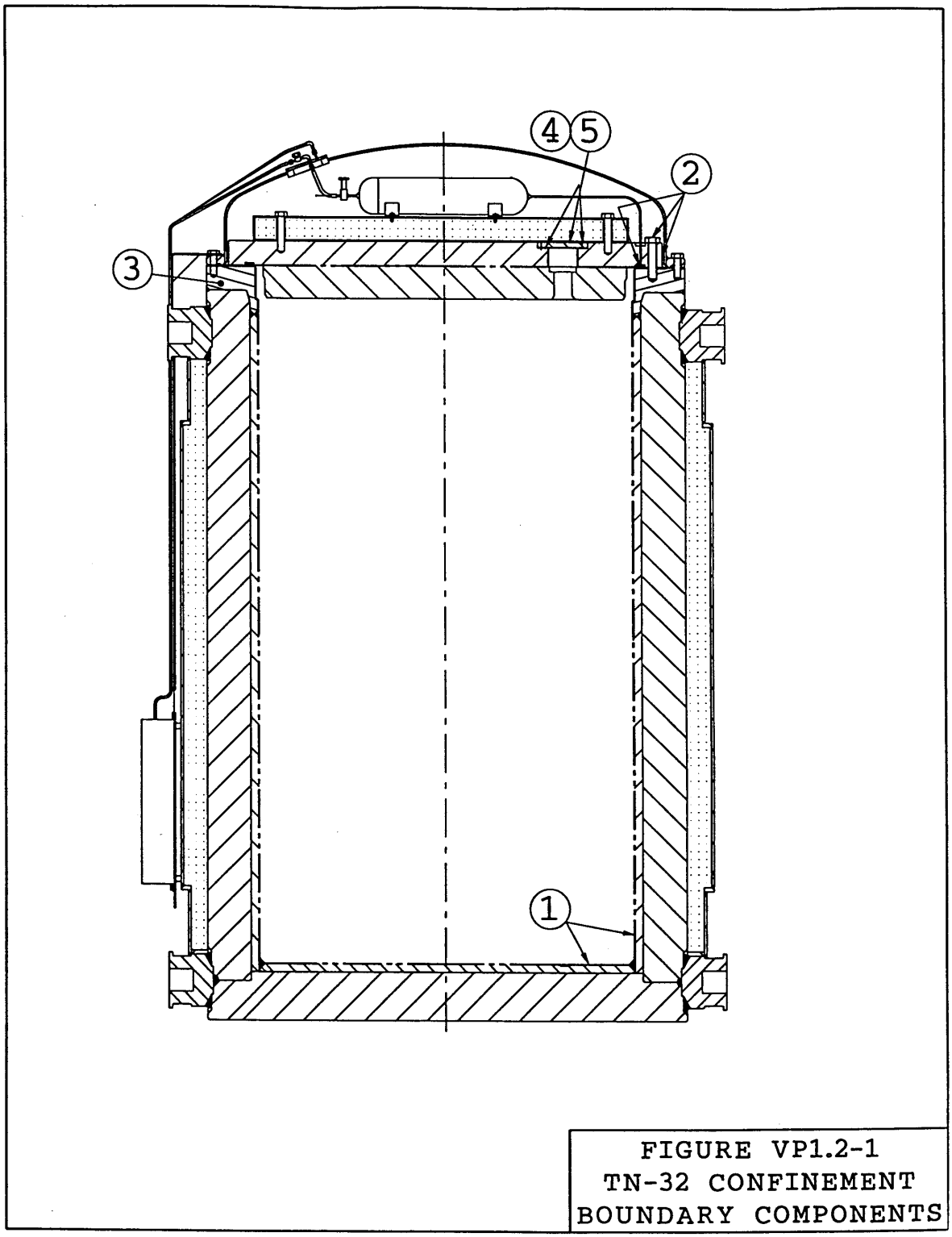
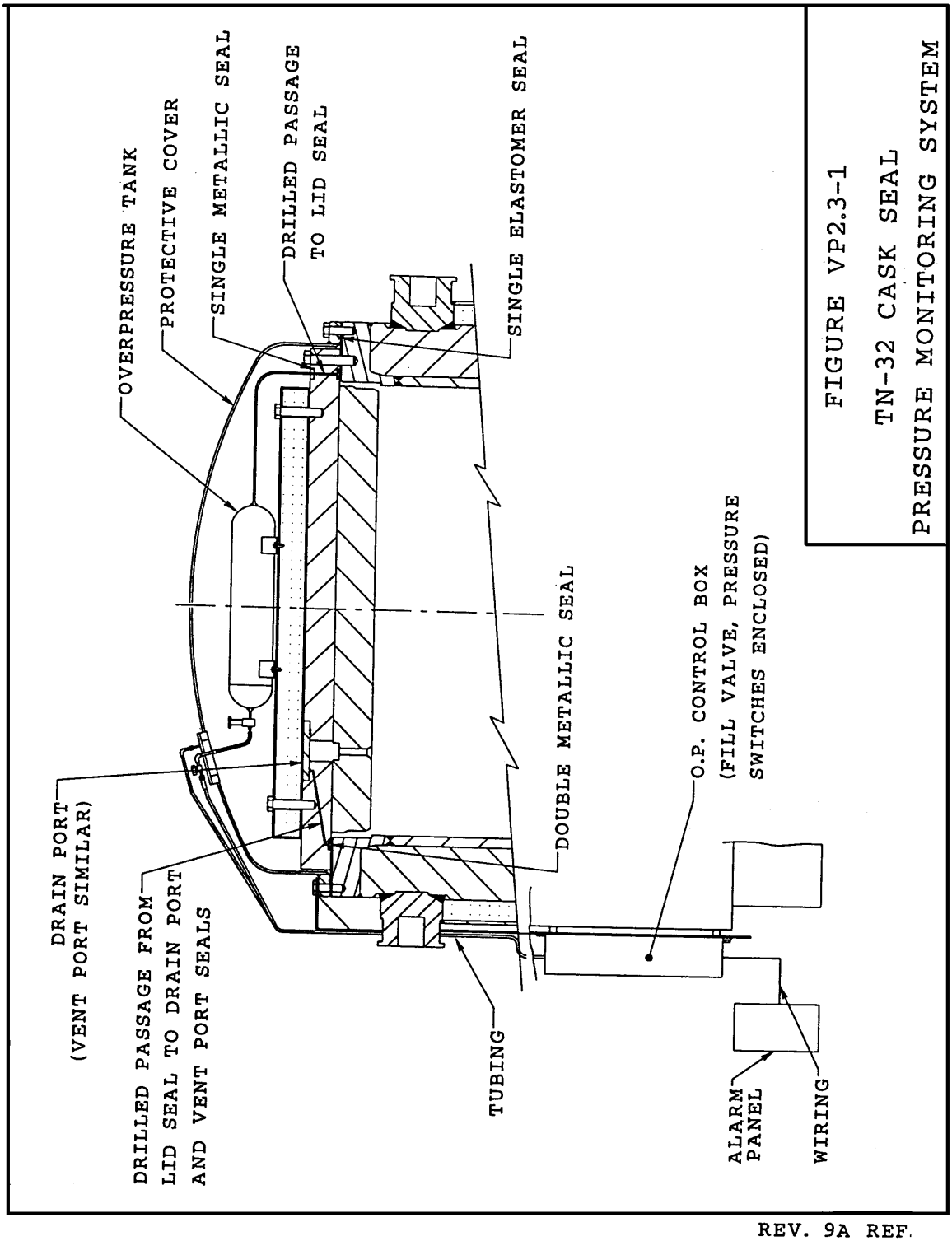


FIGURE VP1.2-1
TN-32 CONFINEMENT
BOUNDARY COMPONENTS

REV. 9A REF.

XI0040


OVERPRESSURE TANK
PROTECTIVE COVER
SINGLE METALLIC SEAL
DRILLED PASSAGE TO LID SEAL
SINGLE ELASTOMER SEAL
DRAIN PORT (VENT PORT SIMILAR)
DRILLED PASSAGE FROM LID SEAL TO DRAIN PORT AND VENT PORT SEALS
DOUBLE METALLIC SEAL
O.P. CONTROL BOX (FILL VALVE, PRESSURE SWITCHES ENCLOSED)
TUBING
ALARM PANEL
WIRING
FIGURE VP2.3-1
TN-32 CASK SEAL
PRESSURE MONITORING SYSTEM
REV. 9A REF.
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Appendix A.5

Attachment 4

Supplement to the Structural Analyses in TN-32 TSAR, Revision 9A, Section 3C.3-1

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3C.3-1.1 Additional Evaluation due to gap size variations occurring from Basket Rail fabrication and Installation Tolerances

This section evaluates the structural effect of the gap size variation between two basket support rails

The buckling analysis of basket bottom rail performed in Section 3C.3-1 assumes a gap of 0.48 inches between the edge of two rails or 0.24 inches between the edge of the rail and centerline of the basket. However, due to fabrication and installation tolerances the gap between these two rails can vary from 0" to 1.1326" (or 0.5663" between the edge of the rail and centerline of the basket).

- Discussion

It is observed from Section 3C.3-1 that in the rail design the most critical locations are locations 1, 2, and 3 as shown on Figure 3C.3-4. Due to the gap changes, the loading and stress at these three locations are discussed as follows:

1. The collapse load calculated in accordance with ASME B&PV Code, Section III, NB-3213.25 and Appendix F, F-1341.3 at Location 1 is 96g which is higher than the 88-g assumed for the tipover accident. The collapse load was calculated conservatively by assuming that the vertical load from the basket is directly applied at the center span of the two vertical rail support plates as shown on Figure 3C.3-2. This loading condition results in a maximum bending stress at the center of the rail horizontal plate. If the location of the rail is shifted either toward or away from the centerline of the basket due to gap size change, then the applied vertical load will move closer to the rail vertical support plates and the bending stress at the rail horizontal plate will decrease. Therefore, the gap changes will not result in increasing the stress at Location 1.
2. The stability of the vertical plates at Locations 2 and 3 is analyzed using the interaction equations 20 and 21 of Paragraph NF-3322.1 (Equations 1 and 2 in Section 3C.3-1). These equations utilize membrane and bending stresses that were determined from three dimensional ANSYS calculations.

   For Location 2 and a gap of 0.24",

   equation (1) becomes,

   $0.0954 + 0.328 = 0.423 \leq 1.0$

   equation (2) becomes,

   $0.440 + 0.483 = 0.923 \leq 1.0$

   and for Location 3, equation (1) becomes,

$0.06 + 0.31 = 0.37 \leq 1.0$

equation (2) becomes,

$0.369 + 0.477 = 0.846 \leq 1.0$

Since the membrane and bending stresses at Locations 2 and 3 will either increase or decrease due to the gap changes the interaction equation must be re-evaluated to insure that the structural integrity of the rail will be maintained.

- Analysis

The membrane and bending stresses presented in Section 3C.3-1 were calculated using a three dimensional ANSYS model. The purpose of this analysis is to determine the sensitivity of the stress values to a range of rail-to-rail gap dimensions, then re-evaluate the interaction equations to properly reflect the full range of stress values. A two-dimensional ANSYS model is sufficient to calculate such sensitivity.

Finite Element Model

In order to calculate the member and bending stress changes due to the gap size variations, an ANSYS two-dimension beam (BEAM 3) finite element model is constructed. This finite element model includes the rail and a small portion of basket for better load transfer to the rail. Gap elements (CONTAC 12) are used between the basket and rail to accurately simulate the basket load transfer to bottom support rail. One-inch widths of rail and basket are used for loading and beam elements section properties. The finite element model is shown on Figure 3C.3-14.

Material Properties

Following data is used in this run (material properties are taken at 350°F):

Material:

Aluminum Rail	$E = 9.0 \times 10^6$ psi (Section 3C.3-4)
304SS Basket	$E = 26.75 \times 10^6$ psi (from Table 3.3-5)

Loading Conditions

The membrane and bending stresses at locations 2 and 3 are computed by using unit loads F_1, F_2, F_3 and a distributed load w (for 1g). The locations of these loads and displacement boundary conditions are shown in Figure 3C.3-14.

Fuel Assembly Weight, W = 1,533 lbs. (Table 3.2-1)
Rail Length, L = 159.75 in. (Drawing 1049-70-5)

F_1 (at basket center line, x = 0.0) = 0.5 (No. of stacked fuel assemblies x W)/L
= 0.5 x 5 x 1533/159.75 = 23.991 lb.

F_3 (at basket centerline, x = 18.61") = 23.991 lb.

F_2 (at basket middle, x = 8.70 + .105 +.5 = 9.305") = (No. of stacked fuel assemblies x W)/L = 5 x 1533/159.75 = 47.981 lb.

Distributed Load, w = Fuel Assembly Weight / (L x Basket Span) = 1533 / (159.75 x 9.301) = 1.03174 lb/in

Section Properties:

Rail: Section Area, A = 0.47 (depth) x 1.0 (width) = 0.47 in^2
Moment of Inertia, I = 1.0 x $0.47^3/12$ = 0.008652 in^4

Basket : Steel – Aluminum Composite Section
E_s, Steel = 26.75 x 10^6 psi
E_a, aluminum = 9.0 x 10^6 psi

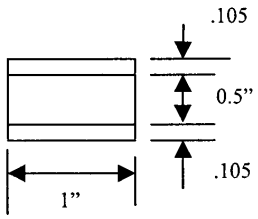
I_c, Composite Section = [1.0 ($0.71^3/12$ - 1.0 ($0.5^3/12$] + (1x $0.5^3/12$) x (9.0 x $10^6/26.75$ x 10^6) = 0.022914 in^4

Depth, d_c = $(12 \times .022914)^{1/3}$ = 0.65 in.
A_c = 0.65 x 1.0 = 0.65 in^2

Contact Elements: K = 1.0 x 10^6

Coefficient of friction = 0

Composite Steel/Aluminum Section



Load Case 1

The analysis is performed to calculate the membrane and bending stresses by using the existing loading condition (0.48" gap or 0.24" gap for half model).

An elastic non-linear run was made using the above loads and section properties. The membrane and bending stress components at location 2 and 3 are recorded in Table 3C.3-1. The deformed shape of model is given in Figure 3C.3-16.

Load Case 2

The same model is run by shifting the rail to the right to simulate the maximum gap of 1.1326" or o.5663" for the half model. In this run, all loads and section properties are same as in 0.24 in. gap case. However the finite element model was revised by transferring the 'x – coordinates' of rail nodes by 0.5663 0- 0.24 = 0.3263".

The membrane and bending stress components at location 2 and 3 are recorded in Table 3C.3-1. Also, the ratio between the values from this run and Load Case 1 are included in Table 3C.3-1. The deformed shape of model is given in Figure 3C.3-17.

Load Case 3

The same model is run by shifting the rail to the left to simulate the minimum gap of 0.0" for the half model. In this run, all loads and section properties are same as in 0.24 in. gap case. However the finite element model was revised by transferring the 'x – coordinates' of rail nodes by 0- 0.24 = -0.24".

The membrane and bending stress components at location 2 and 3 are recorded in Table 3C.3-1. Also, the ratio between the values from this run and Load Case 2 are included in Table 3C.3-1. The deformed shape of model is given in Figure 3C.3-18.

Evaluation

The interaction equation is re-evaluated by applying the results of the sensitivity analysis to the compression and bending components of the equation. Since the result from the equation (2) bounds equation (1), therefore only result from equation (2) is re-evaluated. So, for Case 2, which reflects the maximum gap between the two rails, at location 2:

$$0.440(1.034) + 0.483(1.101) = 0.987 \leq 1.0$$

and at Location 3:

$$0.369(1.076) + 0.477(1.084) = 0.914 \leq 1.0$$

For Case 3, which reflects the minimum gap between the rails, the interaction equation at Location 2 becomes

$$0.440(0.961) + 0.483(0.863) = 0.840 \leq 1.0$$

and at Location 3:

$$0.369(0.955) + 0.477(0.940) = 0.801 \leq 1.0$$

- Conclusion

The results of this analysis show the following conclusions:

1. As the gap between these two rail decreases, the likelihood of buckling decreases.
2. At the maximum possible rail gap of 1.1326" (or 0.5663" between the edge of the rail and centerline of the basket), the buckling interaction equations indicate that the rail will not buckle.
3. The stresses at Location 1 are not affected by a change in the rail gap size.

Therefore, for any possible gap sizes, the structural integrity of the rail will be maintained.

Table 3C.3-1
Summary of Stresses and Interaction Equation Evaluation

Case	Type	At Location 2 (Node 71)	At Location 3 (Node 81)
0.48" Space between Rails	Membrane Stress (psi)	-59.182	-65.290
	Bending Stress (psi)	27.765	38.627
1.1326" Space between Rails	Membrane Stress (psi)	-61.181	-70.267
	Bending Stress (psi)	30.568	41.871
	Ratio Membrane Stresses For 0.5663" & 0.24" cases	-61.181/-59.182 = 1.034	-70.265/-65.290 = 1.076
	Ratio Bending Stresses For 0.5663" & 0.24" cases	30.568/27.765 = 1.101	41.871/38.627 = 1.084
	Interaction Equation	1.034(.44*) + 1.101(.483*) = 0.987	1.076(.369*) + 1.084(.477*) = 0.914
0.0" Space between Rails	Membrane Stress (psi)	-56.883	-62.327
	Bending Stress (psi)	23.962	36.315
	Ratio Membrane Stresses For 0.5663" & 0.24" cases	-56.883/-59.182 = 0.961	-62.327/-65.290 = 0.955
	Ratio Bending Stresses For 0.5663" & 0.24" cases	23.962/27.765 = 0.863	36.315/38.627 = 0.940
	Interaction Equation	0.961 (.44*) + 0.863(.483*) = 0.840	0.955(.369*) + 0.940(.477*) = 0.801

* These coefficients are calculated in Section 3C.3-1. Since the result from the equation (2) bounds equation (1), therefore only result from equation (2) is re-evaluated.

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Figure 3C.3-14
Finite Element Model – Bottom Support Rail

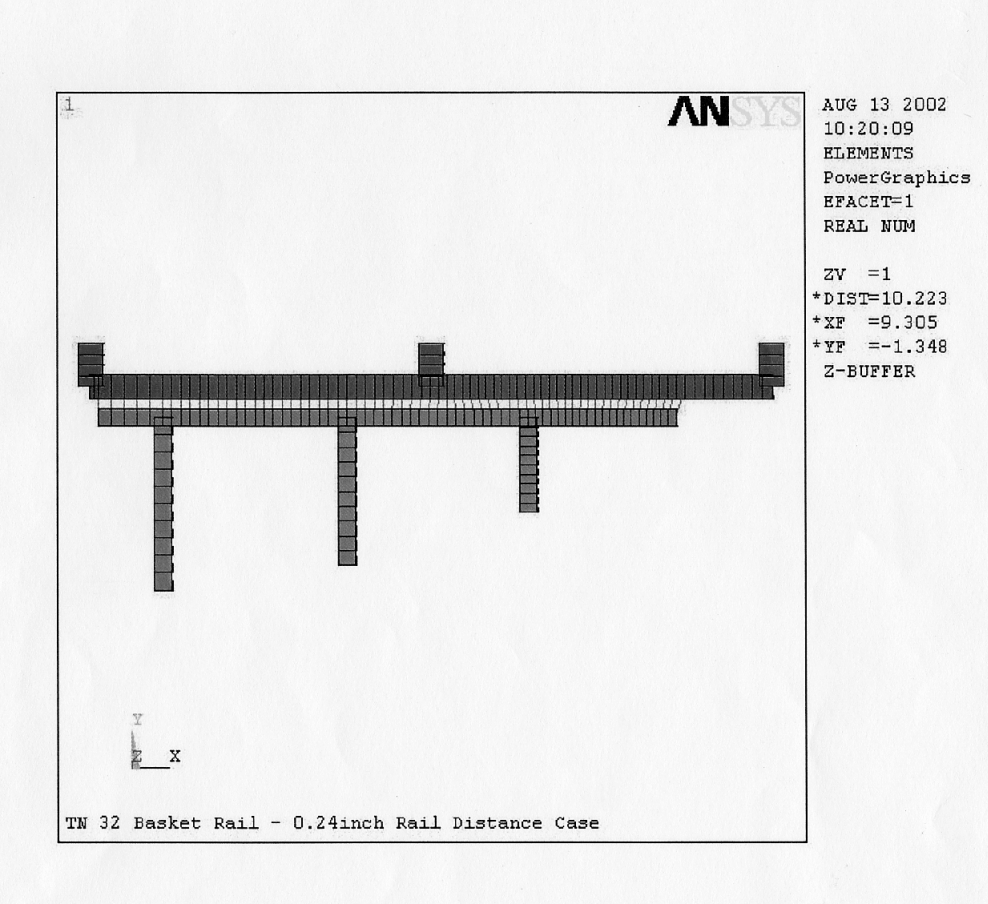

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Figure 3C.3-15
Finite Element Model – Loading and Boundary Conditions

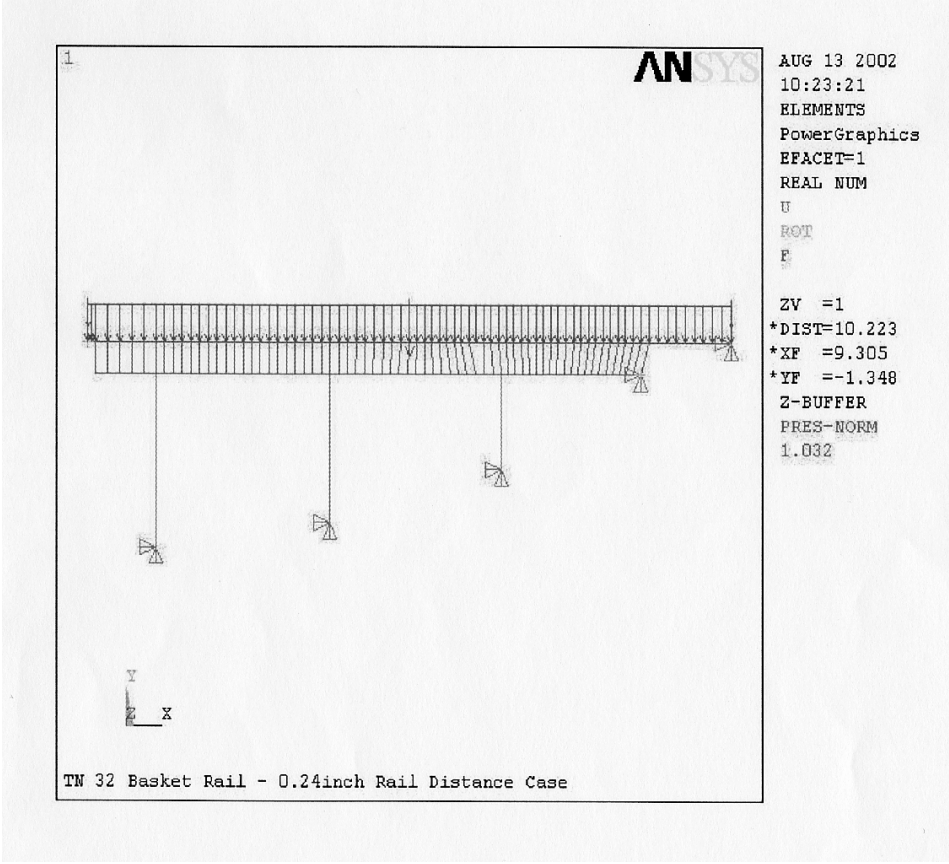

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Figure 3C.3-16
Finite Element Model – Deformed Shape, 0.24" Distance

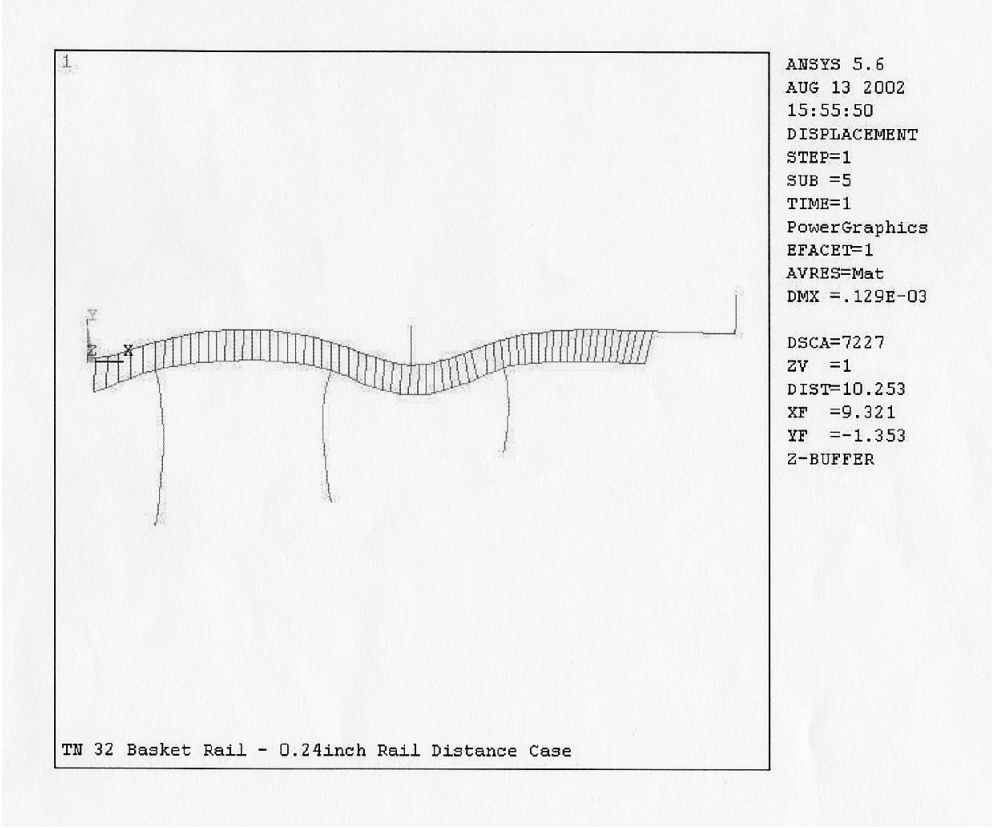

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Figure 3C.3-17
Finite Element Model – Deformed Shape, 0.5663" Distance

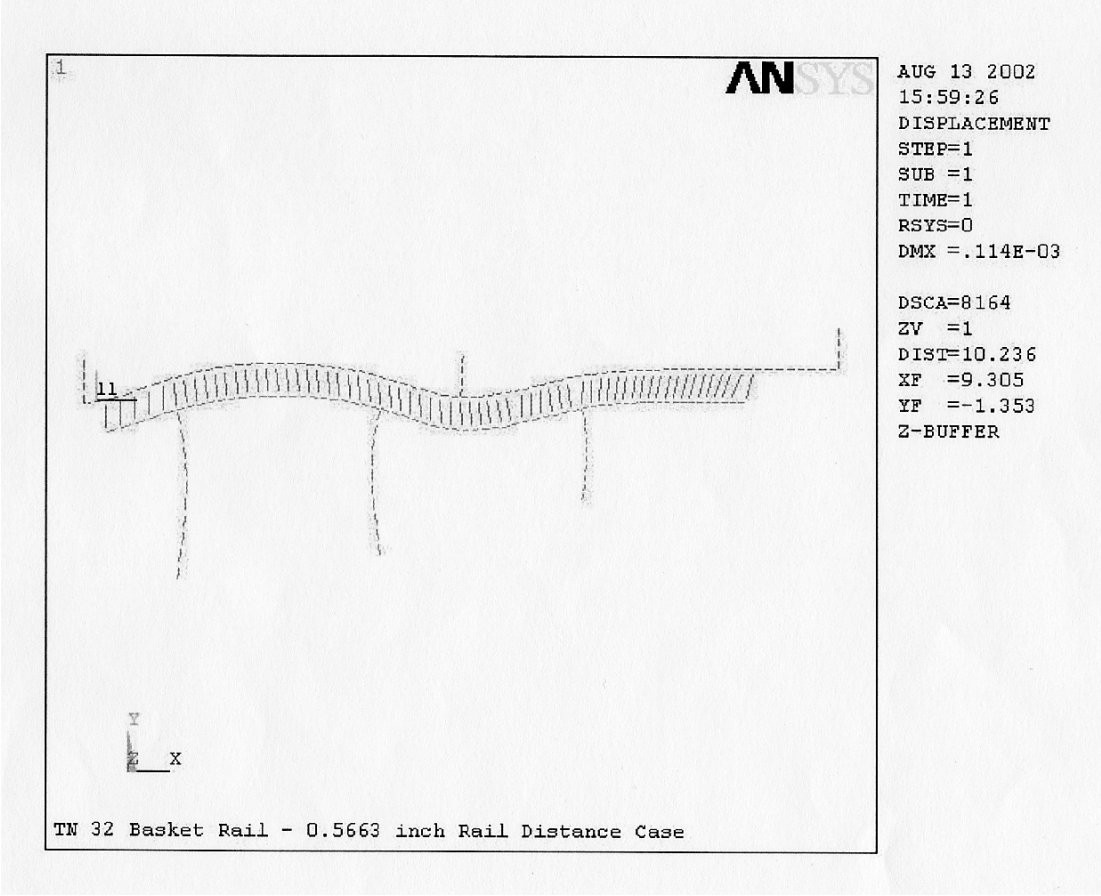

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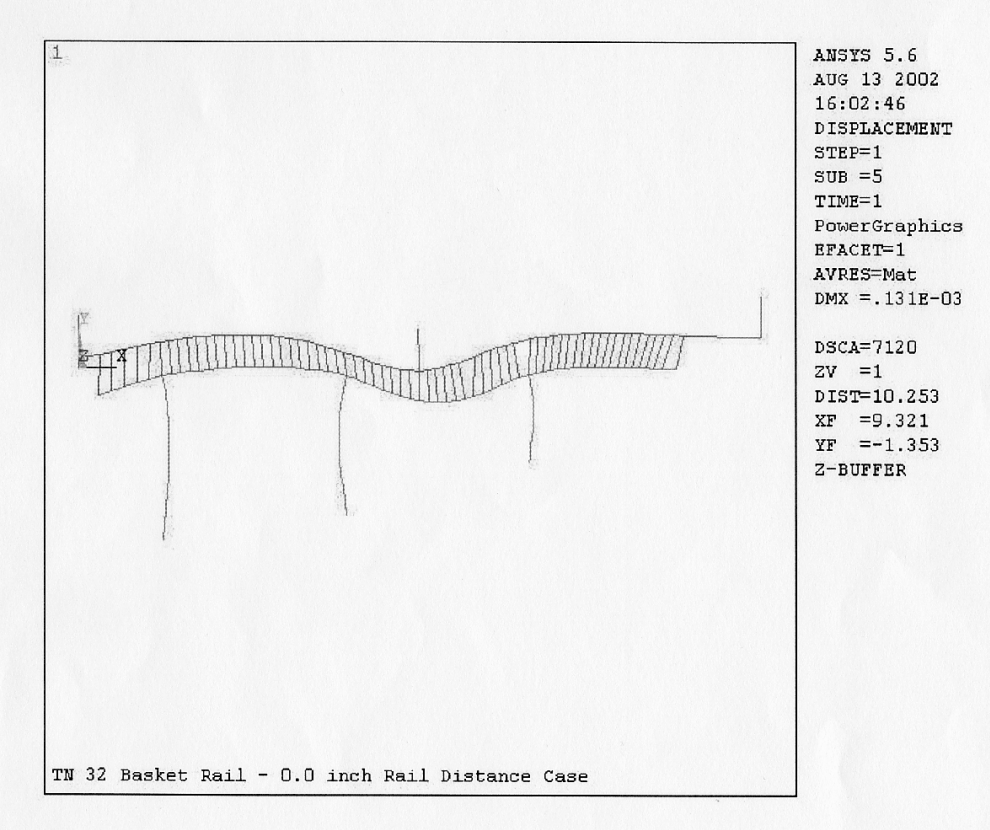
Figure 3C.3-18
Finite Element Model – Deformed Shape, 0.0” Distance



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