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UniStar
NUCLEAR ENERGY

10 CFR 50.4
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June 30, 2010

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ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: UniStar Nuclear Energy, NRC Docket No. 52-016
Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3,
RAI 103, Probable Maximum Surge and Seiche Flooding
Questions 02.04.05-2 and 02.04.05-4

Reference:
1) John Rycyna (NRC) to Robert Poche (UniStar Nuclear Energy), RAI No 103 RHEB 2089.doc (PUBLIC), dated April 20, 2009

2) UniStar Nuclear Energy Letter UN#10-148, from Greg Gibson to Document Control Desk, U.S. NRC, Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI No. 103, Probable Maximum Surge and Seiche Flooding, dated May 27, 2010

The purpose of this letter is to respond to the request for additional information (RAI) identified in the NRC e-mail correspondence to UniStar Nuclear Energy, dated April 20, 2009 (Reference 1). This RAI contains five questions regarding Probable Maximum Surge and Seiche as discussed in Section 2.4.5 of the Final Safety Analysis Report, as submitted in Part 2 of the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 Combined License Application (COLA), Revision 6.

The May 27, 2010 letter (Reference 2) anticipated that the responses to Questions 02.04.05-2 and 02.04.05-4 would be provided by June 30, 2010.

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NRO

The enclosure to this letter provides the response to RAI 103, Questions 02.04.05-2 and 02.04.05-4 and includes revised COLA content. A Licensing Basis Document Change Request has been initiated to incorporate these changes into a future revision of the COLA.

The enclosed responses do not include any new regulatory commitments. This letter does not contain any sensitive or proprietary information.

If there are any questions regarding this transmittal, please contact me at (410) 470-4205, or Mr. Wayne A. Massie at (410) 470-5503.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on June 30, 2010

Christian Clement for

Greg Gibson

Enclosure: Response to NRC Request for Additional Information, RAI No. 103; Probable Maximum Surge and Seiche Flooding, Questions 02.04.05-2 and 02.04.05-4, Calvert Cliffs Nuclear Power Plant, Unit 3

cc: Surinder Arora, NRC Project Manager, U.S. EPR Projects Branch
Laura Quinn, NRC Environmental Project Manager, U.S. EPR COL Application
Getachew Tesfaye, NRC Project Manager, U.S. EPR DC Application (w/o enclosure)
Loren Plisco, Deputy Regional Administrator, NRC Region II (w/o enclosure)
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GTG/SJS/mdf

Enclosure

Response to NRC Request for Additional Information

RAI No. 103; Probable Maximum Surge and Seiche Flooding, Questions 02.04.05-2 and 02.04.05-4,

Calvert Cliffs Nuclear Power Plant Unit 3

RAI 103

Question 02.04.05-2

The NRC Staff's guidance states that recommendations of Regulatory Guide 1.59 should be supplemented by standard engineering practice currently in use. Please explain how the storm surge water surface elevations obtained from Regulatory Guide 1.59 and adjusted for CCNPP site location using the model developed for the Chesapeake Bay (USACE, 1959) are conservative with respect to current engineering practice described in USACE Engineering Manual 1110-2-1100 (USACE, 2006) and those of the NOAA National Weather Service with regard to the SLOSH model (NOAA, 1992), or justify an alternative approach.

Response

The storm surge elevation reported for Ocean City, MD in Regulatory Guide 1.59 is 17.30 ft (5.3 m) (including wind and pressure setup). The storm surge elevation computed utilizing the National Oceanic and Atmospheric Administration operational storm surge model SLOSH (*Sea, Lake, and Overland Surges from Hurricanes*) (at the upper range of error) is 23.9 ft (7.3 m).

Comparative and confirmatory hurricane wind speeds were computed based on historical wind data, statistical methods, and storm decay scenarios. These wind speeds were then used to recalculate significant wave height and wave runup using empirical methods established by the United States Army Corps of Engineers (USACE) Engineering Manual 1110-2-1100. Based on the results of the wind speed analysis, the probable maximum storm surge (PMSS) at the CCNPP Unit 3 site was calculated to be 17.4 ft (5.29 m).

In addition, SLOSH was used to predict the PMSS at the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 site. To determine the PMSS elevation, SLOSH model runs were performed to investigate the effects of the probable maximum hurricane (PMH) forward speed, size, direction, and track distances from the site and Chesapeake Bay entrance on the storm surge elevation. The ranges of the parameters used in the simulations include steady state PMH forward speeds (the lower and upper bounds), PMH radii of maximum wind (the mean, the lower bound and upper bound), and several PMH directions and track distances. The selected hurricane directions include unidirectional and composite directional tracks.

The antecedent water level, including 10% exceedance high spring tide, sea level anomaly and long-term sea level rise was added to the water level predicted in the SLOSH model simulation. The predicted PMSS elevation result of 17.6 ft (5.35 m) also takes into account the upper bound of the 20% margin associated with SLOSH model uncertainties as suggested in Technical Report NWS 48. Consequently, it is concluded that the PMSS elevation obtained from the SLOSH model is conservative with respect to methods presented in Regulatory Guide 1.59 and other current engineering practice.

COLA Impact

Changes to FSAR Sections 2.4, 2.5, 3.4 and 19.1 associated with this response are shown below. Changes associated with FSAR Section 3.8 are not included at this time. FSAR Section 3.8 is being re-written based upon RAI questions 144 and 145 and will be submitted in accordance with the schedule for those RAIs.

FSAR Section 2.4.2.2 is updated as shown below:

2.4.2.2 Flood Design Considerations

The design basis flood elevation for the CCNPP site is determined by considering a number of different flooding possibilities. The possibilities applicable and investigated for the site include the probable maximum flood (PMF) on streams and rivers, potential dam failures, probable maximum surge and seiche flooding, probable maximum tsunami, and ice effect flooding. Each of these flooding scenarios was investigated in conjunction with other flooding and meteorological events, such as wind generated waves, as required in accordance with guidelines presented in ANSI/ANS 2.8-1992 (ANS, 1992). Detailed discussions on each of these flooding events and how they were estimated are found in Section 2.4.3 through Section 2.4.7.

The estimation of the PMF water level on Johns Creek, located just west of the CCNPP Unit 3 substation/switchyard area is discussed in detail in Section 2.4.3. The maximum PMF water level for Johns Creek is Elevation 65.0 ft (19.8 m). All safety-related facilities for CCNPP Unit 3 are located in the Maryland Western Shore watershed. The low point of the drainage divide between the Maryland Western Shore watershed and the Johns Creek watershed is at Elevation 98.0 ft (29.9 m) and passes through the CCNPP Unit 3 switchyard as shown on Figure 2.4-7. Since the maximum PMF water level is 33 ft (10.1 m) below the drainage divide, the Johns Creek PMF does not pose a flooding risk to the CCNPP Unit 3 safety-related facilities.

Section 2.4.4 presents a detailed discussion on potential flood elevations on Johns Creek from dam failures on the Patuxent River. The resulting water level increase in the tidal portions of Johns Creek and St. Leonard Creek would be about 2.0 ft (0.6 m). This water level increase poses no risk to the CCNPP site.

Probable maximum surge and seiche flooding on the Chesapeake Bay as a result of the probable maximum hurricane (PMH) is discussed in Section 2.4.5. The ~~estimated~~ probable maximum storm surge (PMSS) water level is estimated to be at Elevation ~~19.1 ft (5.8 m)~~ 17.6 ft (5.35 m). Wave action from coincident winds associated with the storm surge produce a wave run-up height of ~~17.5 ft (5.3 m)~~ 16.3 ft (4.96 m) above the PMSS resulting in a maximum flood level of Elevation ~~36.6 ft (11.2 m)~~ 33.9 ft (10.31 m) ~~along the shore of~~ on the slope to the CCNPP Unit 3 power block ~~site~~. The grade elevation of the Ultimate Heat Sink (UHS) makeup intake structure area is at Elevation 10.0 ft (3.0 m) and the UHS makeup water intake building will be completely submerged as a result of the PMH as described in Section 2.4.5. The PMSS and coincident wave run-up water level at the CCNPP Unit 3 site produce the highest potential water levels on the Chesapeake Bay and become the design basis flood elevation for the CCNPP Unit 3 UHS makeup intake structure area. The UHS makeup intake structure will be provided with flood protection measures such as water tight doors, roof vents, and piping and conduit penetrations. Flood protection measures are discussed in Section 2.4.10. The CCNPP Unit 3 power block site grade is at nominal Elevation 85.0 ft (25.9 m) and all safety-related facilities other than the UHS makeup intake structure are located above the PMSS and wave run-up water level.

FSAR Section 2.4.2.3 is updated as shown below:

2.4.2.3 Effects of Local Intense Precipitation

. . . [Note: the change is in the second to last paragraph]

Flood protection measures are required for the CCNPP Unit 3 UHS makeup water intake structure and its associated electrical building. The grade level at the UHS makeup water intake structure location is at Elevation 10.0 ft (3.0 m). The maximum flood level at the intake location is Elevation ~~36.6 ft (11.2 m)~~ 33.2 ft (10.11 m) as a result of the surge, wave heights, and wave run-up associated with the probable maximum hurricane (PMH).as discussed in Section 2.4.5. Thus, the UHS makeup water intake structure and the electrical building associated with the UHS makeup pumps would experience flooding during a PMH and flood protection measures are required for these buildings.

The general arrangement of the UHS makeup water intake area is described in Section 9.2.5. Flood protection for the UHS makeup water intake structure and electrical building, as described in Section 2.4.10, will consist of structural measures to withstand the static and dynamic flooding forces as well as water proofing measures to prevent the flooding of the interior of the structures where pump motors and electrical or other equipment associated with the operation of the intake are located.

FSAR Sections 2.4.5.1 through 2.4.5.6 are replaced in their entirety by the re-write below. This update also replaces Table 2.4-23, Table 2.4-24, Figures 2.4-21 through Figure 2.4-24, and Figure 2.4-26.

2.4.5 PROBABLE MAXIMUM SURGE AND SEICHE FLOODING

The U.S. EPR FSAR includes the following COL Item for Section 2.4.5:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information on the probable maximum surge and seiche flooding and determine the extent to which safety-related plant systems require protection. The applicant will also verify that the site-parameter envelope is within the design maximum flood level, including consideration of wind effects.

This COL Item is addressed as follows:

~~{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.~~

Sections 2.4.5.1 through 2.4.5.6 are added as a supplement to the U.S. EPR FSAR.

2.4.5.1 Probable Maximum Winds and Associated Meteorological Parameters

The meteorological events that can cause severe coastal flooding at the CCNPP Unit 3 site fall into two categories: hurricanes and northeasters. Historical water level data from National Oceanic and Atmospheric Administration (NOAA) tide gauges at Baltimore MD, Annapolis MD, and Sewells Point VA, where water level records are available for at least 78 years, show that the top five maximum water levels at these locations occurred mostly during passage of hurricanes near the Chesapeake Bay area (NOAA, 2004). Although the third highest water level at Sewells Point VA occurred during a winter storm, the highest water level at this location was due to the passage of the August 1933 hurricane (NOAA, 2004).

Northeasters move along the Atlantic coast with winds blowing from the northeast, off the Atlantic Ocean, onto the shoreline, typically producing winds ranging from 30 to 40 mph (48 to 64 km/h) with gusts that can exceed 74 mph (119 km/h). Winds of northeasters are typically below hurricane force, in terms of sustained surface wind speed as used in the Saffir-Simpson Hurricane Scale, but can persist for several days to a week, generating large waves and enhanced storm surges. In comparison, hurricanes are more severe in terms of wind speed and storm surge elevations, and their shoreline effects tend to be more localized, generally confined to stretches of coastline of about 65 mi (105 km) or less. In addition to having lower wind intensities and forces than hurricanes, the general wind direction of the northeasters in the Chesapeake Bay region will produce a water level decrease (set-down) in the northern (or upper) part of the Chesapeake Bay where the CCNPP Unit 3 site is located. Thus, it is postulated that the highest water level at the CCNPP Unit 3 site will be controlled by hurricane-induced storm surges.

The NOAA National Weather Service (NWS) Technical Report NWS 23 defines the probable maximum hurricane (PMH) as a hypothetical steady-state hurricane with a combination of meteorological parameters that will give the highest sustained wind speed that can probably occur at a specified coastal location (NOAA, 1979). The meteorological parameters that define the PMH wind field include the hurricane peripheral pressure (p_n), central pressure (p_o), radius of maximum winds (*RMW*), forward speed (*T*), and track direction (θ).

The PMH parameters on the Atlantic coast near the Chesapeake Bay entrance are obtained from the Technical Report NWS 23 (NOAA, 1979). The PMH parameter values in NWS 23 were based on data from historical hurricanes from 1851 to 1977 and were presented for multiple locations along the Gulf of Mexico and Atlantic Ocean coastlines corresponding to their milepost distances from the U.S.-Mexico border. The entrance to Chesapeake Bay is located approximately at latitude 37° 00' North corresponding to a distance of approximately 2,300 nautical miles (4,260 km) from the U.S.-Mexico border. The characteristic parameters of the PMH at the entrance of the Chesapeake Bay, as obtained from the Technical Report NWS 23 (NOAA, 1979), are summarized below:

- Peripheral pressure is 30.12 in Hg (102 kPa)
- Central pressure is 26.49 in Hg (89.7 kPa)
- Radius of maximum wind is 10.0 to 26.0 nautical miles (18.5 to 48.2 km)
- Forward speed is 17.0 to 38.0 knots (31.5 to 70.4 km/h)

The pressure difference between the hurricane peripheral and central pressures, Δp, is identified as the most important meteorological parameter in defining the hurricane wind field (NOAA, 1979). The Technical Report NWS 23 provides single values of PMH peripheral and central pressures along the mileposts, thereby giving single values for Δp. However, a range of values (i.e., lower and upper bounds) is provided for other PMH parameters. As can be seen from the PMH parameters above, the Δp at this location is 3.63 inches of mercury or 12.3 kPa.

2.4.5.2 Surge and Seiche Water Levels

2.4.5.2.1 Historical Surges

Between 1851 and 2005, 281 hurricanes have been reported to hit the coast of the continental U.S. Only twelve hurricanes, with intensities equal to or stronger than Category I in the Saffir-Simpson Hurricane Scale, have passed through Maryland and Virginia, including the Chesapeake Bay Area (Blake, 2007).

The surge mechanism that significantly impacts the Chesapeake Bay is characterized by two hurricane paths. One of the storm paths is the southerly hurricane path that passes by the eastern side of the Chesapeake Bay in the open ocean. These hurricanes cause an interaction of the initial primary surge wave that propagates through the Chesapeake Bay entrance and the water level induced by the northerly wind of the hurricane. The resulting water levels show a water level increase (set-up) in the lower Chesapeake Bay and a set-down in the upper Chesapeake Bay areas.

The other storm path is the southeasterly hurricane path. When the storm path passes by the western side of the Chesapeake Bay on the land, the primary surge wave in the Chesapeake Bay interacts with the water level induced by the southerly wind. This results in a set-down in the lower Chesapeake Bay and a set-up in the upper Chesapeake Bay. The water surface set-up in the upper Chesapeake Bay, which also includes the CCNPP Unit 3 site, is attributed to the combination of the primary surge propagating northward and a wind setup due to cross wind of the hurricane. This storm path will produce a higher storm surge height at the CCNPP Unit 3 site than that produced by a southerly hurricane path that passes by the eastern side of the Chesapeake Bay.

The hurricanes that generated the five highest water levels at the Baltimore and Annapolis tidal stations are listed in Table 2.4-22 (NOAA, 2004). The observed water level records at these two major stations represent the storm surge patterns for the upper Chesapeake Bay where the CCNPP Unit 3 site is located. Data presented in Table 2.4-22 indicate that, with the exception of Hurricane Connie, the highest water levels at Baltimore and Annapolis were generated by hurricanes passing by the west side of the Chesapeake Bay. While the highest water level at Baltimore was due to the August 1933 hurricane, the highest water level at Annapolis was due to Hurricane Isabel of 2003. These two hurricanes also resulted in the highest recorded water levels at several other tidal gages in the Chesapeake Bay, and caused roughly equivalent storm surges in the upper Chesapeake Bay (Baltimore and Annapolis) (NOAA, 2004).

The maximum storm surge height recorded in history at Baltimore (after correction for sea level rise) was 7.4 ft (2.26 m) during the passage of the August 1933 hurricane. At Annapolis, the maximum storm surge height was 6.3 ft (1.93 m) recorded during Hurricane Isabel of 2003. The second highest storm surge height recorded in history at Baltimore was 7.3 ft (2.21 m) during Hurricane Isabel of 2003. At Annapolis, the second highest storm surge was 6 ft (1.82 m) during the August 1933 hurricane (NOAA, 2004). The storm surge heights at different locations in the Chesapeake Bay during Hurricane Isabel in 2003 are presented in Figure 2.4-27.

2.4.5.2.2 Estimation of Probable Maximum Storm Surge

2.4.5.2.2.1 Antecedent Water Level

According to RG 1.59 (NRC, 1977), the 10% exceedance high spring tide including initial rise should be used to represent the PMSS antecedent water level. RG 1.59 defines the 10% exceedance high spring tide as the high tide that is equaled to or exceeded by 10% of the maximum monthly tides over a continuous 21-year period. For locations where the 10% exceedance high spring tide is estimated from observed tide data, RG 1.59 indicates that a separate estimate of initial rise (or sea level anomaly) is not necessary.

The 10% exceedance high spring tide at the site is estimated to be 2.05 ft (0.62 m) mean low water (MLW) or 1.53 ft (0.47 m) mean sea level (MSL), following the procedures described in ANSI/ANS 2.8-1992 (ANS, 1992). It is the average of the 10% exceedance high spring tides at the Long Beach and Cove Point tide stations. The two stations are second order tide stations of Baltimore and are located on either side (upcoast and downcoast) of the CCNPP Unit 3 site. The MLW and MSL tidal datum are based on the 1983 to 2001 National Tidal Datum Epoch (NOAA, 2006a). The initial rise or sea level anomaly of 1.1 ft (0.34 m) at Sewells Point (ANS, 1992) is adopted for the CCNPP Unit 3 site.

In addition to the 10% exceedance high spring tide and initial rise, the long-term trend observed in tide gage measurements is also considered to account for the expected sea level rises over the design life of the plant. Based on measured tide levels from 1902 to 1999 at Baltimore MD, NOAA reported a long-term sea level rise trend of 1.02 ft/century or 3.12 mm/year. At Solomons Island MD the rate of rise in the mean sea level between 1937 and 2006 is 1.12 ft/century or 3.41 mm/year. Assuming that the sea level at the site would continue to rise at the average rate of the two stations, a nominal long-term sea level rise of 1.07 ft/century (3.26 mm/yr) is estimated for the site. To account for potential global warming effects, the entire 1.07 ft (0.33 m) is assumed even though the end of the plant license is expected to be reached in about 50 years.

At the NOAA gage station located about 3 mi (4.8 km) from the CCNPP Unit 3 site at Cove Point MD the MSL is 0.64 ft (0.20 m) above the NGVD 29. Applying the tidal datum relationship to the 10% exceedance high spring tide, and adding the initial rise and the long-term sea level rise, the antecedent water level is 4.4 ft (1.34 m) NGVD 29.

2.4.5.2.2.2 Empirical Method for Estimating Probable Maximum Storm Surge

Based on USACE Hurricane Surge Predictions for Chesapeake Bay (USACE, 1959) and USACE Coastal Engineering Manual (USACE, 2008), storm surge in the open ocean due to a PMH can be estimated by empirical methods. The probable maximum surge on the open ocean is composed of the wind setup and pressure setup.

The USACE published the results of hurricane surge study specific to the Chesapeake Bay which is based on the August 1933 hurricane (USACE, 1959) because it caused the highest surge within the Chesapeake Bay. The storm surge in the open ocean due to the PMH just outside of the entrance to the Chesapeake Bay is calculated using the value given in Regulatory Guide 1.59 (NRC, 1977). The primary component of the surge just inside the mouth of the Chesapeake Bay is calculated according to the relationship between the surge at this point and the open ocean surge provided in Figure 15 of USACE (1959). The primary component of the surge is defined as the wave of water which enters through the mouth of the Chesapeake Bay and travels up the bay. Once the surge height just inside the Chesapeake Bay is known, the surge hydrographs provided in Table II of USACE (1959) are used to proportion the surge at the mouth of the Chesapeake Bay to obtain the surge height closest to CCNPP Unit 3 site. The effect (i.e., setup) of local cross-winds is added to this primary surge height, along with the 10% exceedence high spring tide, sea level anomaly (i.e., initial rise), and long term-rise to the primary component of the surge at CCNPP Unit 3 site to obtain the probable maximum storm surge (PMSS). The PMSS closest to CCNPP Unit 3 was computed by this approach to be 17.4 ft (5.29 m) NGVD 29.

2.4.5.2.2.3 SLOSH Model

PMSS at the site can also be predicted by using the NOAA computer model Sea, Lake, and Overland Surges from Hurricane (SLOSH) version 3.94 (Jelesnianski, 1992; Glahn et al, 2009)

SLOSH

The SLOSH computer model was developed to forecast real-time hurricane storm surge levels on continental shelves, across inland water bodies and along coastlines, including inland routing of water levels. SLOSH is a depth-averaged two-dimensional finite difference model on curvilinear polar, elliptical, or hyperbolic grid schemes. Modification of storm surges due to the overtopping of barriers (including levees, dunes, and spoil banks), the flow through channels and floodplains, and barrier cuts/breaches are included in the model. The effects of local bathymetry and hydrography are also included in the SLOSH simulation. Details of model formulation and application can be found in Jelesnianski (1992).

The NOAA SLOSH model requires the hurricane pressure difference (Δp), hurricane track description including landfall location, forward speed, and size, given as the radius of maximum wind, as input to define the physical attributes of a hurricane in performing a storm surge simulation (Jelesnianski, 1992). The SLOSH Chesapeake Bay basin model extent includes CCNPP Unit 3 site. The model is set up using a curvilinear polar grid system (NOAA, 2006b). The basin bathymetry and water levels in the model input and output are referenced to NGVD 29.

The time sequence of hurricane movement or the hurricane track is a required input to the SLOSH model represented by a series of successive locations of the center of hurricane. The hurricane track is derived as a function of the hurricane direction (angle), forward speed, and landfall location (defined as the location where the hurricane crosses the shoreline). Model simulations are performed for different combinations of the PMH parameters to obtain the maximum surge water level at the site. The model results are processed using the NOAA SLOSH Display Program (NOAA, 2009). The CCNPP Unit 3 is located in the SLOSH model grid cell (31, 59) and the simulated time histories of water levels are extracted from this grid cell for the PMSS evaluation. The model grid for the Chesapeake Bay basin and the location of CCNPP Unit 3 site are shown in Figure 2.4-21.

Comparison of SLOSH Results with Observations

The SLOSH model predictions have been validated against observed hurricane surge levels at several locations (Jelesnianski, 1992; Jarvinen, 1985). The errors of the SLOSH model predictions, defined by subtracting the observed surge water levels from model predictions, were evaluated for ten storms in eight SLOSH model basins, 90 percent of which were in the Gulf of Mexico. Based on a comparison of the SLOSH simulated surge heights against 523 observations, a mean error of -0.09 m (–0.3 ft) was reported. The range of errors was from –2.16 m (–7.1 ft) to 2.68 m (8.8 ft) with a standard deviation of 0.61 m (2 ft) (Jarvinen, 1985).

NOAA Technical Report NWS 48 (Jelesnianski, 1992) also provides a comparison of SLOSH model results with observations for well-documented hurricanes. A total of 570 observations from 13 significant hurricanes in nine SLOSH basins were evaluated. NOAA concludes that the model results generally stayed within ± 20% for significant surges (Jelesnianski, 1992). i.e., if the model calculates a peak storm surge of 10 ft (3 m) for the event, the observed peak could range from 8 to 12 ft (2.4 to 3.7 m).

SLOSH model simulation of the August 1933 hurricane was performed to facilitate a comparison with observed data in the Chesapeake Bay. The comparisons at Baltimore, MD, Annapolis, MD, and Sewells Point, VA indicate that model results underestimate observed surge elevations by a maximum of approximately 7%.

Comparison with RG 1.59

RG 1.59 provides estimates of the PMSS elevation along the U.S. Gulf and Atlantic Coasts (NRC, 1977). At the entrance of the Chesapeake Bay, RG 1.59 provides a PMH surge height (including wind and pressure setup) of 17.30 ft (5.3 m). By comparison, the surge height simulated by the SLOSH model at the entrance of the Chesapeake Bay (model grid cell 45, 15) for the PMH parameters provided in Table 2.4-23 is higher at 19.9 ft (6.1 m) or 23.9 ft (7.3 m) accounting for the 20% uncertainty. Consequently, it is concluded that the PMSS elevation obtained from the SLOSH model is conservative with respect to RG 1.59.

Sensitivity of PMH Parameters on Storm Surge Elevation

SLOSH model runs were performed to investigate the effects of the PMH forward speed, size, direction, and track distances from the site and Chesapeake Bay entrance on the storm surge elevation. The ranges of the parameters used in the simulations include two steady state PMH forward speeds (the lower and upper bounds), three PMH radiuses of maximum wind (the mean, the lower bound and upper bound), nine PMH directions and thirteen track distances. Based on the results of the SLOSH model sensitivity runs, it was concluded that the PMSS at the site would be generated by a PMH that:

1. has the lower bound forward speed of 17 knots (19.6 mph or 31.5 km/h);
2. has the upper bound size (radius of maximum wind of 26 nautical miles (29.9 mi 48.2 km);
3. approaches the Atlantic Ocean shoreline with a westward direction (270 degrees from the north), and with a track distance of approximately 1.5 times the upper bound radius of maximum wind south of the Chesapeake Bay entrance; and
4. passes by the west of the site with a distance of approximately 0.25 times the upper bound PMH size and is directed towards north (360 degrees from north).

Application of SLOSH for CCNPP Unit 3

Based upon the above studies a PMH track was developed. The selected PMH track direction and the envelope of simulated maximum surge elevation for the SLOSH Chesapeake Bay basin is shown on Figure 2.4-22. The PMH parameters (e.g., Radius of Maximum Winds and Central Pressure) were computed for 16 points (1 hour intervals) along the PMH track. This information is provided in Table 2.4-23 and is used to compute surge height using the SLOSH model.

The methodology in Technical Report NWS 23 (NOAA, 1979) was utilized to compute the wind field at the site accounting for the reduction in wind speed after landfall. The maximum 10 meters 10-minute wind speed at the point of landfall was computed as 152.6 mph (245.6 km/h). The CCNPP Unit 3 site is located near point 8 of the 16 point path (Table 2.4-23). The 10 minute maximum wind speed at point 8 is 116.4 mph (187.3 km/h) after 8 hours from landfall. Point 8 is located inland; therefore, the PMH wind speed will further decay due to friction. At the site, the estimated 10-meter 10 minute maximum wind speed is 111.7 mph (179.8 km/h) by accounting the decay in the wind field due to landfall at Point 8.

The simulated storm track contains the defined 16 points the PMH track. The SLOSH model was initialized with a water level of 0.0 ft (0.0 m), to allow the maximum possible antecedent water level, the sea level anomaly, 10% exceedence high spring tide and long term sea level rise to be addressed separately.

2.4.5.2.2.4 Probable Maximum Storm Surge Elevation at CCNPP Unit 3

The SLOSH model predicted a maximum surge elevation at the site of 11.0 ft (3.35 m) from a water level of 0.0 NGVD 29. The simulated surge height was then adjusted to take into account the 20% margin (SLOSH model uncertainties) suggested in Technical Report NWS 48 (Jelesnianski, 1992) and the antecedent water level of 4.4 ft (1.34 m) NGVD 29. The surge over time is shown in Figure 2.4-23. The final PMSS elevation thus obtained is 17.6 ft (5.35 m) NGVD 29.

Using the empirical method, the PMSS was computed to be 17.4 ft (5.29 m) NGVD 29, indicating a strong agreement between the empirical method and the SLOSH model. See Table 2.4-24 for comparison of results between SLOSH and empirical method.

2.4.5.3 Wave Action

With the exception of the intake structures, CCNPP Unit 3 is approximately at 85 ft (26 m) NGVD 29 and beyond 1,000 ft (305 m) from the shoreline and is not expected to be affected by the PMSS including wave action. The safety-related forebay, UHS Makeup Water Intake Structure (MWIS), and UHS Electrical Building, shown in Figure 2.4-25, are affected by the PMSS and by wind waves generated during a PMH event.

2.4.5.3.1 Hurricane Maximum Wind Speed

The hurricane wind direction at the CCNPP Unit 3 site will change clockwise from southwestward to southeastward, as the PMH passes by the western side of the Chesapeake Bay moving in the composite direction from landfall to a location north of the CCNPP Unit 3 site as shown in Figure 2.4-22. The hurricane wind speed will decrease as the PMH moves closer to the site after landfall. As discussed in Section 2.4.5.2.2.3, the wind speed corresponding to the PMH conditions is 111.7 mph (179.8 km/h).

2.4.5.3.2 Wave Height and Run-up

As described in Section 2.4.5.2, the PMH will cause the highest surge height at the CCNPP Unit 3 site when it travels north following a track on the west side of the Chesapeake Bay. The SLOSH simulation results show that the highest sustained wind speed of a PMH to generate the maximum wave height at the CCNPP Unit 3 site will come from the east or southeast and will occur when the eye of the hurricane is southwest of the CCNPP Unit 3 site at a distance equal the radius of maximum wind. Because the peak surge and the maximum wind speed from the PMH are active at the site for a relatively short duration compared to the total duration of the PMH (Figures 2.4-23 and 2.4-24), the growth of wind- induced waves at the site would be limited by duration instead of the large fetch length. The wind-induced wave height and period at the CCNPP Unit 3 site is calculated following the procedure described in the USACE Coastal Engineering Manual (USACE, 2008). The significant wave height (Hmo) is 10.8 ft (3.31 m) and the 1% wave height (1.67 times Hmo) is 18.1 ft (5.52 m).

During the passage of the PMH event at the CCNPP Unit 3 site, the elevation of the storm surge is 17.6 ft (5.35 m) NGVD 29. The grade elevation surrounding the intake structures is 10 ft (3.05 m), leaving the grade inundated with 7.6 ft (2.30 m) of water. Since the storm surge is above grade, some waves will propagate unimpeded around the intake structure to a graded slope farther inland, while other waves will directly impact the intake structure façade.

The maximum sustainable unbroken wave height in 7.6 ft (2.30 m) of water was calculated to be 5.9 ft (1.79 m). Waves larger than this value will break and diminish in size while waves 5.9 ft (1.79 m) or smaller may strike the intake structures without breaking. The maximum wave runup on the intake structure was computed to be 15.6 ft (4.76 m). This runup, combined with the PMSS, will reach an elevation of 33.2 ft (10.11 m) NGVD 29 as shown on Figure 2.4-26.

Waves that travel past the intake structure will break on a smooth 3H:1V slope farther inland. The runup in this location was calculated to be 16.3 ft (4.96 m), which combined with the PMSS reaches an elevation of 33.9 ft (10.31 m) NGVD 29.

2.4.5.3.3 Effect on Safety-Related Structures

Because the grade elevation of the CCNPP Unit 3 power block is approximately 85 ft (26 m) NGVD 29 and the power block is located approximately 1,000 ft (305 m) from the shoreline, the CCNPP Unit 3 power block will not be impacted by the PMH-induced flood events.

The safety-related UHS MWIS and Electrical Building will be flooded during the PMSS and the UHS MWIS will be over-topped by waves. These structures are designed to meet the requirements of Regulatory Guide 1.27 (NRC, 1976b). Access into the UHS MWIS and UHS Electrical Building below the maximum water level during the PMH is designed to be watertight to prevent the internal flooding of the structures. The design of the UHS MWIS and Electrical Building is discussed in Section 3.8 and Section 9.2.5.

2.4.5.4 Resonance

No significant oscillations appear in the historical storm surge records of the Chesapeake Bay. Recorded surge hydrographs at different locations in the Chesapeake Bay during the passage of Hurricane Isabel in 2003 are shown in Figure 2.4-27. The figure shows that the storm surge gradually rises to its peak and then gradually reverts back to the normal water level when the influence of the hurricane is diminished.

When the storm surge due to a hurricane traveling in a northerly direction enters the Chesapeake Bay, the water level at the lower Chesapeake Bay will increase (set-up) due to the passage of the surge wave. At the same time the water level at the upper Chesapeake Bay is likely to decrease (set-down) due to the counterclockwise pattern of the wind field. Similarly, when the storm surge approaches the upper Chesapeake Bay combined with a southerly wind, the water level in the upper Chesapeake Bay will increase and the water level in the lower Chesapeake Bay will eventually decrease.

Except for this variation in water level during the passage of a hurricane, historical records in the Chesapeake Bay do not show any significant oscillations affecting the storm surge levels in the Chesapeake Bay. Once the hurricanes move beyond the Chesapeake Bay region, small oscillations have been observed. However, these oscillations did not amplify the water level during the passage of the peak storm surges.

Sustained wind speed along the axis of the Chesapeake Bay (north-south) may trigger a seiche event in the Chesapeake Bay. The period of these oscillations along the north-south axis of the Chesapeake Bay is reported to be between 2 and 3 days. Because the effects of seiche oscillation are eliminated by a change in sustained wind direction, any existing seiche oscillation in the Chesapeake Bay prior to the arrival of any hurricane will be eliminated by the strong and changing wind field of the hurricane. Hence, resonance of seiche oscillation with PMSS is precluded.

2.4.5.5 Protective Structure

The shoreline near the UHS makeup water intake structure will be protected against the PMH and coincident wind-wave conditions. The design crest elevation of the shore protection structure will be 10 ft (3 m) NGVD 29. Flood protection measures for the UHS MWIS and Electrical Building are discussed in Section 2.4.10.

2.4.5.6 References

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NRC, 1977. Regulatory Guide 1.59, Design Basis Floods for Nuclear Power Plants, Revision 2, U.S. Nuclear Regulatory Commission, August 1977, with errata dated July 30, 1980.

USACE, 1959. Hurricane Surge Predictions for Chesapeake Bay, Paper No. 3-59, U.S. Army Corps of Engineers, 1959.

USACE, 2008. Coastal Engineering Manual, EM 1110-2-1100, U.S. Army Corps of Engineers, 2008.}

Table 2.4-23, Table 2.4-24, Figures 2.4-21 through Figure 2.4-24, and Figure 2.4-26 are replaced with the tables and figures provided below:

Table 2.4-23 - {PMH Parameters}

Location		Time after landfall	Central Pressure	Peripheral Pressure	Radius
Lat	Long	(hours)	mbar	mbar	Miles
36.3784	75.805	0	897	1020	29.9
36.4800	76.108	1	906	1020	36.7
36.6309	76.344	2	914	1020	35.4
36.8372	76.501	3	921	1020	34.1
37.0903	76.589	4	928	1020	32.9
37.3777	76.624	5	935	1020	31.7
37.6869	76.624	6	941	1020	30.6
38.0057	76.603	7	946	1020	29.5
38.3215	76.579	8	951	1020	28.4
38.6246	76.563	9	956	1020	27.4
38.9156	76.557	10	961	1020	26.4
39.1978	76.558	11	965	1020	25.4
39.4743	76.564	12	969	1020	24.5
39.7484	76.572	13	972	1020	23.6
40.0233	76.579	14	976	1020	22.8
40.3016	76.583	15	979	1020	22.0
40.5831	76.585	16	982	1020	21.2

Table 2.4-24 – {Comparison of Surge Results}

Method	Primary Surge	Cross Wind Setup	Initial Rise	High Tide (NGVD 29)	Long Term Sea Level Rise	PMSS (NGVD 29)
Empirical	12.1 ft (3.69 m)	0.9 ft (0.27 m)	1.1 ft (0.34 m)	2.2 ft (0.67 m)	1.1 ft (0.33 m)	17.4 ft (5.29 m)
SLOSH	13.2 ft (4.02 m)		1.1 ft (0.34 m)	2.2 ft (0.67 m)	1.1 ft (0.33 m)	17.6 ft (5.35 m)

Figure 2.4-21—{SLOSH Chesapeake Bay Model Grid (SLOSH Basin cp2) and the Location of CCNPP Unit 3}

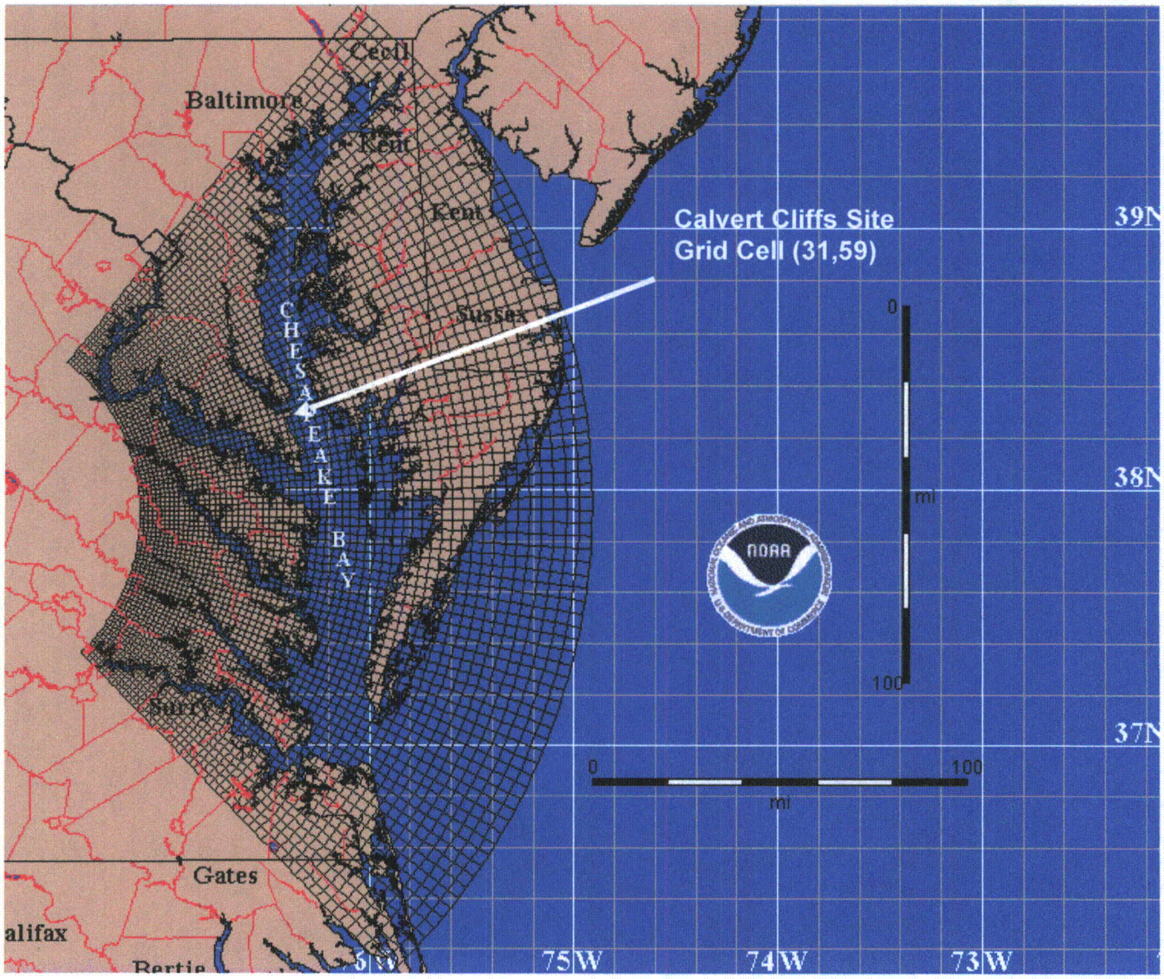
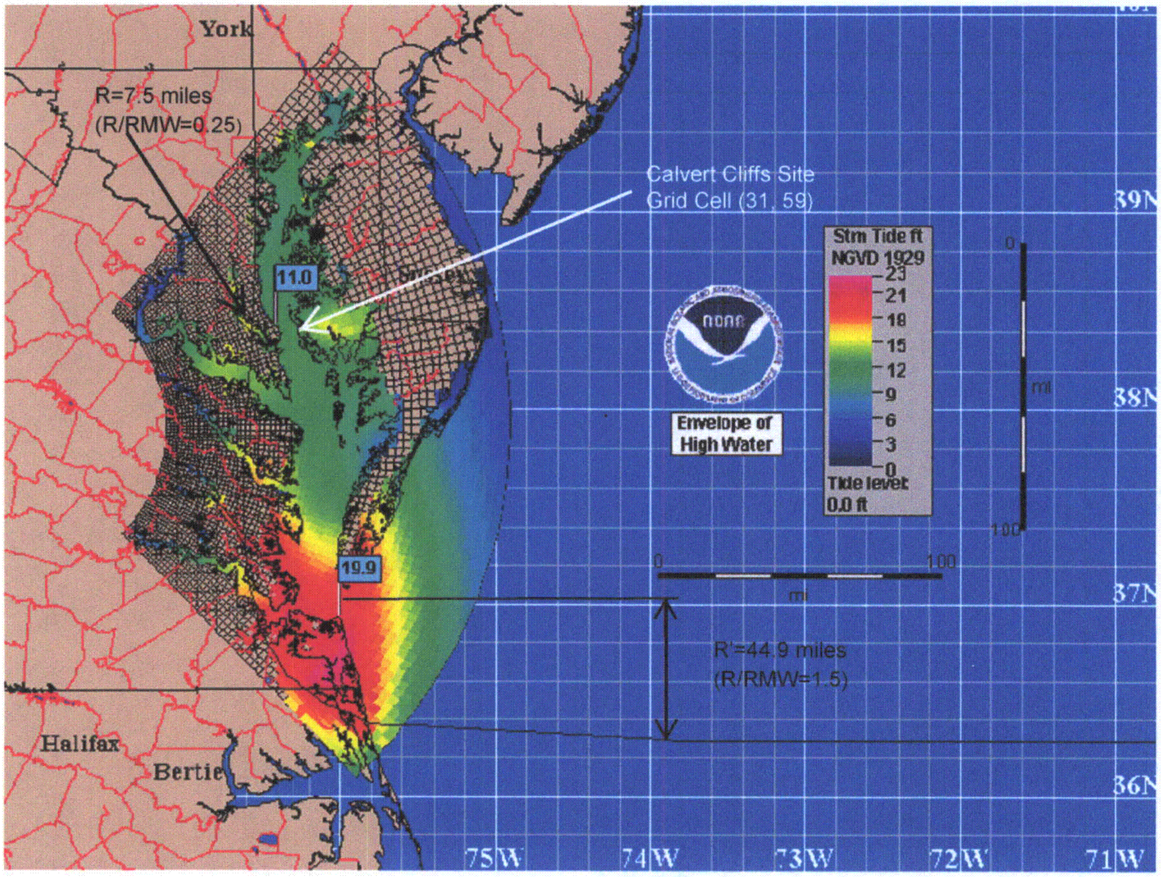


Figure 2.4-22—{Selected PMH Track and the Envelope of Resulting Surge Elevation in the SLOSH Chesapeake Bay Basin for the PMH}



Note: R is the distance from the site; R' is the distance from the Chesapeake Bay entrance; RMW is the PMH upper bound radius of maximum wind.

Colors and the flags show the maximum surge elevation at the grid locations.

Figure 2.4-23—{SLOSH Model Simulated Time History of Surge Elevation at the Site (grid cell 31, 59) for the Selected PMH Conditions}

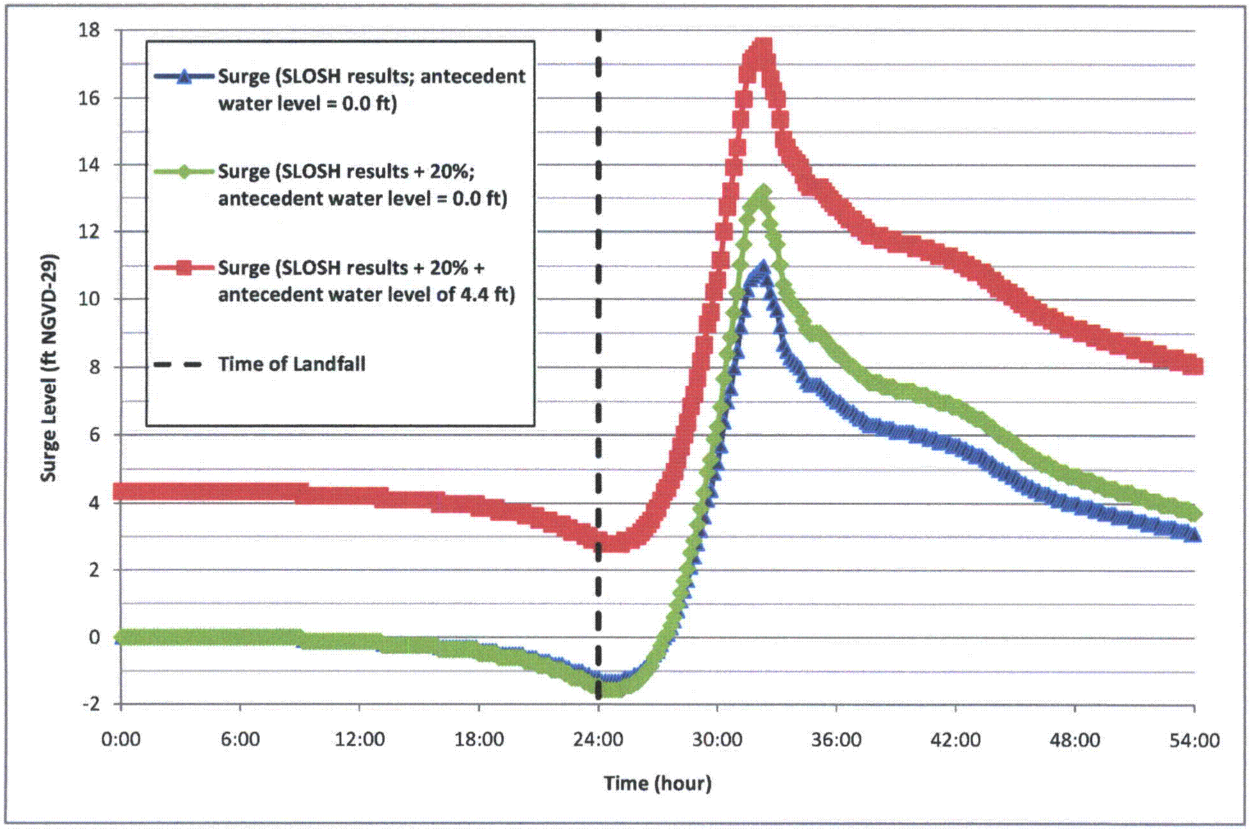
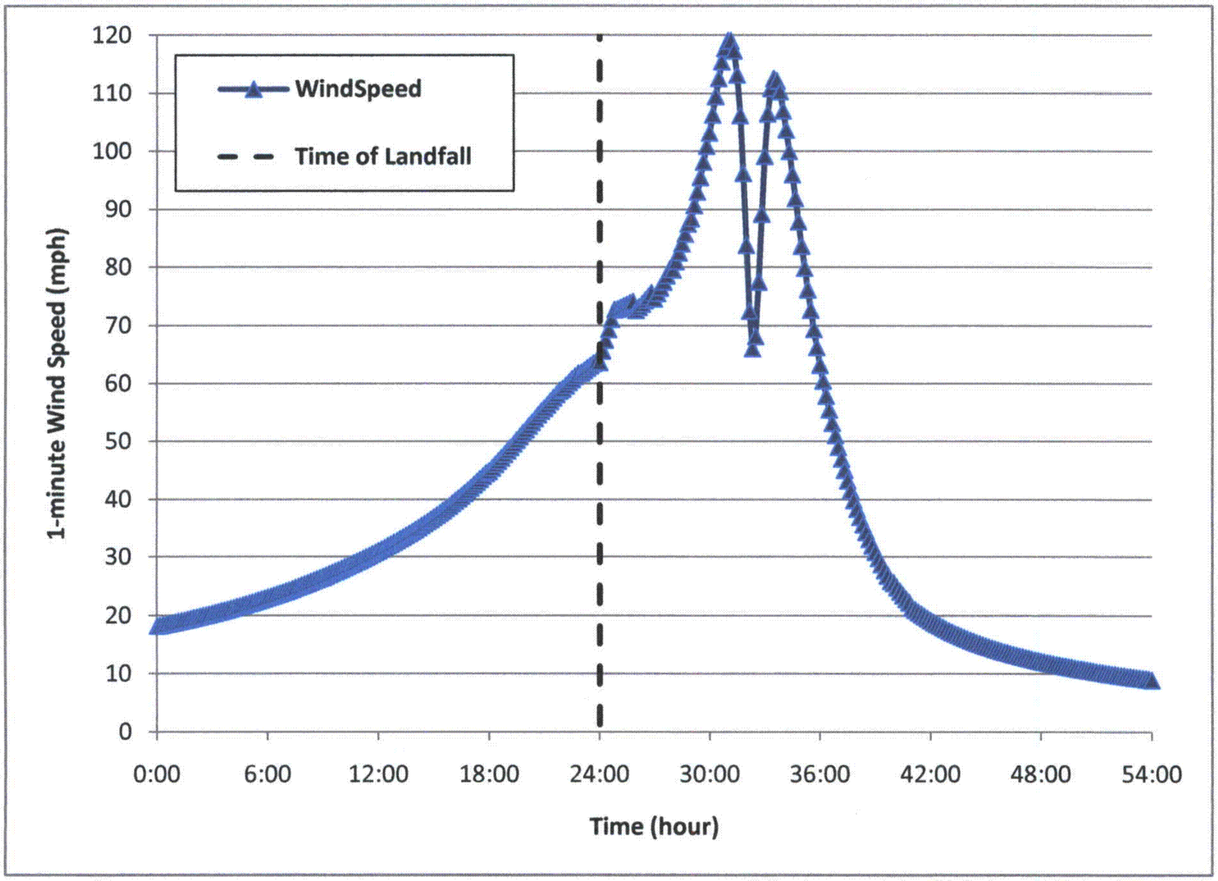
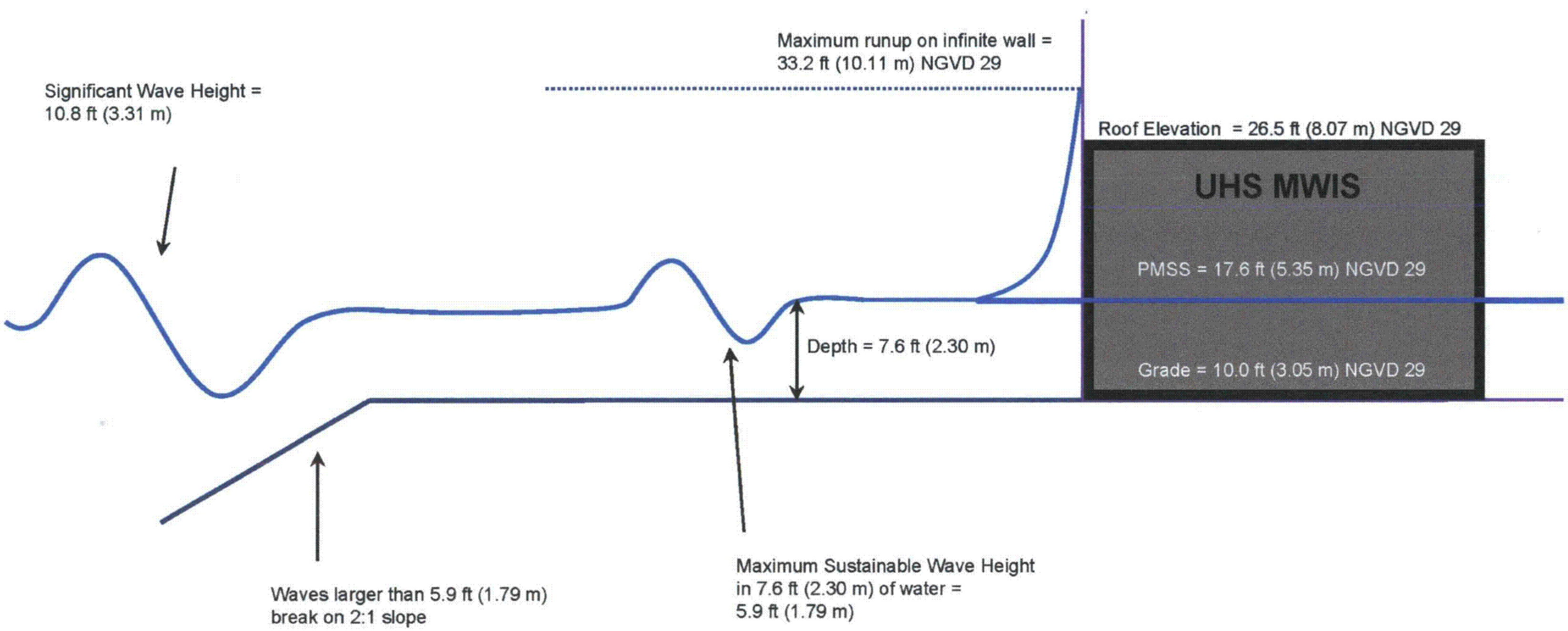


Figure 2.4-24 - {SLOSH Model Simulated Time History of Wind Speed at the Site (grid cell 31, 59) for the Selected PMH Conditions}



Note: First peak provides westward maximum wind speed as the PMH approaches the site. Wind speed decreases when the site lies within the radius of maximum wind with the trough representing the nearest location of the PMH center to the site. The second peak is from eastward wind as the PMH moves away towards north from site.

Figure 2.4-26 --{Schematic Diagram Wave Runup on the UHS Make Water Intake Structure (MWIS)}



FSAR Section 2.4.10 is updated as shown below:

2.4.10 FLOODING PROTECTION REQUIREMENTS

The U.S. EPR FSAR includes the following COL Item in Section 2.4.10:

> A COL applicant that references the U.S. EPR design certification will use site-specific information to compare the location and elevations of safety-related facilities, and of structures and components required for protection of safety-related facilities, with the estimated static and dynamic effects of the design basis flood conditions.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

This section discusses the locations and elevations of safety-related facilities to identify the structures and components exposed to flooding. The safety-related facilities are compared to design basis flood conditions to determine if flood effects need to be considered in plant design or in emergency procedures.

All safety-related facilities are located in the power block area with the exception of the Ultimate Heat Sink (UHS) makeup water intake structure and its associated electrical building. The CCNPP Unit 3 UHS makeup water intake structure and the makeup water intake for the Circulating Water System (CWS) are located on the Chesapeake Bay shore southeast of the CCNPP Units 1 and 2 intake structure as shown in Figure 2.4-51. As discussed in Section 2.4.2, the maximum water level in the power block area due to a local PMP is Elevation 81.5 ft (24.8 m). All safety-related structures in the power block area have a minimum grade slab or entrance at Elevation 84.6 ft (25.8 m) or higher. Grading in the power block area around the safety-related facilities is such that all grades slope away from the structures at a minimum of 1% towards runoff collection ditches.

Additionally, the maximum estimated water surface elevations resulting from all design basis flood considerations discussed in Section 2.4.2 through Section 2.4.7 are below the entrance and grade slab elevations for the power block safety-related facilities. Therefore, flood protection measures are not required in the CCNPP Unit 3 power block area.

Flood protection measures are required for the CCNPP Unit 3 UHS makeup water intake structure and its associated electrical building. The nominal grade at the UHS makeup water intake structure is approximately at Elevation 10.0 ft (3.0 m). The maximum flood level at the UHS makeup water intake structure location is Elevation ~~36.6 ft (11.2 m)~~ 33.2 ft (10.11 m) as a result of the surge and wave run-up associated with the probable maximum hurricane (PMH) as discussed in Section 2.4.5. Thus, the UHS makeup water intake structure and the associated electrical building would experience flooding during a PMH and flood protection measures are required for these buildings.

FSAR Section 2.5.5.2.1 is updated as shown below. Note that this markup is to the FSAR text provided in UNE letter UN#09-427[1] on October 9, 2009.

2.5.5.2.1 Stability of Constructed Slopes

. . . [Note: the change is in the last paragraph]

There are no dams or embankments that would affect the CCNPP Unit 3. Probable Maximum Flood (PMF) at the CCNPP Unit 3 area is accounted for by assuming a high groundwater level of 37 ft at the Intake Slope. A maximum flood level of ~~36.6~~ 33.9 ft is postulated, this would only affect the Intake Slope.

1 G. Gibson (UniStar Nuclear Energy) to Document Control Desk (U.S. NRC), "Update to Calvert Cliffs Nuclear Power Plant, Unit 3 FSAR Sections 2.5.4 and 2.5.5," Letter UN#09-427, dated October 9, 2009.

FSAR Section 3.4.3.10 is updated as shown below:

3.4.3.10 Ultimate Heat Sink Makeup Water Intake Structure Flooding Analysis

The U.S. EPR FSAR includes the following COL Item in Section 3.4.3.10:

> A COL applicant that references the U.S. EPR design certification will perform a Flooding analysis for the ultimate heat sink makeup water intake structure based on the site-specific design of the structure and the flood protection concepts provided herein.

This COL Item is addressed as follows:

{The maximum flood level at the UHS Makeup Water Intake Structure and UHS Electrical Building location is elevation ~~39.4 ft (12.0 m)~~ 33.2 ft (10.11 m) as a result of the surge, wave heights, and wave run-up associated with the PMH as discussed in Section 2.4.5. The UHS Makeup Water Intake Structure and the UHS Electrical Building would experience flooding during a PMH. These structures are designed to withstand the static and dynamic flooding forces, and the UHS Makeup Water pump room areas and electrical rooms are designed to be watertight. The flood protection measures for the UHS Makeup Water Intake Structure and UHS Electrical Building are described in Section 2.4.10.

FSAR Section 19.1.5.4.2 is updated as shown below:

19.1.5.4.2 External Flooding Evaluation

Section 2.4.3 through 2.4.7 provide an evaluation of the different flooding conditions considered for the CCNPP Unit 3 site, as well as the U.S. EPR FSAR's protection features against those conditions. The flooding conditions include the probable maximum flood (PMF) on streams and rivers, potential dam failures, probable maximum surge and seiche flooding, probable maximum tsunami and ice effect flooding. Maximum flooding levels due to local intense precipitation are also addressed.

Section 2.4.2 summarizes the flooding evaluations and provides required flood protection requirements. The maximum water level for Nuclear Island due to a local probable maximum precipitation (PMP) is Elevation 81.5 ft (24.8 m) with respect to the reference level. Safety-related structures of the Nuclear Island have a minimum grade slab or entrance at Elevation 84.6 ft (25.8 m) or higher. Grading in the power block area around the safety-related facilities is such that all grades slope away from the structures at a minimum of 1% towards collection ditches. Other than for local PMP flooding, the maximum estimated water surface elevations resulting from all design basis flood considerations discussed in Sections 2.4.2 through 2.4.7 are well below the entrance and grade slab elevations for the power block safety-related facilities. Therefore, flood protection measures are not required for the CCNPP Unit 3 Nuclear Island.

However, flood protection measures are required for the UHS Makeup Water Intake Structure and the UHS Electrical Building. The grade level at the UHS intake location is at elevation 10.0 ft (3.05 m). The maximum flood level at the intake location is elevation ~~39.4 ft (12.0 m)~~ 33.2 ft (10.11 m) as a result of the surge, wave heights, and wave run-up associated with the probable maximum hurricane (PMH) as discussed in Section 2.4.5.

RAI 103

Question 02.04.05-4

Please provide a set of alternate locations of the eye of the Probable Maximum Hurricane storm (FSAR Figure 2.4-26) to demonstrate that the chosen location would maximize the overwater fetch and therefore result in the most severe plausible storm surge near the CCNPP site.

Response

As described in the response to Question 02.04.05-2 and in the update of FSAR Section 2.4.5 provided with that response, the National Oceanic and Atmospheric Administration operational storm surge model SLOSH (*Sea, Lake, and Overland Surges from Hurricanes*) was used to develop a storm track (replacing the single location previously provided in FSAR Figure 2.4-26).

The Probable Maximum Hurricane (PMH) will cause the highest surge height at the CCNPP Unit 3 site when it travels north following a track on the west side of the Chesapeake Bay. The SLOSH simulation results show that the highest sustained wind speed of a PMH to generate the maximum wave height at the CCNPP Unit 3 site will come from the east or southeast and will occur when the eye of the hurricane is southwest of the CCNPP Unit 3 site at a distance equal the radius of maximum wind. The selected PMH track is provided in new FSAR Table 2.4-23 and shown on new FSAR Figure 2.4-22.

Because the peak surge and the maximum wind speed from the PMH are active at the site for a relatively short duration compared to the total duration of the PMH (new FSAR Figures 2.4-23 and 2.4-24), the growth of wind- induced waves at the site would be limited by duration instead of the large fetch length. The wind-induced wave height and period at the CCNPP Unit 3 site is calculated following the procedure described in the USACE Coastal Engineering Manual The significant wave height (Hmo) is 10.8 ft (3.31 m) and the 1% wave height (1.67 times Hmo) is 18.1 ft (5.5 m).

During the passage of the PMH event at the CCNPP Unit 3 site, the elevation of the storm surge is 17.6 ft (5.35 m) NGVD 29. The grade elevation surrounding the intake structures is 10 ft (3.05 m), leaving the grade inundated with 7.6 ft (2.30 m) of water.

The maximum sustainable unbroken wave height in 7.6 ft (2.30 m) of water was calculated to be 5.9 ft (1.79 m). Waves larger than this value will break and diminish in size while waves 5.9 ft (1.79 m) or smaller may strike the intake structures without breaking.

COLA Impact

The markup of FSAR Section 2.4.5 provided in response to Question 02.04.05-2 includes the above information.