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LIST OF ACRONYMS

ANSI	American National Standards Institute
BGE	Baltimore Gas and Electric Company
CAB	Controlled Area Boundary
CCNPP	Calvert Cliffs Nuclear Power Plant
HSM	Horizontal Storage Module
HSM-HB	High Burnup Horizontal Storage Module
ISFSI	Independent Spent Fuel Storage Installation
LNG	Liquified Natural Gas
MLW	Mean Low Water
MRI	Meteorological Research Institute
MSL	Mean Sea Level
PMH	Probable Maximum Hurricane
SPT	Standard Penetration Test
SSI	Soil-Structure Interaction

2.0 SITE CHARACTERISTICS

2.1 GEOGRAPHY AND DEMOGRAPHY

2.1.1 SITE LOCATION

The Independent Spent Fuel Storage Installation (ISFSI) is located on the Calvert Cliffs Nuclear Power Plant (CCNPP) site in Calvert County, MD at latitude 38°-25'-39.7" N and longitude 76°-26'-45" W. Calvert Cliffs Nuclear Power Plant, LLC owns and Exelon Generation operates CCNPP. The power plant is approximately 10.5 miles southeast of Prince Frederick, MD, and is situated on the west bank of the Chesapeake Bay. The ISFSI is sited approximately 2300' southwest of the Power Plant at Elevation 114.0' above Mean Sea Level (MSL) and about 70' above the existing plant yard elevation. Figure 2.1-1 shows the ISFSI location with respect to neighboring states and counties within 50 miles. The metropolitan centers closest to the ISFSI are: Washington, DC, approximately 45 miles to the northwest; Baltimore, MD, approximately 60 miles to the north; Richmond, VA, approximately 80 miles to the southwest; and Norfolk, VA, approximately 110 miles to the south.

2.1.2 SITE DESCRIPTION

Figure 2.1-2 shows the ISFSI, property line, controlled area, power plant structures and general features of the area. The controlled area for the ISFSI is within the property boundary of the CCNPP, which covers 962 acres, and has a minimum radius of 3900' (1189 m). Calvert Cliffs Nuclear Power Plant, LLC owns all of the property within the controlled area boundary (CAB). Local and regional topography are shown on Figures 2.4-1 and 2.4-2, respectively.

2.1.2.1 Other Activities Within the Site Boundary

The ISFSI is located within the owner controlled area of the nuclear plant. The interaction between the ISFSI and the power plant is described in Chapter 5. Other non-plant related activities are limited to CCNPP's Visitors Center; Camp Conoy, a summer camp used by CCNPP for various recreational purposes; and a working farm of about 100 acres.

2.1.2.2 Boundaries for Establishing Effluent Release Limits

There are no effluent releases from the ISFSI. The CAB is shown in Figure 2.1-2. Access will be actively controlled at the ISFSI security perimeter fence. The minimum distance from the ISFSI to the CAB is 3900' (1189 m).

2.1.3 POPULATION DISTRIBUTION AND TRENDS

2.1.3.1 Population Within 10 Miles

Figure 2.1-3 shows the general locations of the ISFSI and the towns and other cultural features within 10 miles of the site. The population distribution is based on the 1980 census and the annual land use survey done for the Calvert Cliffs Radiological Environmental Monitoring Program. Table 2.1-1 gives the population distribution within 10 miles of Calvert Cliffs.

Between 1970 and 1980 the population of Calvert County increased by an average of 5.19% annually. The Tri-County Council of Southern Maryland projects an increase of almost 75% between 1980 and the year 2010. Solomons and the St. Leonard/Long Beach communities are major growth areas within the 10 mile radius of the ISFSI. Table 2.1-2 shows the projected population within 10 miles of the ISFSI for the year 2010 based upon the projections of the Tri-County Council.

2.1.3.2 Population Between 10 and 50 Miles

The population distribution shown in Table 2.1-3 is based on the 1980 census. Projections of population, Table 2.1-4, are based on the growth rates used in the CCNPP Updated Final Safety Analysis Report. Major population centers are Washington, DC, 45 miles northwest of the ISFSI with a 1980 population, including surrounding urbanized areas, of 2,763,105 and Annapolis, MD, population 31,740, located 40 miles to the north.

2.1.3.3 Transient Population

Winter daytime population variations are caused by schools, major employers, and facilities where a significant number of people gather regularly during the winter months. Summer daytime population variations are due to visitor attractions which include recreation areas, attractions such as a marine museum, and marinas. The summer night transient population adds 22.8% to the permanent population in Calvert County. St. Mary's County sees a 2% increase, Dorchester County a 21% increase. Table 2.1-5 identifies major public institutions within the 10 mile radius and their associated current populations.

2.1.4 USES OF NEARBY LAND AND WATERS

The Calvert Cliffs ISFSI is located approximately 3000' west of the western shore of the Chesapeake Bay. The Bay is used by the public for fishing, shellfish harvesting, boating, and swimming. The area within 10 miles of the ISFSI covers parts of Calvert, St. Mary's, and Dorchester counties. The counties are predominantly rural and are characterized by farmland and wetlands. The major crops are tobacco and corn.

Five miles to the southeast of the ISFSI is the Calvert Cliffs State Park. Ten miles south of the ISFSI is the Patuxent River Naval Air Station. Agricultural activities in the immediate area of the ISFSI have been addressed in the Environmental Report for CCNPP Units 1 and 2.

TABLE 2.1-1
1980 POPULATION DISTRIBUTION WITHIN 10 MILES

	0-1 Mile	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles
N	0	0	0	0	0	0
NNE	0	0	0	0	0	0
NE	0	0	0	0	0	0
ENE	0	0	0	0	0	231
E	0	0	0	0	0	43
ESE	0	0	0	0	0	8
SE	0	2	0	2	2	0
SSE	0	10	0	183	150	327
S	0	24	29	77	217	2,207
SSW	0	32	70	55	162	2,755
SW	0	17	37	135	107	3,582
WSW	0	58	90	99	152	2,616
W	0	22	41	24	107	925
WNW	0	50	10	39	48	755
NW	0	0	660	226	210	650
NNW	0	0	0	0	0	409
TOTALS:	0	215	937	840	1,366	14,508

TABLE 2.1-2
PROJECTED POPULATION WITHIN 10 MILES FOR THE YEAR 2010

	0-1 Mile	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles
N	0	0	0	0	0	0
NNE	0	0	0	0	0	0
NE	0	0	0	0	0	0
ENE	0	0	0	0	0	296
E	0	0	0	0	0	58
ESE	0	0	0	0	0	10
SE	0	4	0	4	442	0
SSE	0	18	0	385	312	515
S	0	43	42	649	449	12,548
SSW	0	42	76	113	338	5,299
SW	0	26	43	277	674	4,618
WSW	0	270	114	426	314	3,908
W	0	38	72	96	222	1,432
WNW	0	52	17	182	64	1,446
NW	0	0	1,086	462	2,651	852
NNW	0	0	0	0	0	624
TOTALS:	0	492	1,450	2,594	5,465	31,607

TABLE 2.1-3
1980 POPULATION DISTRIBUTION, 10 - 50 MILES

	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles
N	0	5,499	71,328	102,207
NNE	193	5,501	5,755	9,266
NE	833	6,105	12,617	9,817
ENE	2,295	16,226	8,724	20,296
E	522	1,204	4,230	41,637
ESE	742	781	3,852	19,305
SE	227	205	1,122	8,549
SSE	418	418	355	1,259
S	17,082	2,443	4,494	6,683
SSW	8,371	3,210	6,559	4,881
SW	5,317	1,919	4,228	6,087
WSW	4,896	4,093	7,690	6,487
W	5,518	5,836	5,821	19,038
WNW	8,047	24,283	39,497	163,167
NW	6,144	18,770	249,650	1,056,378
NNW	10,028	15,223	76,161	234,819
TOTALS:	70,633	111,716	502,083	1,709,876

TABLE 2.1-4
PROJECTED POPULATION, 10 - 50 MILES FOR THE YEAR 2010

	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles
N	0	9,137	105,460	147,511
NNE	209	8,384	6,781	12,695
NE	940	10,906	17,684	11,937
ENE	2,690	33,949	14,531	21,893
E	634	1,957	6,603	51,275
ESE	934	985	5,634	27,124
SE	337	313	1,776	12,865
SSE	732	772	608	2,029
S	29,516	4,112	6,659	10,166
SSW	14,263	4,924	8,407	7,008
SW	8,891	3,221	5,445	8,466
WSW	8,034	7,516	9,950	8,739
W	9,035	9,819	8,426	30,537
WNW	13,146	37,426	63,931	311,316
NW	9,490	31,363	432,300	1,799,508
NNW	14,644	27,570	141,067	356,982
TOTALS:	113,495	192,354	835,262	2,820,051

TABLE 2.1-5
MAJOR PUBLIC INSTITUTIONS WITHIN 10 MILES

FACILITY	SECTOR LOCATION	POPULATION
Governmental		
Naval Ordnance Lab and Recreation Facility	6-8 miles S & SSW	1,500
Calvert Cliffs State Park	2-4 miles S, SSE & SE	325
Chesapeake Biological Lab	8-9 miles S	125
Battle Creek Cypress Swamp Nature Area and Visitor Center	9-10 miles WNW	100
Flag Ponds Nature Park	1-2 miles NW	100
Calvert County Marine Museum	7-8 miles S	200
Schools		
Appeal Elementary	4-5 miles S	837
Mutual Elementary	6-7 miles WNW	782
Southern Middle	1-2 miles SSW	597
Our Lady Star of the Sea	7-8 miles S	120
Town Creek Elementary	9-10 miles SSW	320
St. John Elementary	9-10 miles SW	237
Hollywood Elementary	9-10 miles SW	268
Private Facilities		
Calvert Cliffs Nuclear Power Plant	2300' NW	1,100
Columbia Gas System	3-4 miles SSE	105

2.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

There are no other major nuclear facilities within a 50 mile radius of the ISFSI, other than the CCNPP. The Patuxent River Naval Air Station, located 10 miles south of the ISFSI, is the only nearby military installation. Nearby transportation routes are shown on Figure 2.1-3. The only industrial facility within approximately 10 miles of the ISFSI is the Cove Point Liquified Natural Gas (LNG) terminal and pipeline. There are no tall structures or discharge stacks on-site with the potential to impact the ISFSI upon collapse.

2.2.1 LOCAL AIRPORTS

Three airports operate within approximately 10 miles of the ISFSI and their location is shown on Figure 2.1-3. A helipad is located at the northern end of the CCNPP site, more than 1000' from the ISFSI. The helipad location is shown on Figure 2.1-2. The aircraft hazards analysis performed due to aircraft flights in the vicinity of CCNPP was found to be acceptable as documented in Reference 2.16.

2.2.1.1 Patuxent River Naval Air Station

Located approximately 10 miles south of the ISFSI is the only major aviation facility in the area. Known as the Patuxent River Naval Air Station, it operates all types of Naval Aircraft in test and development oriented missions. Most of the aircraft operate in specified restricted areas to the east and south; hence, their flight paths would be in these directions and away from the ISFSI. Aircraft involved in test and evaluation operations remaining in the local training pattern operate within 5 miles of the air station while involved in normal operations. Aircraft departing and arriving under Visual Flight Rules follow specific routes that go east and south and therefore their flight paths are away from the ISFSI, at altitudes of 1000' or 1500' depending on the type of aircraft.

Aircraft following Instrument Flight Rules follow preset arrival and departure procedures and none of these flight paths approach the ISFSI. Aircraft on a radar approach are vectored by a ground controller. However, in the event of loss of radar contact with the aircraft (and in training runs for such scenarios) some instrument approach and takeoff patterns pass at a ten nautical mile (11.5 mile) radius from the Naval Air Station, effectively flying aircraft directly over the ISFSI. Although these patterns pass over the ISFSI, it is unlikely that the aircraft come within three miles of the ISFSI because pilots should take a three mile bypass to avoid flyovers of the CCNPP site as directed.

Available information indicates about 100,000 takeoffs and landings per year with a peak of about 300 per day (Reference 2.17). The aircraft types and the maximum gross takeoff weights are listed in Table 2.2-1. The heaviest transient military aircraft visiting the base would be a Lockheed E-6A, which has a maximum gross takeoff weight of 240,000 lbs.

2.2.1.2 Chesapeake Ranch Airport

This private airport is located about 6 miles southeast of the ISFSI. It has a single 2,500' runway which limits the size of aircraft to single engine or light twin engine aircraft. No aircraft are permanently based there, and it is used mainly during summer months. A busy summer weekend would bring about six airplanes to the field. A representative sample is listed in Table 2.2-2.

The airport is located within the control zone of the Patuxent River Naval Air Station, which restricts free access to the field. All operations are under Visual Flight Rules only through a direct entry corridor provided by the Navy on a heading of 150° magnetic to the airport, at an altitude of 800'.

2.2.1.3 St. Mary's County Airport

This airport, located approximately 10 miles southwest of the plant, is owned by St. Mary's County. It has a single 3,250' runway with a full-length taxiway, a paint shop, four individual hangers and three ten-unit hangers. The airport is the base for about 100, mostly single engine, airplanes and can handle medium twin-engine, propeller-driven planes and small jet engine-driven planes. The Maryland State Police have a Dauphine rescue helicopter based at the airport (Tables 2.2-2 and 2.2-3).

The airport averages 3400 takeoffs and landings per month, with a peak daily activity of 300. Air traffic operates under Visual Flight Rules and Instrument Flight Rules with a pattern altitude of up to 2000'. The airport is situated on the edge of an airspace restricted for use by the Patuxent River Naval Air Station.

2.2.1.4 Corporate Helipad

A helipad is located at the northern end of the CCNPP site, more than 1000' from the ISFSI. Generally, this helipad is used for corporate flights from utility headquarters (normally less than 20 flights annually) and for an estimated six Medivac helicopter flights annually. There are no specific flight paths or exclusion areas for helicopter flights in the vicinity of the ISFSI; however, flight paths over the ISFSI are generally not used unless weather conditions warrant such a route to ensure a safe landing or takeoff. Helicopters using the corporate helipad weigh less than 12,000 pounds.

2.2.2 LIQUIFIED NATURAL GAS PLANT AND PIPELINE

The Cove Point LNG Terminal is located about 3.5 miles south-southeast of the Calvert Cliffs power plant. The Cove Point facility was designed as a receiving terminal for the importation of LNG with the capability of receiving LNG carriers at an average rate of once every 2.5 days. The LNG is unloaded and revaporized at the terminal and transported by a 36" pipeline to the Columbia transmission network at a connection in Loudoun County, VA.

The Cove Point Terminal, which received its first LNG shipment in March, 1978, has been idle since April 1980 but is scheduled to be reopened in 1994. The location of the terminal and pipeline relative to the ISFSI is shown on Figure 2.1-3. The effects of an LNG spill or explosion at the Cove Point Terminal or the pipeline are evaluated in Section 8.2.11.

TABLE 2.2-1
REPRESENTATIVE AIRCRAFT DATA AT THE PATUXENT RIVER NAVAL AIR STATION

AIRCRAFT	TYPE	MAXIMUM GROSS TAKE-OFF WEIGHT
A6	Attack bomber	60,626
A10	Attack bomber	50,000
AV8	V/STOL fighter/bomber	over 22,000
C2	Transport	54,830
C12	Transport	12,500
C130	Transport	175,000
C880	Transport	193,000
E2	Airborne early warning	49,638
E6	Transport	240,000
EA-6B	Electronic countermeasures	61,500
F14	Fighter	72,900
F18	Fighter	51,900
H1	Helicopter	16,800
H2	Helicopter	12,500
H3	Helicopter	21,000
H34	Helicopter	14,000
H46	Helicopter	23,000
H53	Helicopter	42,000
H60	Helicopter	23,000
H65	Helicopter	8,900
P3	Anti-Submarine Warfare patrol	139,760
S3	Anti-Submarine Warfare	52,539
T2	Trainer	13,284
T34	Trainer	4,425
T38	Trainer	12,500
T39	Trainer	18,650

TABLE 2.2-2
REPRESENTATIVE AIRCRAFT DATA, CHESAPEAKE RANCH AIRPARK

AIRCRAFT	TYPE	MAXIMUM GROSS TAKE-OFF WEIGHT
Aero Comm. Lark Comm.	Four place single engine	2,475
American Avia. AA1	Two place single engine	1,500
Beechcraft Musketeer	Four place single engine	2,750
Beechcraft Bonanza	Four/five place single engine	3,400
Beechcraft Baron E55	Four/six place twin engine	5,300
Cessna 150	Two place single engine	1,600
Cessna 172	Four place single engine	2,300
Cessna 177	Four place single engine	2,500
Cessna 182	Four place single engine	2,950
Cessna 206	Six place single engine	3,600
Cessna 210	Six place single engine	3,800
Cessna 310	Five place twin engine	5,300
Cessna 337	Four place twin engine	4,400
Champion Citabria	Two place single engine	1,650
Lake Amphibian	Four place single engine	2,400
Mooney Ranger	Four place single engine	2,575
Mooney Statesman	Four place single engine	2,532
Mooney Executive	Four place single engine	2,740
Mooney M22	Five place single engine	3,680
Piper Super Cub	Two place single engine	1,750
Piper Cherokee series	Two-four place single engine	2,900
Piper Cherokee Six	Six place single engine	3,400
Piper Comanche C	Four place single engine	3,200
Piper Twin Comanche	Fzour place twin engine	3,600
Piper Aztec	Six place twin engine	5,200

TABLE 2.2-3
REPRESENTATIVE AIRCRAFT DATA, ST. MARY'S COUNTY AIRPARK

St. Mary's County Airport would accommodate all of the aircraft listed in Table 2.2-2, as well as the following heavier types:

AIRCRAFT	TYPE	MAXIMUM GROSS TAKE-OFF WEIGHT
Aero Comm. Shrike Comm.	Four/six place twin engine	6,750
Aero Comm. Hawk Comm.	Eight place twin engine	9,400
Beechcraft Duke	Four/six place twin engine	6,775
Beechcraft Queen Air	Six/eleven place twin engine	8,800
Beechcraft King Air	Six/ten place twin engine	12,500
Cessna 401	Six/seven place twin engine	6,300
Cessna 414	Six/seven place twin engine	6,350
Cessna 421	Six/eight place twin engine	7,250
Citation I & II	Six/eight place jet engine	12,500
Piper Navajo	Six/ten place twin engine	6,200

2.3 METEOROLOGY

2.3.1 REGIONAL CLIMATOLOGY

2.3.1.1 Data Sources

Data acquired by the National Weather Service and summarized by the Environmental Data Services were used to determine the regional climatology as shown in Table 2.3-1. Local long-term weather station data were used from the Patuxent River Naval Air Station for periods of record from 1949 to 1980.

2.3.1.2 General Climate

The Chesapeake Bay area is marked by generally mild winters and summers. The Bay absorbs much of the sun's heat during the day and releases some of it during the night when the air above the water becomes cooler. This area is in the belt of "prevailing westerlies." Most of the weather comes from a westerly direction across the continental United States, or directly from Canada. Cold air masses, such as those which produce the colder days of winter and the cool days of summer, come generally from the northwest. Warm air masses originate either in the desert and plateau sections of the southwestern states and Mexico, or from over the Gulf of Mexico. Those from the Gulf generally produce considerable precipitation, while those from the desert regions generally produce warm or hot dry periods.

Northwesterly winds prevail from October to April, and southwesterly winds prevail in the warmer months. Ordinarily, the velocity of the wind varies directly with the intensity of the low pressure area and inversely with the distance from its center. The usual diurnal variations in wind speed occur with a minimum generally before dawn, increasing with the daily temperature to a maximum at the time of highest temperature. High winds of destructive velocity are rare.

2.3.1.3 Severe Weather

2.3.1.3.1 Maximum and Minimum Temperatures

As listed in Table 2.3-1, a maximum recorded local temperature of 103°F was recorded at Patuxent River Naval Air Station in July, 1980. The minimum temperature of -3°F was recorded at Patuxent River Naval Air Station in 1956 and 1977. In the region, a maximum temperature of 105°F during August, 1983 and a minimum temperature of -7°F in January, 1984 were recorded at Baltimore-Washington International Airport.

The Nuclear Regulatory Commission has not provided explicit guidance on selection of design temperatures for ISFSI analysis. The maximum and minimum temperatures presented in Table 2.3-1 are based on the historic extreme recorded temperatures at Patuxent River Naval Air Station. The CCNPP ISFSI site is located on the Chesapeake Bay, just 10 miles NNE of the Patuxent River Naval Air Station.

The station is an National Oceanic & Atmospheric Administration station which has been recording data continuously since 1945. It represents the most accurate record available for weather in the vicinity of CCNPP and is referenced as such in the CCNPP Final Safety Analysis Report. The data for Washington, DC and Baltimore, MD, was included in Table 2.3-1 to demonstrate that the Chesapeake Bay has a moderating influence on the temperature extremes. LaPlata and College Park measurement locations are located further inland from the Bay and have larger variations in temperature extremes.

Document NUREG/CR-1390 (Reference 2.14) is not included as a requirement in the criteria of 10 CFR Part 72, or by other documents providing guidance for the design and analysis of the CCNPP ISFSI. NUREG/CR-1390 itself also does not provide criteria for selection of design temperatures. If the probabilistic estimates of temperature extremes from Reference 2.14 are used for the location of the CCNPP ISFSI site, it will yield the following values. NUREG/CR-1390 presents three sets of isotherms for the U.S. representing the 2-year, 50-year, and 100-year return values for maximum and minimum temperatures corresponding to 0.5, 0.98, and 0.99 probability levels. The 2-year max/min return values for CCNPP are 98°F/8°F and the 50-year return values are 104°F/-8°F. The design values chosen for the CCNPP ISFSI, which has a 20-year license period, are 103°F/-3°F. These values are very close to the 50-year return values. The 100-year return values are 106°F/-16°F, not significantly different from the design values chosen.

Published data for the Patuxent River Naval Air Station shows the average daily maximum temperatures to be 85°F (July) and the average daily minimum temperature of 29°F. Also, Reference 2.15, page 24.8, shows that for Baltimore (latitude 39° 20' and longitude 76° 25') the 1% summer (July) and 99% winter (January) temperatures are 92°F and 14°F and the median of annual extremes are 97.9/7.2°F, respectively.

Based on these temperatures, the design temperatures of 103°F/-3°F are more closely applicable to the CCNPP ISFSI site than the suggested values of 116°F/-40°F. The 116°F/-40°F values were selected by other ISFSI site applicants applicable for their ISFSI site locations only.

Regulatory Guide 3.48 requires that the analysis consider off-normal and accident conditions for the ISFSI and refers to the four categories of design events defined in American National Standards Institute (ANSI) 57.9. Off-normal analyses, as defined in Regulatory Guide 3.48, include Design Events I and II. These events are expected to occur "frequently" (I) or "with moderate frequency or on the order of once during a calendar year of ISFSI operation" (II). Accident conditions defined in Regulatory Guide 3.48 include Design Events III and IV which are "infrequent events that could reasonably be expected to occur during the lifetime of the ISFSI" or postulated events.

The historical extreme temperatures of -3°F and 103°F recorded at Patuxent River Naval Air Station were used for all four types of design events. It is clear that the local historical extreme temperatures meet the requirements for analyses of Design Events I and II. Since the Patuxent River data includes 45 years of records and the ISFSI license period is 20 years, it also seems clear that the criterion of "events that could reasonably be expected to occur during the lifetime of the ISFSI," is enveloped by these temperatures. Only in the case of postulated events should the use of the historical extremes be questioned. While 10 CFR Part 71 specifically includes postulated temperatures of -40°F and 125°F for analysis, such definitions are not included in 10 CFR Part 72, Regulatory Guide 3.48 and ANSI 57.9. The events defined in the SAR Design Event IV category include tornado wind and tornado generated missiles, the cask drop accidents, HSM air flow blockages, etc. For accident analyses where weather may affect system performance, the historical extreme temperatures were used and appear to be appropriate and defensible based on existing regulatory guidance.

2.3.1.3.2 Extreme Winds

Records from Baltimore-Washington International Airport indicate that the fastest recorded wind speed was 80 mph in March of 1952. Available data from other stations indicate slower maximum winds. Winds can be expected to reach a fastest speed in excess of 50 mph in any month of the year as an estimate of maximum winds to be encountered. Destructive velocities are rare and occur mostly during summer thunderstorms.

2.3.1.3.3 Tornadoes

Five tornadoes were observed during the 10-year period 1953-1962 in the general vicinity of a single latitude-longitude square near the ISFSI. The mean annual frequency was 0.5 tornadoes per year and the probability of a tornado striking a single point within that area was calculated to be 3.75×10^{-4}. The recurrence frequency was calculated to be once about every 2,700 years.

2.3.1.3.4 Hurricanes and Tropical Storms

Approximately one hurricane per year poses a threat to the area, and about one hurricane every 10 years produces a significant effect. Northeasters, or extratropical storms, also can influence the area in terms of flooding of low-lying land. The ISFSI is, however, on high ground. The detrimental effects of northeasters are considerably less than those postulated for hurricanes.

2.3.1.3.5 Precipitation Extremes

Table 2.3-1 lists some extremes of meteorological measurements for selected National Weather Service stations in the Calvert Cliffs region. At Patuxent River Naval Air Station, the 24-hour maximum was 5.88" in August, 1969.

2.3.1.3.6 Thunderstorms

Fifteen years of records at Patuxent River Naval Air Station showed 814 observations of thunderstorm activity with an average duration of about 1 hour 20 minutes. Baltimore averages 27.6 thunderstorms per year. Ronald Reagan Washington National Airport reports 29.8 thunderstorms per year. June and July are the months of greatest frequency of thunderstorms.

2.3.1.3.7 Snow and Freezing Precipitation

The Patuxent River Naval Air Station records for 1949 through 1964 list 910 hours of snow and 264 hours of frozen or freezing precipitation, other than snow, for a total of 1,175 hours (70,500 minutes) in 15 years. Interpolating for a 10 year span yields 47,000 minutes. The regional maximum monthly snowfall occurred in February, 1979, when Baltimore received 33.1" and Washington received 30.6". The maximum 24-hour snowfall at Patuxent River Naval Air Station of 11.7" occurred in February, 1979.

2.3.2 LOCAL METEOROLOGY

2.3.2.1 Data Sources

The local meteorology is based upon on-site data collected since 1967 and off-site data from Patuxent River Naval Air Station. Additional data was taken from Andrews Air Force Base and Ronald Reagan Washington National Airport near Washington, DC, and Baltimore-Washington International Airport.

2.3.2.2 Topography

Detailed topographic features in the region surrounding the ISFSI are shown on Figure 2.4-2. A discussion of topographical effects on diffusion estimates is described in Section 2.3.4.1.

2.3.3 ON-SITE METEOROLOGICAL MEASUREMENT PROGRAM

On-site meteorological measurements include wind direction and speed, temperature, and vertical temperature gradient. The accident analysis meteorological data base is for the period January 1, 1984 — December 31, 1986. Joint frequency tables of wind direction, wind speed, and atmospheric stability are shown in Table 6.1-1A of the ISFSI Updated Environmental Report.

The meteorological data for Calvert Cliffs presented in this section were collected from three meteorological towers: the inner south tower, discontinued in 1975; the microwave tower (ST), discontinued in 1993; and the primary tower placed in service in 1982 (Figure 2.3-1). The joint frequency tables digitized from strip charts by Dames & Moore (1969-1980) and by Envirodata (1981-1984) were used.

The relative position of instruments with respect to the power plant and the ISFSI is noted in Figure 2.3-1. Relative elevations of both surface levels and instrument levels are depicted in Figure 2.3-2. The available meteorological instrumentation for each tower is described in Table 2.3-2.

Regular operability, maintenance and calibration checks of the meteorological instrumentation are performed. As required by the CCNPP Technical Requirements Manual, a daily channel check and semiannual calibration of the meteorological monitoring instrumentation channels are performed. The calibration is performed according to a surveillance procedure.

Data loggers located in the building at the meteorological tower site sample each meteorological data channel every second and average the data every 15 minutes. The 15 minute averages are transmitted to the plant computer. For long-term storage, the data is archived by Plant Information Technology. Data averages are displayed locally at plant computer workstations located in the Control Room, Technical Support Center, Technical Support Center Annex, Simulator Control Room, and Emergency Operations Facility. Data from these workstations is used to assess the impact of routine effluents and accidental effluents. The hardware components and display locations are shown in Figure 2.3-3.

2.3.4 DIFFUSION ESTIMATES

2.3.4.1 Basis

The design 2-hour relative concentration (χ/Q) at the CAB for an accidental release at the ISFSI is 3.0x10^{-4} sec/m^3. Meteorological conditions resulting in a higher value will occur less than 5% of the time annually.

The 3.0x10^{-4} sec/m^3 design χ/Q is a conservative estimate which is based on a Pasquill turbulence class of G and a transport speed of 1.0 m/sec. Meteorological data used in this diffusion estimate was measured by the Baltimore Gas and Electric Company (BGE) on-site measurements program during the period from January 1, 1984 through December 31, 1986. Frequency distribution statistics of stability type and wind speed class were compiled by Pickard, Lowe and Garrick for BGE and were used for these calculations (Reference 2.7). The Pasquill G type stability class is selected based on Delta T measurements between the 10-60 m interval at the primary meteorological tower, which is approximately 1000' north of the ISFSI. During the 3-year period of record, the frequency of occurrence of a Pasquill G stability was 6%. A transport speed of 1.0 m/sec was selected during a G stability class. These meteorological conditions occurred less than 5% of the time annually during the measurement period. The distance to the nearest CAB used for this calculation is 3900' (1189 m).

Local topographic influences are considered in evaluating the diffusion characteristics of the ISFSI location. The ISFSI is located on a northeast-southwest ridge which descends in Elevation 40' to 60' northwest and south of the ISFSI out to 1000'. Because of this local terrain feature, an accidental release, during a strong inversion with near calm winds, would result in the plume becoming decoupled from the atmosphere and drain, due to gravity, on either side of the ridge. As a result, it is very likely that the plume will be contained within the Calvert Cliffs CAB until adequate mixing is available for dispersion. The table below is a list of χ/Q values as a function of distance from the storage facility:

Distance (m)*	(χ/Q) sec/m^3
1000	3.5×10^{-4}
1189 (CAB)	3.0×10^{-4}
1500	2.4×10^{-4}
2000	1.8×10^{-4}
2500	1.6×10^{-4}
3000	1.3×10^{-4}

* Distance, in this case, is the centerline distance from the storage facility for a plume under a Pasquill G class stability.

2.3.4.2 Calculations

The calculations of a 2-hour χ/Q value to estimate radiological doses for a potential accidental release from the ISFSI is based on a Pasquill G type stability with a wind speed of 1.0 m/sec. The following equation for calculating χ/Q is referenced in Nuclear Regulatory Commission Regulatory Guide 1.145 (Reference 2.8), and considers plume "meander" during low wind speeds and stable atmospheric conditions:

$$\chi/Q = \left[\bar{\mu}\pi\Sigma_y\sigma_z\right]^{-1} = 3.0 \times 10^{-4}\ \text{sec/m}^3$$

Where:

- χ/Q = relative concentration, sec/m^3
- $\bar{\mu}$ = average wind speed in m/sec
- π = 3.14159
- σ_y = the lateral plume spread in meters as a function of atmospheric stability and distance
- σ_z = the vertical plume spread in meters as a function of atmospheric stability and distance
- Σ_z = (M-1) σ_{y800m} + σ_y, where M is obtained from Figure 3 in Reference 2.8

The σ_y and σ_z values obtained for the χ/Q calculations are estimated from the figures in Reference 2.9.

TABLE 2.3-1
METEOROLOGICAL EXTREMES IN THE CALVERT CLIFFS REGION

	Baltimore-Washington International Airport	Ronald Reagan Washington National Airport	Patuxent River Naval Air Station
Maximum temperature (°F)	105 (8/83)	103 (7/80)	103 (7/80)
Minimum temperature (°F)	-7 (1/84)	-5 (1/82)	-3 (1/65,77)
Max monthly rainfall (in)	18.35 (8/55)	14.31 (8/55)	15.51 (7/45)
Max monthly snowfall (in)	33.1 (2/79)	30.6 (2/79)	32.3 (2/79)
Max 24-hour rainfall (in)	7.82 (8/55)	7.19 (6/72)	5.88 (8/69)
Max 24-hour snowfall (in)	22.8 (2/83)	18.7 (2/79)	11.7 (2/79)
Fastest mile wind (mph)	80 (3/52)	78 (10/54)	Not Available

TABLE 2.3-2
ON-SITE METEOROLOGICAL STATIONS AND INSTRUMENTATION

DESIGNATION	ELEVATION	PERIOD	INSTRUMENTATION
Inner South Tower	48' MSL +12' Mast	1/9/69 to 1/12/70	MRI Mechanical Weather Station Model 1071
		2/11/69 to 2/20/69	MRI Vector Vane Sigma Meter, Model 1053
	48' MSL +12' & 49.5'	5/15/69 to 9/4/74	Temperature Gradient System, Packard Bell Corp. (Beckman-Whitley), Model 327 Aspirated Radiation Shields
	48' MSL +12' Mast	6/1/69 to 8/7/69	MRI Wind Diffusion System, Model 2040
	48' MSL +33'	8/7/69 to 5/15/71	MRI Wind Diffusion System, Model 2040
	48' MSL +33' & 97'	5/15/71 to 8/14/75	MRI Wind Diffusion System, Model 2040
		9/29/71 to 8/14/75	Temperature Gradient System
		7/17/71 to 8/14/75	Weather Measure Corp. Aspirated Radiation Shields w/Rosemount Sensors Beckman-Whitley Model WS-101 Quick Vane Wind System
		3/13/72 to 1/11/74	Gill Anemometer Bivane
Secondary Tower (Microwave Tower)	75' MSL +40' & 125' & 200'	8/8/73 to Fall 1993	125' & 200' MRI Wind Diffusion System, Model 2040
		8/8/73 to Fall 1993	40', 125' & 200' Weather Measure Corp. Aspirated Radiation Shields w/Rosemount Sensors. Temperature Gradient System
		8/23/73 to Fall 1993	125' Weather Measure Corp. Dewpoint System
Meteorological Towers			
a. Primary Tower	110' MSL +33' & 197’	4/82 to Present	33’ & 197’ Wind Sensors
		4/82 to Present	33’ & 197’ Temperature Sensors
		4/82 to Fall 1995	33’ Dewpoint Sensor
		4/82 to Present	0’ Rain Gauge
b. Backup Tower	110' MSL +33'	12/05 to Present	33’ Wind Sensor
		12/05 to Present	33’ Temperature Sensor

MRI Meteorological Research Institute

2.4 SURFACE HYDROLOGY

2.4.1 HYDROLOGIC DESCRIPTION

2.4.1.1 Site and Facilities

The ISFSI is located approximately 2300' southwest of the existing CCNPP at Elevation 114.0' above MSL. The ISFSI yard is approximately 226' by 666' and was created by excavation on the north end of the yard and by earth fill on the south end of the yard. The horizontal storage module (HSM) foundations are supported near yard grade at Elevation 111.0'. The Dry Shielded Canisters are supported approximately 5.5' above yard grade and the air intakes for cooling of the spent fuel is 2' above yard grade. The topography and local drainage pattern in the immediate area of the ISFSI is shown on Figure 2.4-1. The ISFSI yard is well drained and not susceptible to flooding.

2.4.1.2 Hydrosphere

Calvert County is bounded on the east by the Chesapeake Bay and on the west by the Patuxent River. The area is characterized by gently rolling terrain. A drainage divide extends longitudinally across the county. The county is well drained by a relatively large number of streams, although most are less than 7 miles long. Many streams have moderately steep valley walls, while others form estuaries to the Patuxent River. Swampy areas and tidal flats are common along the coastal areas.

The topography of the CCNPP property around the Calvert Cliffs ISFSI is gently rolling with steeper slopes along stream courses. Local relief ranges up to about 130'. The area is well drained by short intermittent streams. A drainage divide, which is generally parallel to the coastline, extends across the area as shown on Figure 2.4-2. The area to the east of the divide includes the plant area and drains into the Chesapeake Bay. The western area which includes the ISFSI is drained by tributaries of Johns Creek which flow into St. Leonard Creek and subsequently into the Patuxent River. Grading performed during construction of the CCNPP has not substantially altered the drainage system shown on Figure 2.4-2.

The ISFSI is just west of the drainage divide shown on Figure 2.4-2 and is not subject to flooding.

The surface waters adjacent to the Calvert Cliffs ISFSI are used for navigation, recreation, and commercial fishing. Almost all potable water used in Calvert County is from subsurface sources. The major use of water is for domestic and agricultural purposes. A discussion of groundwater users is provided in Section 2.5.1.

2.4.2 FLOODS

2.4.2.1 Flood History

Historical storms and tides in the Chesapeake Bay, as well as maximum water levels resulting from a probable maximum hurricane (PMH) in the entrance to the Bay were established in order to evaluate the maximum flood level for design at the CCNPP. The resulting maximum water level including wind and wave runup is 28' above MSL which is about 86' below the ISFSI yard grade.

2.4.2.2 Flood Design Considerations

As discussed in Section 2.4.2.1, the ISFSI yard grade is 86' above the elevation of the probable maximum water level for the CCNPP and is not susceptible to flood. Accordingly, the ISFSI is not designed for flood. The design flood level for the ISFSI was established based on a review of historical flood levels near the ISFSI location and evaluation of the PMH postulated at the entrance to the Chesapeake Bay. The PMH and the resulting wave runup resulted in the maximum water level at the ISFSI.

2.4.3 PROBABLE MAXIMUM FLOOD ON STREAMS AND RIVERS

See Sections 2.4.2.1 and 2.4.2.2.

2.4.4 POTENTIAL DAM FAILURES, SEISMICALLY INDUCED

There are no upstream dams or river structures which could affect water levels at the ISFSI.

2.4.5 PROBABLE MAXIMUM SURGE AND SEICHE FLOODING

The Calvert Cliffs ISFSI yard grade is above the maximum water level for the CCNPP site. The PMH results in the highest water level for the ISFSI. The following discussion summarizes the historical maximum storms and tides and the basis of the maximum water level as shown in Reference 2.1.

Historic Storms and Tides

Historic accounts of early hurricanes affecting the Chesapeake Bay area date back to the 17th Century. Early chronologies of tidal flooding record extreme events which occurred in August 1667, October 1749, September 1769, and July 1788. United States Weather Bureau records show at least 80 tropical hurricanes or their remnants affected the Bay area in the 75 year period between 1889 and 1964. One of the most destructive hurricanes in recent years to affect the Chesapeake Bay region was the hurricane of August 23, 1933. Other notable storms include hurricanes "Hazel" in October 1954, "Connie" and "Diane" in August 1955 (only 5 days apart), "Donna" in September 1960, "Agnes" in 1972, "David" in 1979, and "Gloria" in 1985. The "Great Atlantic Hurricane" of September 1944, which passed some 50 miles offshore of the Chesapeake Bay, was also a storm of major size and intensity. As noted above, the relative frequency of hurricane occurrence for this area is slightly more than one hurricane per year. In general, record hurricanes passing over or near Chesapeake Bay have had central pressures of 27.8 to 28.5" of mercury; peak wind speeds over the ocean approaching 100 mph, and maximum winds over the bay area of up to 75 mph. The forward speed of these storms has ranged from 10 to 36 knots. Northeast storms also affect the Chesapeake Bay area; however, because of the general orientation of the bay, the magnitude of tides reached in the bay, is not as great as those generated by record hurricanes. The northeast storm of March 6-8, 1962, resulted in 4.9' mean low water (MLW) tide in the lower Potomac River.

Tides and Storm Surges

Normal tides in the bay area have two highs and lows roughly every 23.5 hours, with a higher high and lower low as a daily occurrence. The mean and spring tide ranges to be expected at the Calvert Cliffs shore are 1.2 and 1.4', respectively. The travel time of high and low tide occurrence from the Bay entrance to the local area is approximately 5 hours.

Storm surges and extreme high tides have been recorded at numerous locations in the Chesapeake Bay and in the various rivers entering the Bay. Peak tide elevations above MLW range from 8.2' at Solomons Island near the mouth of Patuxent River to 7.4' at Point Lookout at the mouth of the Potomac River. Tide levels of 4.1' and 5.1', respectively, were recorded at these locations in the October 1954 hurricane. In the August 23, 1933 hurricane, a peak tide of about 8.5' MLW occurred at Norfolk, VA. A generalized tide-frequency curve was developed for the Chesapeake Bay area utilizing observed hurricane surge elevations. A reproduction of that relation is shown on Figure 2.4-3. The tide elevations noted above include the cumulative effects of tidal surge, pressure effect, local wind effect, wave effect (in open bay areas) and the astronomical tidal component. The contribution of the latter can add as much as 3' to the total recorded hurricane tide height if the peak ocean surge entering the Bay coincides with a peak spring tide condition. The time of translation of tides up the Bay, noted above, is also an important consideration in determining the coincidence of both ocean and bay peak surge heights with normal and spring high and low tides.

Probable Maximum Hurricane

A comprehensive investigation of hurricane surge problems for the Chesapeake Bay area was made using parameters from Memorandum HUR 7-97, "Interim Report — Meteorological Characteristics of the Probable Maximum Hurricane, Atlantic and Gulf Coasts of the United States," Reference 2.10. Parameters describing the maximum probable hurricane were selected from Reference 2.10 at the approximate latitude of the Chesapeake Bay entrance (36.1°). Definition of each of those parameters for a maximum probable hurricane is given below.

Central Pressure (P_o) — Minimum central pressures in hurricanes passing over or near the Chesapeake Bay area have been as low as the 27.88" of mercury for the September 1944 hurricane. Except for hurricanes occurring within the last several decades, sufficient information on central pressures to establish a reliable pressure-frequency relationship for the area is not available. A central pressure of 26.94" was selected.

Asymptotic Pressure (P_n) — A value of 30.92" was selected to represent the peripherical pressure of the PMH.

Radius of Maximum Winds (R) — A value of 30 statute miles was used for this parameter, being considered representative of severe storm occurrences in the general area. Its use results in a storm of reasonable size for transposition purposes.

Forward Speed (T) — The value selected for forward speed is 23 mph, a moderate speed of translation. The forward speed of the storm affects not only the peak 30' overwater wind speed, but also the height of peak ocean tide at or near shore and the shape of the resulting hydrograph. In the case of the Chesapeake Bay, the forward speed is especially important in that it is related to the development of surge elevation within the Bay, the speed of the free wave up the Bay, and the resulting surge height at the ISFSI shore. A very slow moving storm would permit the Bay surge to crest at Calvert Cliffs before the maximum effect of crosswinds could reinforce and increase that height. A fast moving storm would result in the converse.

Maximum winds at radius R would be 124.7 mph; adding half the forward speed results in a peak isovel wind speed of 136.2 mph.

Path — The path selected for the PMH is shown in Figure 2.4-4. It would approach the coast from the east, curving northward on passing inland west of Chesapeake Bay.

Parametric relationships describing the wind speed profile, pressure profile, pressure effect profile and basic wind data used in constructing the isovel pattern for the PMH were derived using a computer program developed and employed by personnel of the Jacksonville District Corps of Engineers. Graphical representation of the overwater wind profile, the pressure and pressure effect profiles can be seen on Figure 2.4-5.

Tidal Surge Computations

Procedures used in the tidal surge analysis for the open ocean across the Continental Shelf are those described in the U.S. Army Coastal Engineering Research Center publication "Shore Protection — Planning and Design," Technical Report No. 4, Reference 2.11. Formula (1-65) shown on page 140 of that report was used for the computations. Peak tide at the Chesapeake Bay entrance will occur at time T_o. Peak winds in the zone of maximum winds were oriented over the shallow bay entrance channel area to obtain the maximum surge height. Based on the selected forward speed, the surge hydrograph at the coast would have about a 12 to 14 hour rise from slightly above normal tides to the peak surge at T_o. This is based on a comparison of storm features of the PMH with that of the August 1933 hurricane which affected the area.

Results — The peak tidal surge elevation that would occur at the Bay entrance was computed to be 18.67' MLW (17.32' MSL). It should be noted that wave effect was not considered to be applicable. Water depths in the channel entrance to the Bay would be on the order of 40' (22' depth + 18' surge). That depth would sustain a 30-32' wave which would move into the bay area to break farther inland. A reduction in ocean surge occurs as it passes into and up the Bay due to the comparative dimensions and hydraulic characteristics of the entrance channel and the various sections of the Bay between Hampton Roads and Baltimore. Movement of the surge up the Bay to the Calvert Cliffs area will occur at approximately the speed of the free wave in the Bay (about 24 to 27 mph depending on depth changes) and at a speed coincident with the speed of the hurricane. The presence of large rivers with added storage volume will result in a further minor reduction in surge height in its passage up the Bay. A factor of 0.96 x the surge elevation in the lower Bay will give the value of the surge elevation to be expected in the vicinity of the installation. Using that factor gives a surge elevation of 13.44' MLW (14.0x0.96). That elevation represents the height of the surge in the Bay as it moves northward past the Calvert Cliffs site. To that value must be added the additional effect of hurricane winds blowing from east to west across the Bay and the effect of coincident occurrence of normal high tide, plus any wave effect.

Surge Elevation at Plant Site — Movement of the PMH inland and overland will result in a reduction in intensity and wind speed. Wind directions slightly ahead of the zone of maximum winds will be oriented generally east to west over the Bay in the vicinity of the ISFSI at the time the peak surge reaches that area. An evaluation of wind speed and direction was made for that condition. Wind speeds of from 115 to 120 mph (117 mph average) were found to be applicable for the wind direction and fetch conditions shown on Figure 2.4-6. An effective crosswind of 94 mph was used to compute the additional height of Bay setup. The total fetch length is approximately 10 Statute miles. The computed setup elevation in the vicinity of the ISFSI was determined to be 15.21' MLW. A value of 1' was added to that elevation for estimated wave effect, giving a total peak surge elevation at the Calvert Cliffs shore of 16.21' MLW (15.6' MSL).

<u>Wave Analysis</u> — The significant wave height that can be expected to occur in the vicinity of the ISFSI during the PMH peak surge will be a function of wind speed, water depth, and length of available fetch. Evaluation of average water depth with fetch length in the Bay offshore indicated a 50' depth for about 7 miles; a 40' depth for about 9 miles. Using a wind speed of 94 mph results in a significant wave height of 11.4'; with a corresponding wave period of 9 sec. The wave will break in approximately 14.5' of water. The height of the wave above still water level would be 6.8' (11.4x0.6). Added to the peak surge elevation of 16.2', the elevation of the top of that wave, unbroken, would be 23.0' MLW.

The resulting maximum runup elevation of 27.5' MSL is well below the ISFSI yard grade elevation of 114.0'.

2.4.6 PROBABLE MAXIMUM TSUNAMI FLOODING

The occurrence of tsunamis is infrequent in the Atlantic Ocean. Other than the tidal fluctuation recorded on the New Jersey shore during the Grand Banks earthquake of 1929, there was no record of tsunamis on the northeastern United States coast prior to about 1970. The earthquake of November 18, 1929, on the Grand Banks about 170 miles south of Newfoundland, resulted in a tsunami which struck the south end of Newfoundland, about 750 miles northeast of the Massachusetts Coast. This tsunami occurred at a time of abnormally high tide and resulted in some loss of life and destruction of property. The effect of this tsunami was recorded on tide gauges along the east coast of the United States as far south as Charleston, South Carolina. A tidal fluctuation of approximately nine-tenths of one foot was noted at Atlantic City, NJ and Ocean City, MD (Reference 2.12).

The Lisbon earthquake of November 1, 1755, produced great waves which contributed heavily to destruction on the coast of Portugal. These waves were noticeable in the West Indies. It has been reported that the Cape Ann, MA, earthquake of November 18, 1755, caused a tsunami in Saint Martin's Harbor in the West Indies. However, there is no record of tsunami occurrence along the east coast of the United States at this time and it appears that the Saint Martin's Harbor report actually refers to the tsunami caused by the Lisbon earthquake, which occurred less than 3-weeks before the Cape Ann shock. Some tsunami activity has occasionally followed earthquakes in the Caribbean, but none of these was reported in the United States.

The ISFSI is not susceptible to a tsunami effect. The maximum expected tsunami would result in only minor wave action, and the maximum expected storm wave effect, discussed in Section 2.4.5, is the basis of the ISFSI flood design.

2.4.7 ICE FLOODING

The ISFSI is not subject to floods resulting from ice on adjacent streams or the Chesapeake Bay. As discussed in Sections 2.4.1 and 2.4.2 the ISFSI is near the drainage divide between the Patuxent River and the Chesapeake Bay at Elevation 114.0' above MSL.

2.4.8 FLOODING PROTECTION REQUIREMENTS

The ISFSI is in a flood-free zone as described in Sections 2.4.1 and 2.4.2.

2.4.9 ENVIRONMENTAL ACCEPTANCE OF EFFLUENTS

There are no effluent releases from the ISFSI during normal operation as described in Section 2.4.1.2.

2.5 SUBSURFACE HYDROLOGY

A detailed discussion of the groundwater aquifers, flow directions, recharge points, and users is provided in Reference 2.1 and is summarized in the following sections.

2.5.1 REGIONAL CHARACTERISTICS

Ground water occurs in the surficial soils and is tapped by many shallow dug and driven wells. Ground water in deeper aquifers occurs under artesian conditions. These aquifers, the Piney Point, Nanjemoy, and Aquia formations, are separated from the surficial deposits by an aquiclude averaging about 270' in thickness. Recharge to these aquifers occurs in their outcrop areas about 15 to 30 miles west of the ISFSI. The geologic position of these aquifers relative to other formations in Calvert County is presented in Table 2.5-1 and Figure 2.6-4.

The hydrologic characteristics of the Piney Point, Nanjemoy, and Aquia formations are discussed in greater detail in the following subsections.

2.5.1.1 Piney Point Formation

The Piney Point formation consists of glauconitic sand interspersed with shell beds and a little clay. Well cuttings and particle-size analyses indicate that the aquifer is composed mainly of medium to fine sand. The formation occurs as a wedge-shaped geologic unit and is known only in southern Maryland. It is about 30' thick in the vicinity of the ISFSI and increases in thickness to the southeast.

The Piney Point formation is widely utilized as a source of ground water in Calvert County and adjoining St. Mary's County. Several hundred domestic wells in these two counties tap the Piney Point and the underlying Nanjemoy formations. These two aquifers are hydrologically connected. The yields of domestic wells generally range from about 3 to 20 gpm. The specific capacities of 25 selected wells in these formations range from 0.1 to 3.3 and average 1.2 gpm/ft of drawdown.

2.5.1.2 Nanjemoy Formation

The lower part of the Nanjemoy formation consists of an impermeable red clay known as the Marlboro Clay. The remainder of the formation consists chiefly of greensand, but contains some clayey greensand. A limited number of particle-size analyses indicate that the sand is predominantly medium to fine grained.

The Nanjemoy formation is an important aquifer in Calvert County where it is tapped by several hundred wells. Most wells are completed in the permeable water bearing sands occurring in the uppermost 80' of the formation and yield less than 10 gpm. The specific capacities of 11 wells in Calvert County tapping this aquifer range from 0.2 to 2.4 and average 0.8 gpm/ft of drawdown. On the basis of water level recovery measurements made during a pumping test, a coefficient of transmissibility of approximately 2,000 GPD/ft has been computed. The field coefficient of permeability was 66 GPD/ft^2. The results of a similar test in Prince George's County indicate coefficients of transmissibility ranging from 260 to 840 GPD/ft.

2.5.1.3 Aquia Formation

The Aquia formation is characterized by an abundance of glauconitic sand with some quartz sand and clay. The thickness of permeable sandy beds in the formation ranges up to slightly more than 40' in parts of Calvert County. Particle-size analyses of samples from the Aquia formation show that the sand is medium to fine-grained.

Yields of individual wells tapping this formation range from 125 to 350 gpm. The specific capacities of eight of these wells range from 0.8 to 4.2 and average 2.5 gpm/ft of drawdown. The results of six pumping tests indicate field coefficients of permeability ranging from 130 to 1,340 GPD/ft^2. Coefficients of transmissibility determined from the tests range from 5,500 to 33,000 GPD/ft.

Calvert Cliffs Nuclear Power Plant wells tap this formation.

2.5.1.4 Water Levels

The artesian head of the three principal aquifers in Calvert County is generally above sea level. The effect of tidal fluctuations on water levels was noticeable in observation wells completed in the Nanjemoy and Piney Point formations at Solomons Island about 7 miles south of the ISFSI. Recorder charts from these wells, which are 248 and 493' deep, respectively, show fluctuations of about 1/2'.

The approximate configurations of the piezometric surfaces of the Aquia and Nanjemoy formations are shown on Figure 2.5-1. The regional hydraulic gradient in the vicinity of the Calvert Cliffs ISFSI is to the southeast. However, the regional hydraulic gradient in the vicinity of the Calvert Cliffs ISFSI is to the southeast, local minor variations occur.

2.5.1.5 Public Water Supplies

Nearly all potable water used in Calvert County is from subsurface sources. The major use of water is for domestic and agricultural purposes. There are 15 towns and 8 private communities in Calvert County with public water supplies. The output from these systems is relatively small, but may increase substantially in the summer to accommodate the seasonal population increase. Data concerning the public water supplies is presented in Table 2.5-2. The locations of these supplies are shown on Figure 2.5-2.

2.5.1.6 Private Wells

Field surveys have determined that most domestic water supplies in Calvert County are obtained from private wells greater than 300' in depth. In some instances, other wells were less than 50' deep and of limited capacity. The yield of most private wells is less than 60 gpm. The locations of the deep wells, in the vicinity of the ISFSI, are shown on Figure 2.5-3.

There is one well between the ISFSI and Johns Creek. This well and all property between the ISFSI and Johns Creek is owned and controlled by CCNPP.

2.5.2 SITE CHARACTERISTICS

The depth of ground water at the Calvert Cliffs site was measured using piezometers installed in seven Dames and Moore exploratory borings in 1967. The piezometers consisted of small-diameter steel pipe equipped with a well point, or perforated polyvinyl chloride pipe. They were installed in borings DM-1, DM-2, DM-3, DM-5, DM-7, DM-8, and DM-9 immediately after completion of the drilling operations. Water levels ranged from 15' below the ground surface at DM-7 to 82' at DM-5. The locations of the borings are shown on Figure 2.5-4.

An in-situ soil percolation test was performed at the site in Miocene soils typical of those underlying the site. Results of this test indicate a permeability of less than 1 GPD/ft^2. The location of the test is shown on Figure 2.5-4.

Soil samples from borings at the ISFSI were tested in order to measure their grain-size distribution. The results of these analyses were used for soil classification purposes. The results are presented on Figures 2.5-5A through 2.5-5I. The location of borings and the subsurface profile are shown on Figures 2.6-7 and 2.6-7A.

The clay mineral content and the total cation exchange capacity of seven selected soil samples was analyzed by Dames and Moore in the late 1960's. The results of these tests are presented in Table 2.5-3.

Data obtained from the geologic exploratory borings indicate that a large portion of the ISFSI area is mantled by relatively permeable Pleistocene soils. These soils have been eroded from a portion of the area exposing the Chesapeake Group which includes the St. Mary's, Choptank, and Calvert formations. The Chesapeake Group consists of about 270' of impervious sandy and clayey silts of Miocene age. Underlying this material are the Piney Point, Nanjemoy, and Aquia formations of Eocene age.

The elevation of the phreatic surface changes with the surface topography and can be expected to fluctuate slightly as a result of climatic changes. The water table occurs generally within 30' of the ground surface. East of the topographic divide the direction of ground water movement is toward the Chesapeake Bay. The direction of ground water flow west of the divide is toward the existing stream valleys.

The underlying impervious sandy and clayey silts of the Chesapeake Group extend to about 200' below MSL. A percolation test conducted near the Calvert Cliffs ISFSI indicates a permeability of less than 1 GPD/ft^2. Particle-size analyses indicate that the permeability of the Chesapeake Group averages about 3 GPD/ft^2. The rate of ground water movement is extremely low (much less than 1" per day). The formation is an aquiclude which effectively confines the underlying artesian aquifers. Regional studies by the U.S. Geological Survey have shown that the head in the artesian aquifers is above sea level. The result is vertical upward leakage through the Chesapeake Group. The rate of leakage is extremely low because of the low permeability of the Miocene sediments.

At the ISFSI, the combined thickness of the aquifers within the Piney Point and Nanjemoy formations is about 80'. They occur at elevations ranging between 200 and 300' below MSL and are separated from the deeper Aquia formation by a layer of clay (Lower Nanjemoy) about 150' thick. The general direction of ground water movement in the Aquia formation is toward the southeast with a piezometric gradient of about 2' per mile.

Grain-size analyses of samples of the Piney Point formation collected at the site indicate a permeability of about 150 GPD/ft^2. This value is probably typical of both the Piney Point and Nanjemoy aquifers. It is estimated that the permeability coefficient of the Aquia formation may be on the order of 1,000 GPD/ft^2. The computed rate of flow of ground water through these aquifers ranges from about .07 to .004' per day. The possibility of accidental contamination of the Eocene aquifers beneath the ISFSI is remote because, (a) there are no effluent releases from the ISFSI, (b) the aquifers are covered by over 200' of relatively impervious soils, and (c) the vertical component of ground water movement is upward.

2.5.3 CONTAMINANT TRANSPORT ANALYSIS

As discussed in Section 2.5, there are no effluent releases from the ISFSI.

TABLE 2.5-1
GEOLOGIC UNITS IN CALVERT COUNTY

GEOLOGIC UNIT	APPROXIMATE RANGE IN THICKNESS (feet)	PHYSICAL CHARACTERISTICS	WATER BEARING PROPERTIES
Pleistocene surficial deposits	0-150	Silt and sand with some clay and gravel	Yields small quantities of water to relatively shallow dug or driven wells.
Chesapeake Group St. Mary's Fm. Choptank Fm. Calvert Fm.	30-325	Sandy and clayey silt with interbedded sand and fossiliferous layers	An aquiclude. Yields small supplies of water to a few dug wells.
Piney Point Fm.	0-60	Glauconitic sand	Yields up to 200 gpm are reported from drilled wells. An important aquifer in Calvert County.
Nanjemoy Fm.	40-240	Glauconitic sand with clayey layers. Basal part is red or gray clay	Yields of individual wells reported up to 60 gpm. An important aquifer in Calvert County.
Aquia Fm.	30-200	Green to brown glauconitic sand	Yields up to 300 gpm reported from wells. An important aquifer in Southern Maryland.
Brightseat Fm.	0-40	Gray to dark gray micaceous silty and sandy clay	Not known to be an aquifer in Southern Maryland.
Monmouth and Matawan Fm.	20-135	Sandy clay and sand, dark gray to black, with some glaucomite	Not a major aquifer in Southern Maryland, but yields up to 50 gpm have been reported.
Magothy Fm.	0-40	Light-gray to white sand and gravel with interbedded clay layers	A few wells reportedly yield up to 1,000 gpm but average yields considerably less. This aquifer is not used in Calvert County because of its depth.
Raritan Fm.	100	Interbedded sand and clay with ironstone modules	Yields up to a few hundred gpm reported. Not utilized in Calvert County due to depth.

TABLE 2.5-1
GEOLOGIC UNITS IN CALVERT COUNTY

GEOLOGIC UNIT	APPROXIMATE RANGE IN THICKNESS (feet)	PHYSICAL CHARACTERISTICS	WATER BEARING PROPERTIES
Patapsco Fm.	100-650	Interbedded sand, clay, and sandy clay	Large-diameter wells yield up to 1,000 gpm. Not used in Calvert County because of depth.
Arundel Clay Fm.	25-200	Red, brown, and gray clay	Not generally a water bearing formation.
Patuxent Fm.	100-450±	Chiefly gray and yellow sand with interbedded clay	Yields of several hundred gpm reported. Not utilized in Calvert County due to great depth.
Precambrian	Unknown	Gneiss, granite, gabbro, metagabbro, quartz diorite, and granitized schist	Yields moderate supplies of ground water, generally not more than 50 gpm. Not used in Calvert County because of its great depth.

TABLE 2.5-2
PUBLIC SUPPLY WELLS IN CALVERT COUNTY

TOWN	POPULATION SERVED	NUMBER OF CONNECTIONS	AVERAGE OUTPUT (mgd)	WELL	TOTAL DEPTH (ft)	DIA. (in)
Calvert Beach	222	74	0.017	1	475	5
Cavalier County	402	134	0.045	--	--	--
Chesapeake Beach	460	220	0.036	1[a]	400	8
				2	400	8
				3	400	6
				4[a]	400	2
				5	400	2
Chesapeake Heights	612	175	0.043	--	--	--
Chesapeake Ranch Estates	1995	--	0.132	1	400	4
				2	750	4
				3	750	4
Dares Beach	501	--	0.026	1	--	4
Hunting Hills	114	--	0.005	1	--	4
Kenwood Beach	255	--	0.021	1	--	4
				2	--	4
Lakewood	120	--	0.010	--	--	--
Long Beach	1275	--	0.080	1	525	3
				2	500	4
				3	475	4
				4	500	4
				5	357	4
Prince Frederick	372	269	0.091	1	--	6
Randle Cliffs	18	--	0.001	2	--	8
St. Leonard	75	--	0.012	1	550	5
Scientists Cliffs	500	230	0.045	1	240	6

TABLE 2.5-2
PUBLIC SUPPLY WELLS IN CALVERT COUNTY

TOWN	POPULATION SERVED	NUMBER OF CONNECTIONS	AVERAGE OUTPUT (mgd)	WELL	TOTAL DEPTH (ft)	DIA. (in)
Shores of Calvert	414	138	0.030	--	--	--
Solomons Island	400	--	0.020	1	--	--
Summit	80	9	0.002	--	--	--
Wallville Acres	21	7	0.002	--	--	--
Western Shores	175	49	0.022	1	325	3
White Sands	120	34	0.006	1	402	4
				2	315	2.5

NOTE: Information based on 1988 biennial update of the Calvert County Comprehensive Water and Sewerage Plant prepared by the Calvert County Department of Planning and Zoning.

[a] Wells not in use.

TABLE 2.5-3
CATION EXCHANGE AND X-RAY DIFFRACTION ANALYSES

BORING	DEPTH (feet)	SOIL TYPE	GRADATION IN % FINER[a] (in millimeters) .074	.048	.005	.002	% OF TOTAL CLAY MINERALS[b] Illite	Montmorillonite and Mixed Clay Minerals	Chlorite	TOTAL CATION EXCHANGE CAPACITY[c] Test 1	Test 2
DM-1	45	Gray Silty Clay	98	44	23	17	30	50	20	23.8	24.5
DM-6	43.5	Green Silty Sand	28	25	21	15	40	60	--	10.0	11.0
DM-6	115	Green Clayey Silt	98	91	44	31	30	50	20	24.3	27.3
DM-8	30	Green Silty Sand	28	25	22	15	35	65	--	13.8	12.8
DM-8	45	Green Clayey Silt	90	80	45	35	20	60	20	25.0	30.6
DM-9	5	Reddish-Brown Sandy Clay	80	65	38	34	--	--	100	10.0	10.3
DM-10	47	Gray Sandy Silt	59	22	16	11	20	80	--	14.4	10.0

(a) Soil samples soaked for 24 hours in 0.4% sodium hexametaphosphate before hydrometer analysis.
(b) X-ray diffraction analyses of minus 2 micron material.
(c) Because of the $CaCO_3$ in some of the samples, the ammonium acetate method was used. Total Cation Exchange was determined on the minus 40 micron material.

2.6 GEOLOGY AND SEISMOLOGY

Specific soil testing has been performed at the designated location for the ISFSI. The data obtained from this testing is utilized in the foundation design of the ISFSI. It should be noted that foundation conditions at the ISFSI are generally typical of those encountered in the general area. The following sections discuss the Calvert Cliffs area geology and seismology. The initial geologic field work at the Calvert Cliffs ISFSI was performed prior to the licensing of the CCNPP and is summarized in the following sections. Additional evaluations were performed to confirm that the in-situ soil conditions are adequate to support the revised foundation loading due to a change in storage modules for Phases IV and V [use high burnup horizontal storage module (HSM-HB)]. A comparison of the in-situ soil conditions encountered during the subsurface investigation for the original ISFSI to the results of the recent subsurface investigation (2007) was made. Records of earthquake history in the eastern region since construction of Calvert Cliffs have been reviewed and indicate no recent seismic activity that would impact the design bases for the facility.

2.6.1 BASIC GEOLOGIC AND SEISMIC INFORMATION

The Calvert Cliffs site is underlain by approximately 2,500' of southeasterly dipping sedimentary strata of Cretaceous and Tertiary age. Underlying these sediments are crystalline and metamorphic rocks of Precambrian and Early Paleozoic age.

Sediments of the Chesapeake Group of Pleistocene age underlie the ISFSI area to a depth of about 200'. The material in this group consists of essentially horizontally stratified sandy and clayey silt with occasional interbeds of sand and shells. It is relatively impervious and dense and provides adequate foundation support for the ISFSI. The Pleistocene sediments are underlain by dense, relatively pervious, glauconitic sand and silt of Eocene age.

No known or suspected faults are present in the sedimentary strata underlying the site. The closest known faults are located in the Piedmont Province in western Maryland, approximately 50 miles from the site.

The site is considered satisfactory, from a geologic standpoint, for construction and operation of the ISFSI.

2.6.1.1 Regional Geology

The site lies within the Coastal Plain Physiographic Province about 50 miles east of the Fall Zone. The Fall Zone separates the low-lying gently rolling terrain of the Coastal Plain from the higher relief of the Piedmont Physiographic Province. The provinces are shown on Figure 2.6-1.

The Coastal Plain in Maryland is a low plain rising from sea level to about Elevation +250' at the Fall Zone. Relief in the region ranges generally from about 20 to 100'. The regional slope of the Coastal Plain is to the east at approximately 1.5' per mile. The topography of the region is characterized by a series of broad, step-like terraces. The terraces are successively less dissected by stream erosion from west to east. The region is well drained by a large number of small streams.

The general geologic characteristics of the region are shown on Figure 2.6-2. The Piedmont Province consists of a complex of igneous and metamorphic rocks of Precambrian and Early Paleozoic age with areas of sedimentary and igneous rocks of Triassic age. Beneath the Coastal Plain Province these rocks are concealed by younger strata of Cretaceous and Tertiary age. The buried surface of the basement igneous and metamorphic rock slopes to the southeast at about 50' per mile. In the vicinity of the site, the surface of the basement complex is located approximately 2,500' below sea level. The Cretaceous and Tertiary strata consist of sedimentary deposits of silt, clay, sand, and gravel which exhibit considerable lateral and vertical variations in lithology and texture. The strata form a wedge shaped mass which thickens to the southeast and pinches out to the northwest toward the Fall Zone.

A generalized geologic cross-section of the Coastal Plain is presented on Figure 2.6-3. A detailed description of the Stratigraphy at the site is presented on Figure 2.6-4.

The thick sedimentary strata of the Coastal Plain in the vicinity of the site have remained essentially undeformed since they were deposited up to 135 million years ago. They are believed to have been affected only by slow regional crustal downwarping during their deposition. No known faults have been identified within the Cretaceous and Tertiary sedimentary deposits in the site area. Some local, very shallow folds have been recognized in the Coastal Plain sediments about 40 miles south of the site. These structures are possibly related to depositional conditions rather than to post-depositional tectonic activity. The strata exposed for many miles along the Chesapeake Bay shoreline show no visible signs of faulting or deformation.

There is no known fault or geologic evidence of faulting in the deep crystalline rocks in the area. The absence of deformation in the overlying sediments indicates that no major faults are present in the area. Significant tectonic features of the region are shown on Figure 2.6-5.

The closest known faults to the site are more than 50 miles to the west in the Precambrian and Early Paleozoic rocks of the Piedmont Physiographic Province. The rocks in the Piedmont are highly folded, and many zones of major faulting have been identified. Most earthquake activity in the region can be related to them. Some of these faults, the closest of which are located about 60 miles southwest of the site, theoretically could be projected beneath the Coastal Plain strata toward the general location of the site. However, such faults are local rather than regionally continuous and appear to be associated with individual fault troughs containing Triassic sediments.

The recognizable geologic history of the region begins with the deposition of Paleozoic sediments on a Precambrian granitic and metamorphic basement complex. Thick sequences of sedimentary rocks, which accumulated during the Cambrian and Ordovician Periods of geosynclinal deposition were subsequently uplifted, folded, faulted, and metamorphosed during the late Paleozoic Period of mountain building. This activity was followed by another period of uplift along the axis of the Appalachian Mountain chain at the end of the Triassic Period.

Slow regional downwarping of the Coastal Plain started during Early Cretaceous time and continued intermittently through Tertiary time. South and east of the Fall Zone the Piedmont was depressed below sea level providing a base on which the sediments were deposited. Several periods of submergence and emergence resulted in alternate deposition and erosion of continental and marine deposits throughout Cretaceous and Tertiary times.

Near the end of the Tertiary Period (Pliocene time) the area is believed to have been above sea level. This resulted in erosion of the sediments deposited previously during Early Pliocene and Late Miocene time, so that Miocene sediments are exposed in the area.

During Early Pleistocene time, the ocean advanced westward to the Fall Zone, completely covering the Coastal Plain. Fluctuating sea levels, occurring during Pleistocene time, resulted in alternating periods of erosion and deposition along what are now the major terraces and scarps of the region. A veneer of Pleistocene soils covers most of the Coastal Plain. At present, the land is again being submerged by a very slow rise of the sea level.

2.6.1.2 Site Geology

The site is located on the west shore of Chesapeake Bay in an area characterized by densely wooded, low, flat to gently rolling terrain of low to moderate relief. Ground surface elevations at the site range from sea level to about +130', with an average elevation of approximately +100'. Nearly vertical cliffs, over 100' high in places, are located along the shore of the Chesapeake Bay. The ISFSI is located in an area approximately 2800' from the Chesapeake Bay where the preexisting ground elevation is about 100-125'. The final yard grade elevation is about 114.0'.

Areas in the vicinity of the site above about Elevation +70' are underlain by sediments of Pleistocene age. These sediments consist primarily of silt and sand, and as encountered at the boring locations, range up to about 50' in thickness. The portions of the site below about Elevation +70', which includes the Calvert Cliffs plant area, are underlain by relatively impervious sediments of the Chesapeake Group of Miocene age. The contact between the Pleistocene and Miocene sediments is relatively even and slopes very gently toward the southeast. The surficial geology of the site is shown on Figure 2.6-6.

The details of the subsurface geology were originally investigated primarily by means of twelve exploratory borings (Reference 2.19) at the locations shown on Figure 2.6-7.

The initial borings near the HSMs ranged in depth from about 50' to 100' and were drilled with truck-mounted rotary drilling equipment. Data were obtained from the initial borings through continuous observation of drill cuttings and examination of undisturbed samples and bag samples collected by Law Engineering Company engineers.

Soil samples were obtained at intervals in each boring ranging between 2.5 and 5', utilizing a standard split-spoon sampler. The number of hammer blows required to drive the sampler a distance of 1' into undisturbed material is recorded in the column entitled "N" on each boring log.

All initial samples were examined and logged in the field and then shipped to Law Engineering's Baltimore office for further examination and appropriate laboratory testing. Detailed descriptions of the materials encountered in the borings are shown on Figures 2.6-7B through 2.6-7M. The depth of ground water after completion of drilling operations and the date on which the borings were completed are also presented on the logs.

The subsurface soils may be separated into four basic strata, as described in subsequent paragraphs. An estimated subsurface profile along the north-south axis of the site is shown on Figure 2.6-7A. Lines designating the interfaces between strata should be considered approximate and the actual transition may be gradual. Beneath a thin veneer of topsoil the borings encountered:

Stratum I — consists of very loose or soft to very stiff brown clayey sands, silty sands, sandy clays, and sandy silts of the Pleistocene formation. These soils were encountered at each of the ten boring locations as the uppermost stratum. This stratum extended to depths of 12' and had an average thickness of about 8'. Standard penetration resistance values averaged about 10 bpf.

Stratum II — comprised of Pleistocene deposits of firm to dense brown and tan silty fine to medium sand and fine to medium sand. Stratum II was encountered at each boring location beneath the Stratum I soils and appeared to have a generally uniform thickness of about 25'. The lower portion of this stratum often contained coarse sands. Standard penetration test resistances averaged about 23 bpf.

Stratum III — consists of interbedded light gray to tan, brown, and dark gray sandy and silty clays, and clayey and silty sands of the Pleistocene formation. This stratum was encountered beneath the soils of Stratum II at each test location. Where penetrated this stratum had a thickness of about 20'. Standard penetration resistances varied widely in this stratum with values averaging about 7 bpf.

Stratum IV — consists primarily of loose to very dense dark gray and green clayey and silty fine sands of the Miocene formation. These soils were encountered below the Stratum III soils in the deeper borings. Standard penetration test resistances for this stratum averaged about 13 bpf above a depth of 90' (Elevation +25' MSL) and increased to an average of 50 bpf below 90'. The substantial increase in blow count values generally coincided with an increase in shell fragments encountered below a depth of about 90'.

A laboratory testing program was initiated upon completion of the field testing. All testing was conducted in accordance with American Society for Testing and Materials recognized standards and currently accepted procedures.

Laboratory testing of representative soil samples was conducted to determine the soils physical characteristics and engineering properties for use in foundation design. Testing was conducted under static, dynamic, and remolded (fill) conditions in an attempt to simulate or model field conditions during the construction process and design life of the structures.

The testing program included: moisture contents, grain-size, Atterberg limits, and specific gravity tests to determine the soils gradation and plasticity characteristics; consolidated drained triaxial tests to determine the shear strength parameters of undisturbed near surface soils for bearing capacity analyses and slope stability evaluations; direct shear tests on remolded samples of proposed fill soils also for bearing capacity and slope stability evaluation; one-dimensional consolidation testing on undisturbed and remolded soils samples to determine the settlement characteristics of virgin fine-grained soils and proposed compacted fill, respectively; and dynamic triaxial shear tests to determine the dynamic soil properties used in the evaluation of liquefaction potential of virgin foundation soils. In addition, void ratio, natural density, and modified Proctor density tests were also evaluated.

Stratum I — Index properties testing of the upper near surface soils and proposed fill revealed natural moisture content values between 12 to 16%, percent fines varying from 13 to 57% with an average value of about 30%, and plasticity indices ranging from non-plastic to 15. Direct shear tests were conducted on remolded samples of proposed fill soils compacted to 95% of the modified Proctor maximum dry density.

Stratum II — Testing of the soils of this stratum revealed generally non-plastic sands with less than 14% fines. Consolidated drained triaxial tests on undisturbed samples were obtained at depths of 11 and 15' below the surface.

Stratum III — Laboratory testing of **stratum three** was conducted on both fine grained clay soils and silty and clayey sands. Classification tests conducted on the clay soils revealed generally uniform natural moisture contents between 31 and 33%, plasticity testing disclosed liquid limits ranging from 34 to 48 and corresponding plasticity indices from 18 to 30. Consolidation testing was conducted on two undisturbed clay samples obtained from Boring DE-3 at depths of 46 and 50'. The test results indicate soil compression indices (C_c) of 0.30 and 0.34 and associated initial void ratios (e_o) of 0.94 and 0.84, respectively. Maximum preconsolidation pressures of 6.5 and 8.0 were also recorded, resulting in estimated overconsolidation ratios of 1.3 and 1.9, respectively. Classification testing conducted on the granular soils of Stratum III disclosed non-plastic to slightly plastic soils with natural moisture contents between 14 and 30%. The samples contained between 16 and 49% fines (silt and clay fractions).

A subsurface investigation was performed by MACTEC (Reference 2.18) in 2007 to provide additional subsurface information for the expansion of the ISFSI facility. This included drilling four borings to a depth of 100 feet each along the west side and outside of the perimeter fence of the ISFSI facility. A seismic crosshole survey to obtain shear wave velocities for the materials beneath the site was also performed in one of the borings.

The generalized subsurface profile, as depicted by the four borings drilled by MACTEC, can be summarized as the upper 30 feet (layer one) consisting of silty sand and clayey sand with silt or clay having Standard Penetration Test (SPT) N-values between 6 and 20. Layer two is approximately 12 feet in thickness and consists primarily of a mixture of clay, silt, sandy silt, clayey sand, and silty sand with SPT N-values ranging from 2 to 8. Layer 3 is approximately 48 feet in thickness and consists of low plasticity clay, high plasticity clay and silt with sand seams having SPT N-values between 3 and 15. The lowest layer was encountered at a depth of 90 feet and consists of medium dense to very dense silty sand with shell fragments. All of the borings were terminated at a depth of 100 feet and no rock was encountered in any of the borings.

Groundwater was encountered at depths ranging from 12.5 feet to 50 feet during the drilling operations. The higher groundwater levels were most likely attributed to the introduction of water during the mud rotary drilling and possible cave-ins of the boreholes. For design, a groundwater level at a depth of 22.5 feet (Elevation 90 feet) is considered.

This subsurface soil profile is consistent with the soil profile encountered during the original subsurface investigation (Law report, Reference 2.19) performed for the initial ISFSI facility.

2.6.2 VIBRATORY GROUND MOTION

A seismological study for the Calvert Cliffs ISFSI has been performed to determine the Operating Basis and the Design Basis earthquakes for the site and the ground motion associated with them. This section summarizes the study that is detailed in Reference 2.1.

The site is located in a region which has experienced infrequent and minor earthquake activity. Most of the reported earthquakes are related to known faulting more than 50 miles west of the site in the Piedmont Physiographic Province. No known faults occur in the vicinity of the site. The closest earthquake (Intensity VII) which caused any structural damage occurred about 80 miles southwest of the site. Several minor shocks (no greater than Intensity V) have been reported within 50 miles of the site. Because of very limited data, it is not possible to determine whether or not these were of tectonic origin.

The foundations of the ISFSI are established in soil which will not undergo reduction in strength or increased settlement under design basis earthquake conditions.

Significant earthquake ground motion is not expected at the site during the life of the facility. On a conservative basis, the ISFSI is designed to respond elastically to horizontal ground accelerations as high as 15% of gravity and a simultaneous maximum vertical ground acceleration of 10% of gravity.

2.6.2.1 Tectonics

The site is located in the Coastal Plain Physiographic Province. This province is bounded on the east by the Atlantic Ocean, and on the west by the Fall Zone and the Piedmont Physiographic Province. The Coastal Plain consists of easterly dipping Cretaceous and Tertiary sediments which are about 2,500' thick at the site. Crystalline basement rock outcrops near the Fall Zone about 50 miles west of the site.

On the basis of regional data, the Cretaceous and Tertiary sediments are undeformed. The absence of folding and faulting in the sedimentary strata indicates that displacements along unknown faults which may be present in the basement have been negligible.

No known faults occur within the basement rock or sedimentary deposits in the vicinity of the site. The closest known fault systems are found in the rocks of the Piedmont, more than 50 miles west and northwest of the site. The Piedmont Province consists of igneous and metamorphic rocks of Precambrian and early Paleozoic Age, with areas of sedimentary and igneous rocks of Triassic Age. Major tectonic activity that has occurred in the Mid-Atlantic Region can be related to known faults in the Piedmont Province.

2.6.2.2 Seismicity

The site is situated in a region which has experienced only infrequent minor earthquake activity. No shock within 50 miles of the site has been large enough to cause significant structural damage. Since the region has been populated for over 300 years, it is probable that all earthquakes of moderate intensity, approximately VI[1] or greater, would have been reported during this period.

The first report of earthquake occurrence in the general area of the site dates back to the late 18th Century. Through 1989, 18 earthquakes with epicentral intensities of V or greater on the Modified Mercalli[1] Scale were reported within about 100 miles of the site. None of these shocks was greater than Intensity VII. Few were of high enough intensity to cause structural damage and only one of these shocks can be considered more than a minor disturbance. This was an Intensity VII shock near Wilmington, DE in 1871 about 100 miles from the site. A list of earthquakes of Intensity V or greater with epicenters located within a distance of about 100 miles of the site is presented in Table 2.6-1, Significant Earthquakes

[1] All intensity values in this report refer to the Modified Mercalli Scale as abridged in 1956 by Richter. The intensity scale is a means of indicating the relative size of an earthquake in terms of its perceptible effect.

within 100 miles of the site. Several smaller earthquakes, which are significant because of their proximity to the site, are also included in Table 2.6-1. The locations of these and other earthquakes in the region surrounding the site are shown on Figure 2.6-8, Epicentral Location Map. Several small shocks are shown on the Epicentral Location Map but not indicated in Table 2.6-1. Little information is available regarding these shocks.

Most of the reported earthquakes in the region have occurred in the Piedmont Physiographic Province west of the Fall Zone. The closest approach of the Fall Zone to the site is about 50 miles. These shocks were generally related to known faults in the Piedmont rocks.

There have been several large shocks with epicenters in the Coastal Plain, some of which were damaging. The largest of these is the Charleston, SC, earthquake of 1886, which had an epicentral intensity of about IX. This earthquake is probably related to faulting in the basement rock near Charleston.

Among the largest earthquakes in the Coastal Plain close enough to the site to be of significance was the 1927 earthquake near the northern New Jersey coast, about 180 miles northeast of the Calvert Cliffs site. The epicentral intensity of this earthquake was VII. Three shocks were felt over an area of about 3,000 square miles from Sandy Hook to Tom's River. Highest intensities were felt from Asbury Park to Long Branch where several chimneys fell, plaster cracked, and articles were thrown from shelves. This shock has not been related to any known geologic feature.

An earthquake which occurred near Wilmington, DE, in 1871 is the largest reported earthquake within 100 miles of the proposed ISFSI. It is not possible to accurately locate the epicenter of this shock with the limited data available, but it is probable that the shock occurred along the Fall Zone about 100 miles northeast of the site. The epicentral intensity of this shock is rated at VII. At Wilmington, chimneys toppled and windows broke. Damage was also reported at Newport, New Castle, and Oxford, DE. The earthquake was felt over a relatively small area of northern Delaware, southeastern Pennsylvania, and southwestern New Jersey.

Only one earthquake of Intensity V or greater has been reported within 50 miles of the ISFSI. This shock, which had a rated epicentral intensity of V, caused no structural damage. Its epicenter was located near Seaford, DE, about 45 miles northeast of the site.

2.6.2.3 Seismic Design

On the basis of the seismic history of the area, it does not appear likely that the ISFSI site will experience significant earthquake ground motion during the life of the installation. The ISFSI was conservatively designed to respond, with no loss of function, to horizontal earthquake ground accelerations of 15% of gravity, and vertical earthquake ground accelerations of 10% of gravity. It is not believed that this level of ground motion will be exceeded at the site during an earthquake similar to any historical event.

Ground motion response spectra for the Calvert Cliffs ISFSI are presented on Figures 2.6-9 and 2.6-10. The spectra have been normalized to a horizontal ground acceleration of 8% of gravity for the operating basis earthquake and 15% of gravity for the design basis earthquake.

A Soil-Structure Interaction (SSI) analysis specific to the CCNPP ISFSI HSM-HB pads was performed (Reference 2.22). Based on the results of the SSI analyses, the following is concluded:

- The maximum seismic acceleration at top of the HSM-HB concrete pad is 0.21g in the horizontal directions (in NS and EW directions) and 0.13g in the vertical direction,
- The maximum seismic acceleration at center of gravity of the HSM-HB is 0.23g in the horizontal directions (in NS and EW directions) and 0.13g in the vertical direction,
- The maximum seismic acceleration at the center of gravity of the DSC in the HSM-HB is 0.28g in the horizontal directions (in NS and EW directions) and 0.13g in the vertical direction, and
- The existing pads with fuel-loaded HSMs do not have an impact on the SSI results of the HSM-HB pads.

These values are enveloped by the 0.3g horizontal and 0.2g vertical design basis accelerations used for the HSM-HB.

2.6.3 SURFACE FAULTING

See Section 2.6.2.

2.6.4 STABILITY OF SUBSURFACE MATERIALS

Before the initial HSMs were constructed, twelve borings were drilled in the immediate vicinity of the ISFSI to evaluate the static and dynamic properties of materials underlying the site. The general site area is shown on Figure 2.4-1 and the location of all the initial borings is shown on Figure 2.6-7. The drilling, sampling, and testing were performed in accordance with methods specified by the American Society for Testing and Materials. Boring logs are shown on Figures 2.6-7B through 2.6-7M. A subsurface profile along the north-south axis of the site is shown on Figure 2.6-7A.

A discussion of subsurface conditions as determined for field and lab testing is presented in Section 2.6.1.2. Structural mat foundations bear on in-situ soils or structural fill compacted to 95% of modified proctor maximum dry density. The maximum allowable static bearing pressure used in analysis of the ISFSI structures is 3.0 kips/ft^2 which provides a safety factor of 4.0 for the ultimate bearing capacity of site soils. Calculated total settlements are estimated to be about 1.5". Consolidation characteristics of the site soils indicate that about 1" of the total settlement will occur during construction of the ISFSI structures. The remaining 1/2" of settlement will occur over the life of the structure.

The liquefaction potential of the sands and silty sands encountered in the borings were analyzed using both correlations of field and laboratory test data. A simplified procedure was used to compare standard penetration values (N) obtained from known liquefiable soils at various sites around the world with N values recorded for the ISFSI area soils.

The majority of the recorded N values fall within the zone considered to be unlikely to experience liquefaction. Eight of the 46 N values fall within the zone where prediction of liquefaction potential is difficult without some type of laboratory testing. Only two N values fall within the zone of high liquefaction potential.

Laboratory cyclic triaxial tests were performed on two undisturbed sand samples obtained from areas thought to be representative of the most potentially liquefiable soils encountered on site. The samples were obtained using a standard 3" diameter shelby tube sampler. The samples were tested at the geotechnical testing laboratories of Virginia Polytechnic Institute and State University in Blacksburg, VA.

Comparison of the cyclic stress ratio anticipated for this site under design conditions and that available based on the laboratory tests performed indicate liquifaction would not occur.

Another analysis of the liquefaction potential was performed using the cyclic strain method. This method incorporates the stiffness of the soil in terms of shear modulus value and the reduction of that value during the earthquake.

Within the soil profile encountered at the site, only the soils at or around a depth of 30' show a slight potential for a rise in pore pressure. However, the cyclic strain level is only slightly above the threshold value and given the low number of equivalent cycles for the design earthquake no significant potential for liquefaction is anticipated.

Liquefaction of site soils is not anticipated based on established water table depths, standard penetration testing and cyclic triaxial shear testing.

A calculation (Reference 2.20) was generated to determine the allowable bearing capacity and associated settlement for the layout of the HSM-HBs. Based on the properties of the soil materials encountered in the 2007 boring program, the allowable bearing capacity was determined to be 4000 psf considering a factor of safety of 3. For a design load of 2450 psf, the anticipated total settlement is 1.8 inches, comprised of approximately 1.1 inch of immediate settlement and 0.7 inches of long-term settlement. The anticipated differential settlement between the center of the modules and the corner is approximately 0.9 inches. Based on this analysis, approximately 60% of this settlement would occur immediately after application of the load. This settlement is generally within acceptable limits for the storage modules planned for this facility since tipover of the modules is not a concern (Reference 2.25).

The bearing capacity and settlement values determined from the new boring program are also in close agreement with the calculated settlements determined for the initial design of the facility.

Based on the soil data provided in the Geotechnical Exploration report (Reference 2.18), an evaluation of liquefaction potential of the soil profile at the ISFSI site has been performed. The soil profile at the site generally consists of silty sand and clayey sand with silt and clay. Screening method in combination with the empirical method, as recommended in Regulatory Guide 1.198 (Reference 2.23) has been used for the evaluation. Acceptance criteria are based on a factor of safety of 1.4 against liquefaction, as recommended in Regulatory Guide 1.198 for the method of evaluation. Based on the evaluation results, it is concluded that the factor of safety against liquefaction during a seismic event is 1.4 or greater. Hence, the site does not pose any soil liquefaction risk to the ISFSI pads during a seismic event.

Based on the results of the new (2007) subsurface exploration and comparison to the original design for the ISFSI, the following conclusions are made:

1. The 2007 subsurface exploration program confirmed that the soil conditions encountered are similar to the soil conditions encountered during the original subsurface exploration.
2. The factor of safety against liquefaction during a seismic event is 1.4 or greater. Hence, the site does not pose any soil liquefaction risk to the ISFSI pads during the seismic event (Reference 2.21)
3. The in-situ soils are capable of supporting a design load of 2450 psf from the HSM-HBs on shallow mat foundations.
4. The calculated bearing capacity of the soil and anticipated settlement for the HSM-HBs is very similar to that calculated for the original ISFSI foundations. This indicates close agreement between the soil conditions, as was expected.
5. Considering that the estimated total settlement of 1.8 inches and differential settlement of 0.9 inches are within acceptable ranges, no soil remediation is required.
6. Considering a frost depth of 24 inches and a mat thickness of 36 inches, no special subgrade treatment, i.e., the placement of additional frost free material, is required.
7. Since the HSM-HB are a horizontal storage system, tipover of the system is not a concern.

2.6.5 SLOPE STABILITY

As shown on Figure 2.4-1 the original ISFSI was created by a combination of cut and fill to minimize earthwork volumes. The resulting cuts, primarily on the north end of the site, are a maximum of about 16' high and the resulting fills on the south end of the yard are a maximum of 12' high. Since the original poured in place HSMs are located a minimum of 60' from any cut or fill slope and approximately 115' from the maximum cut slope and 95' from the maximum fill slope, there is no potential impact to the safe operation of the ISFSI by postulated site slope failures for the original poured in place HSMs.

Stability analyses were performed for the south slope of the southernmost ISFSI HSM-HB foundation pad to determine the factor of safety of the embankment fill against a mass instability. The soil profile analyzed included the fill placed for the ISFSI embankment, the in-situ soils, as well as the weight of the ISFSI pad and HSM-HBs placed on the ISFSI pad. The slope stability analyses were performed in two dimensions for both static and seismic conditions. The pseudo-static method was used for the seismic analyses. The analyses concluded that the ISFSI pad analyzed is stable under the static and seismic conditions (Reference 2.24).

TABLE 2.6-1
SIGNIFICANT EARTHQUAKES WITHIN 100 MILES OF THE SITE

YEAR	DATE	TIME	INTENSITY[b]	LOCATION	N. LAT.	W. LONG.	AREA FELT (sq. mi.)	DISTANCE FROM SITE (miles)
1733	Jun 14	--	[a]	Vicinity of Annapolis, MD	--	--	--	--
1758	Apr 24	--	[a]	Vicinity of Annapolis, MD	--	--	--	--
1774	Feb 21	14:00	VI	Richmond, VA	37.5	77.5	--	80
1833	Aug 27	06:00	VI	Central Virginia	37.75	78	52,000	90
1871	Oct 9	09:40	VII	Wilmington, DE	39.75	75.5	--	100
1875	Dec 22	23:45	VI	Near Richmond, VA	37	77.5	50,000	80
1876	Jun 19	--	[a]	Vicinity of Annapolis, MD	--	--	--	--
1879	Mar 25	19:30	IV-V	Northern Delaware	39.75	75.5	600	100
1883	Mar 11	18:57	IV-V	Harford County, MD	39.5	76.5	Local	80
	Mar 12	00:00	IV-V	Harford County, MD	39.5	76.5	Local	80
1885	Jan 2	21:16	V	Frederick County	39.5	77.5	3,500	80
1897	Dec 18	18:45	V	Ashland, VA	37.75	77.5	7,500	75
1906	May 8	12:41	V	Seaford, DE	38.75	75.75	400	45
1908	Aug 23	04:30	V	Powhatan, VA	37.5	78	450	95
1919	Sep 5	21:46	VI	Front Royal, VA	38.75	78.25	--	95
1930	Jan 18	--	IV[a]	Pines of the Severn, MD	--	--	--	--
1930	Nov 1	01:34	I-III[a]	Anne Arundel County, MD	39.0	76.5	Local	--
1949	May 8	06:01	IV-V	Richmond, VA	37.5	77.5	1,800	80
1966	May 31	06:19	IV-V	Central Virginia	37.5	78.0	--	100
1969	Dec 11	18:45	V	Richmond, VA	37.8	77.4	6,500	70
1971	Sep 12	00:06	V	Virginia	38.1	77.4	1,900	55
1972	Sep 5	16:00	V	Richmond, VA	37.6	77.7	2,300	85
1977	Feb 10	19:14	VI	Northern Delaware	39.5	75.3	Local	100

[a] Several small shocks in Maryland are included in this table. Little information is available regarding these reports, and the indicated epicenters are uncertain.

[b] II intensity values refer to the Modified Mercalli Scale as abridged in 1956 by Richter. The intensity scale is a means of indicating the relative size of an earthquake in terms of its perceptible effect.

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. Table 2.7-1 is a summary of site-specific information either newly established for the ISFSI or previously established for CCNPP.

TABLE 2.7-1
SITE CHARACTERISTICS SUMMARY

FACTOR	**VALUE OR RANGE**
Ambient temperature	-3°F to 103°F
Direct exposure to sunlight	82 $Btu/hr/ft^2$
Ambient humidity	0 to 100%
Tornado pressure drop	3 psi in 1.5 sec
Tornado winds:	
translational velocity	70 mph
rotational velocity	290 mph
Maximum flood level	Flood Free Zone
Snow and ice loadings	30 lbs/ft^2
Atmospheric dilution value (χ/Q)	3.0×10^{-4} sec/m^3
Design basis earthquake:	
max horizontal acceleration	0.15 g
max vertical acceleration	0.10 g
Operating basis earthquake:	
max horizontal acceleration	0.08 g
max vertical acceleration	0.053 g

2.8 REFERENCES

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2.3 Baltimore-Washington International Airport, 1987, Local Climatological Data, Annual Summary with Comparative Data, National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, NC

2.4 Washington, DC National Airport, 1984, Local Climatological Data, Annual Summary with Comparative Data, National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, NC

2.5 Patuxent River Naval Air Station, Revised Uniform Summary of Surface Weather Observations, U.S. Air Force Environmental Technical Applications Center Air Weather Service

2.6 Calvert Cliffs Independent Spent Fuel Storage Installation Updated Environmental Report, Baltimore Gas and Electric Company

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2.17 Final Environmental Impact Statement, Increased Flight and Related Operations in the Patuxent River Complex, Patuxent River, Maryland: Department of the Navy, Naval Air Warfare Center, Aircraft Division, December 1998

2.18 Report of Geotechnical Exploration, Independent Spent Fuel Storage Installation (ISFSI) Facility, Calvert Cliffs Nuclear Power Plant, MACTEC Engineering and Consulting (MACTEC), October 15, 2007, Project 3551-07-1070

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2.20 CCNPP Calculation CA07261, Soil Design Parameters for ISFSI Mat Foundation, Sargent & Lundy Calculation 11562-019-CALGEO-1, Revision 1, September 17, 2009

2.21 CCNPP Calculation, CA07266, Soil Liquefaction Evaluation, Sargent & Lundy Calculation 11562-019-ST-1, Revision 0, June 21, 2009

2.22 CCNPP Calculation CA07141, Seismic Soil-Structure Interaction Analysis of ISFSI Pad, Sargent & Lundy Calculation 11562-012-ST2, Revision 1, August 22, 2009

2.23 Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plants Sites, Regulatory Guide 1.198, U.S. Nuclear Regulatory Commission, November 2003

2.24 CCNPP Calculation CA07264, ISFSI Pad Embankment Slope Stability, Sargent & Lundy Calculation 11562-19-CALGEO-04, Revision 0, August 19, 2009

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