April 29, 2013

MEMORANDUM TO: Meena Khanna, Chief, Licensing Branch 1

FROM: Henry Jones, Hydrologist, Meteorology and Hydrology Branch /RA/

THRU: Christopher Cook, Chief, Meteorology and Hydrology Branch

SUBJECT: REVIEW OF EMERGENCY2.206 PETITION REGARDING LACK OF ADEQUATE PROTECTION OF SAFETY AT OYSTER CREEK NUCLEAR GENERATING STATION LACY, NJ

In accordance with the request of Mena Khanna (NRR/DORL/LPL1-2) to Chris Cook (NRO/DSEA/RHMB) dated April-24, 2013, Henry Jones (NRO/DSEA/RHMB) has completed the review of the information provided to determine whether the concern was substantiated for the issue of storm surge design basis flood.

In summary, the concern was not substantiated and there were no unresolved technical issues. Hurricane Sandy never exceeded the DBF parameters for OCNGS. The PMH parameters used in the calculation of the storm surge are conservative based on the water level observed during Hurricane Sandy and recent storm surge studies using state-of-the-art methodologies.

See the attached discussion.

Enclosure: RHMB EVALUATION OF OYSTER CREEK 2.206 PETITION

RHMB EVALUATION OF OYSTER CREEK 2.206 PETITION

Site Characteristics

Location

The site (Figure 1), which consists of approximately 800 acres, is located in Lacey and Ocean Townships of Ocean County, New Jersey, approximately two miles inland and west of the shore of Barnegat Bay.

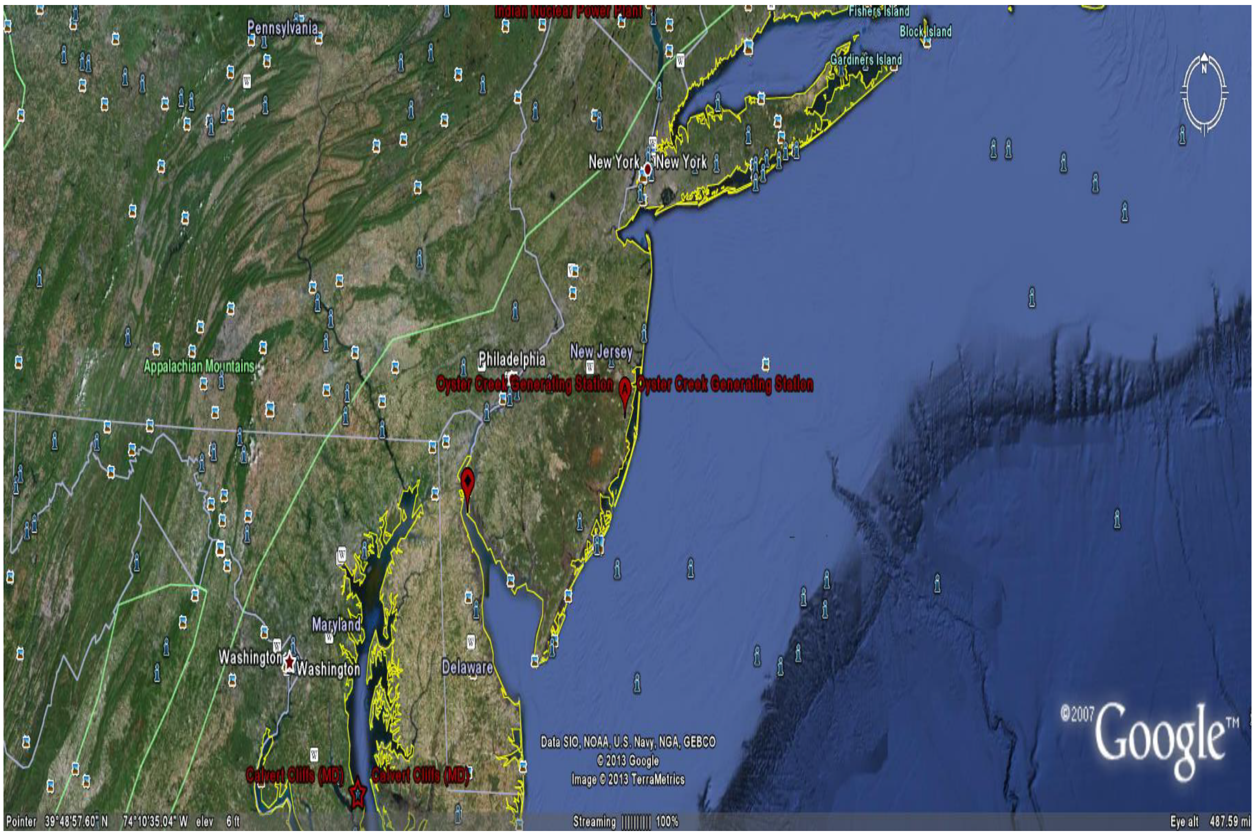

Figure 1. Google image of Oyster Creek Nuclear Generating Station (OCNGS).

Barnegat Bay is located along the middle New Jersey coast, extending approximately 30 miles from Point Pleasant on the north to Manahawkin Causeway on the south. Its width varies from about 1.2 to 4.6 miles with a mean width of about 2.4 miles. The Bay is enclosed by a barrier beach (Figure 2) and is a narrow, shallow tidal basin. It is interconnected with Little Egg Harbor and Great Bay to the south, and through Barnegat Inlet to the Atlantic Ocean. The only break in the barrier beach in this stretch is the one at Barnegat Inlet, opposite Waretown, about 20 miles south of Point Pleasant (Reference 4).

Figure 2. Barnegat Bay

The Oyster Creek and the Forked River are contributing streams to Barnegat Bay. They are situated on the western side of the Bay between the towns of Waretown and Forked River. The Oyster Creek is the more southerly of the two (Figure 3).

Figure 3. Google map of Oyster Creek and Forked River.

The OCNGS intake canal is located along the South Branch of the Forked River measures approximately 10,500 feet in length, 120 feet at the narrowest cross section, 280 feet at the widest section, and 7 to 12 feet in depth. The discharge canal measures about 11,500 feet in length, 110 feet at the narrowest width, 1000 feet at the broadest width, and 8 to 12 feet in depth.

The intake canal was originally designed a capacity of 1,260,000 gallons per minute (gpm) to serve as an intake waterway for four nuclear generating stations. The requirement for post-accident cooling water for OCNGS is 14,000 gpm which amounts to 1.1 percent of the capacity of the canal.

Bathymetry

The Bathymetry for Barnegat Bay (Figure 4) was derived from six surveys containing 74,448 soundings. No surveys were deleted. The average separation between soundings was 49 meters. The six surveys dated from 1934 to 1936. The total range of sounding data was 0.3 meters to -14.3 meters at mean low water. Mean high water values of 0.8 or 0.9 meters were assigned to the shoreline.

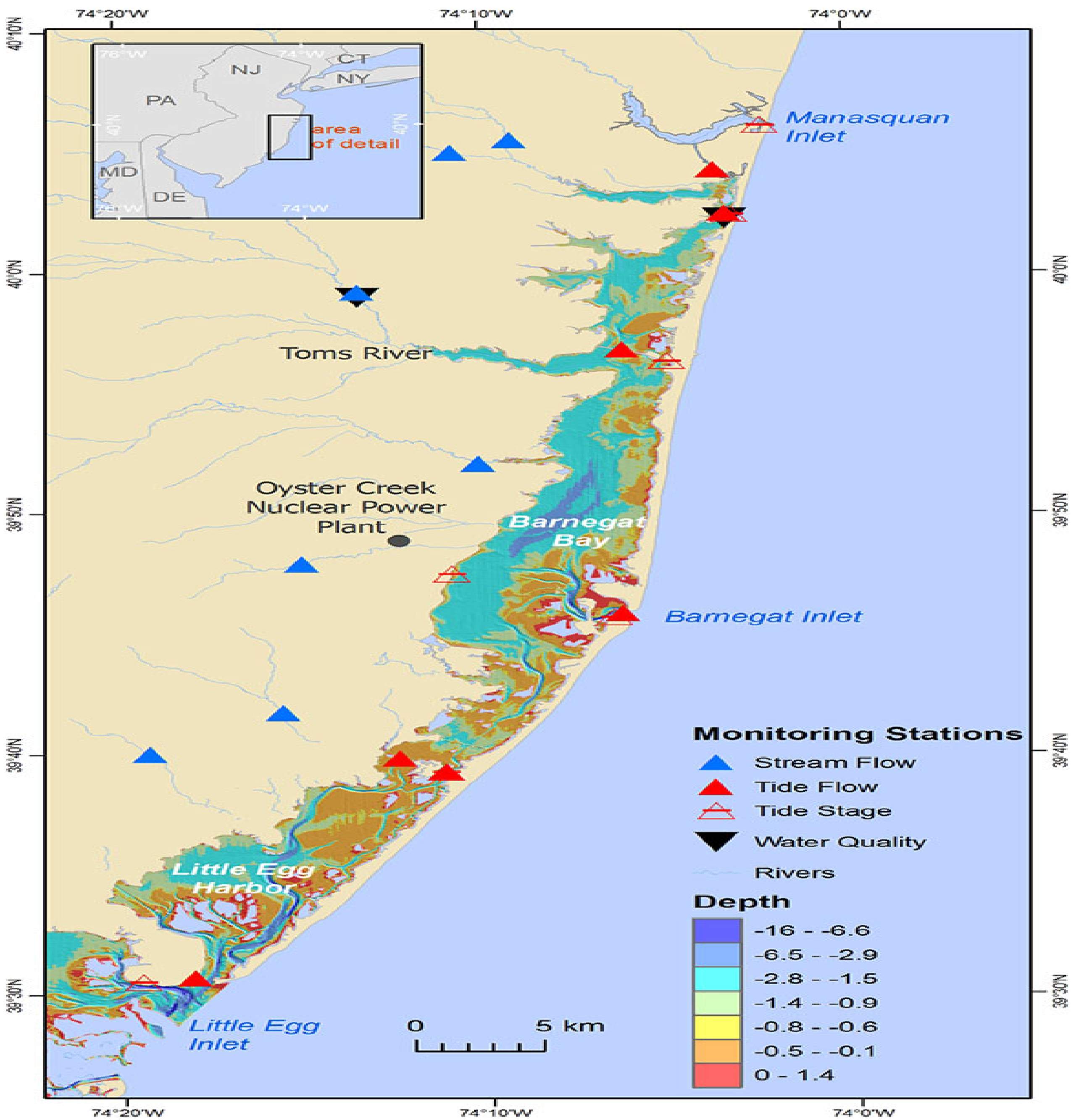

Figure 4. Bathymetry for Barnegat Bay

The average depth of the Bay is less than 5 feet with a range of less than 1 foot to 20 feet at mean low tide (Figure 5). Large areas of the Bay have depths of 1 foot or less; these areas are located mainly in the eastern portions (Reference 4).

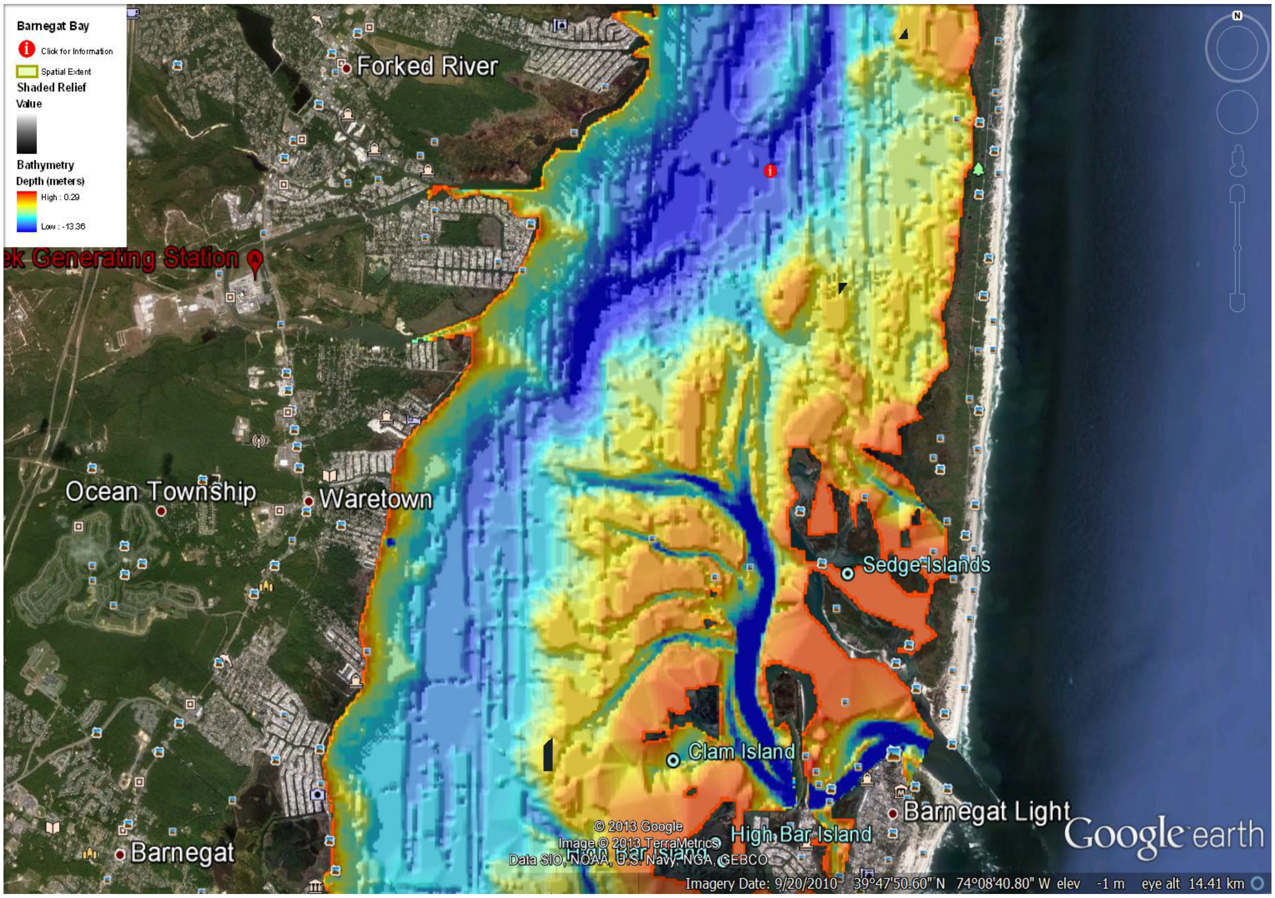

Figure 5. Google Bathymetry for Barnegat Bay with zoom image of OCNGS.

Flooding Hazard

Due to the proximity of the site to Barnegat Bay and the Atlantic Coast, and the relatively small size of the onsite freshwater streams (Figure 3), storm and tidal flooding are used as the design basis in establishing the elevations of various plant components.

Initially, the design basis high water level for the plant was established from a storm which struck New Jersey in 1962 (Reference 1). Until Hurricane Sandy, this storm was the worst ever recorded at the plant site. Flood marks from this storm showed a high tide elevation of 4.5 feet above Mean Sea Level (MSL). The maximum recorded high tide along the Barnegat Bay beachfront is approximately 7 feet MSL.

A study conducted in 1970 to establish the Probable Maximum Hurricane flood level (References 5 & 7) determined that a hurricane storm with a 250 year return frequency would produce a flood elevation of about 5.3 ft MSL at the plant site. This 250 year return period was the criterion used by the US Army Corps of Engineers for determining design basis flood levels of waterfront structures. An amended hurricane storm surge analysis performed after the completion of the OCNGS has concluded that a Probable Maximum Hurricane (PMH) still water level of +22 feet MSL could occur at the site (Reference 7). An additional height of less than 1.0

feet represents the maximum wave runup which raises the flooding level to approximately 23 ft MSL at the plant site.

Flood Protection

Until Hurricane Sandy, the maximum flood height recorded at the facility is 4.5 feet above MSL (Reference 4). Based on the 1962 storm, the deck elevation of the circulating water intake structure was set at elevation 6.0 ft MSL providing 1.5 feet of free board. However, flood level in the plant and canal area can reach elevation 23 ft. (Reference 7) and flood protection is provided so that the plant can be safely shutdown for a flooding level as high as approximately 23 feet above mean sea level (MSL).

The plant grade, elevation 23 ft MSL, is one foot above the PMH flood level and the floor levels of which are generally six inches above grade at elevation 23'-6". The circulating water intake structure with its deck at elevation 6 ft supports the circulating water intake structure and the emergency service water pumps. Thus, the OCNGS circulating water intake structure and service water pumps are considered safe against the 250 year hurricane flood (5.3 ft MSL).

<u>During a PMH flood event, the circulating water and service water pumps will become inoperable and thus emergency plant procedures (See Section 2.4.8 of Reference 4) have been instituted</u> which require the plant to be shutdown when flood waters reach a predetermined level as to ensure the capability for safe shutdown under either normal or abnormal conditions (Reference 4). <u>The fire pumps at the Fire Pond will also be submerged</u>, inoperable and therefore, unable to supply supplemental water to the Isolation Condensers. A redundant fire pump and tank are installed above the flood elevation level (see Section 9.5 of Reference 4) which ensures the availability of this backup service for decay heat removal.

The safety related buildings and structures at the nuclear island remain above flood levels during a PMH event (Reference 4). The two entrances to the emergency diesel generator building are at elevation 23 ft. MSL, which is 6 inches below the flooding level which would be caused by local probable maximum precipitation (23.5 ft. MSL). A 6 inch high asphalt dike is provided at these entrances to provide protection against internal flooding of the emergency diesel generator building (Reference 4).

<u>Technical Evaluation</u>

Wave Heights

The water wave characteristics of length, height and period are determined by the wind duration, fetch and intensity (References 8 & 9). The bathymetry at the site and in the Bay is very shallow making the site fetch limited which significantly limits wave height. In addition, waves break when their height reaches approximately 0.78 times the water depth. The average depth of the Bay if 5 ft and the depth of the intake canal is maximum of 12 ft. Thus, I concur (Reference 4) that the design basis flood would be determined by storm surge.

Meteorology

Table 1 provides the cyclone parameters for Hurricane Sandy and the PMH. The proceedings of the Petition review Board (PEB) for the 2.206 petition provide a significant discussion between NRC and the petitioner regarding Hurricane Sandy and the PMH (Reference 3). In Table 1, it can be seen that Hurricane Sandy didn't exceed the PMH parameters.

Table 1. Hurricane Sandy versus OCMGS PMH Parameters

	Surge at Site (MSL)	**Max Category**	**Landfall Location (Figure 6)**	**Lowest Central Pressure**	**Radius of Maximum Winds**	**Max Wind Speed**	**Forward Speed**	**Path**
Hurricane Sandy	7.4 ft	3	SE of site	940 mb	~175 miles	115 mph	34-46 mph	NW
PMH	23 ft	4	SE of site	917 mb	30 miles	133 mph	20 mph	NW

From a meteorological perspective, the storms were very different. The PMH is a textbook tropical cyclone, with a compact, symmetrical wind field that whipped around a circular low-pressure center. Like most tropical cyclones, the PMH is a warm-core storm that draws its energy from the warm waters of the tropical Atlantic Ocean. Sandy displayed similar characteristics while it was blowing through the tropics. But as the storm moved northward, it merged with a weather system arriving from the west and started transitioning into an extra-tropical cyclone.

While tropical cyclones draw their energy from warm ocean waters, extra-tropical cyclones are fueled by sharp temperature contrasts between masses of warm and cool air. Extra-tropical cyclones also tend to be asymmetric, with broad wind and cloud fields shaped more like commas than circles. So when tropical cyclones become extra-tropical, their wind and cloud fields expand dramatically. Their strongest winds generally weaken during this process, but occasionally a transitioning storm retains hurricane force winds, as was the case with Sandy.

The most noticeable difference is the extent of the strong wind fields. The PMH winds are more intense, cover less area but can generate a locally higher surge. Sandy generated a locally lower surge but was capable of generating a destructive surge over a larger length of coastline. Another difference is the location of the strongest winds. For tropical cyclones in the northern hemisphere, the strongest winds are usually just east of the eye amidst a ring of violent thunderstorms called the eyewall. The windfield of the PMH fits this pattern, but for Sandy the weakest winds are to the east—Sandy had already begun interacting with a system to its northeast and transitioning to extratropical.

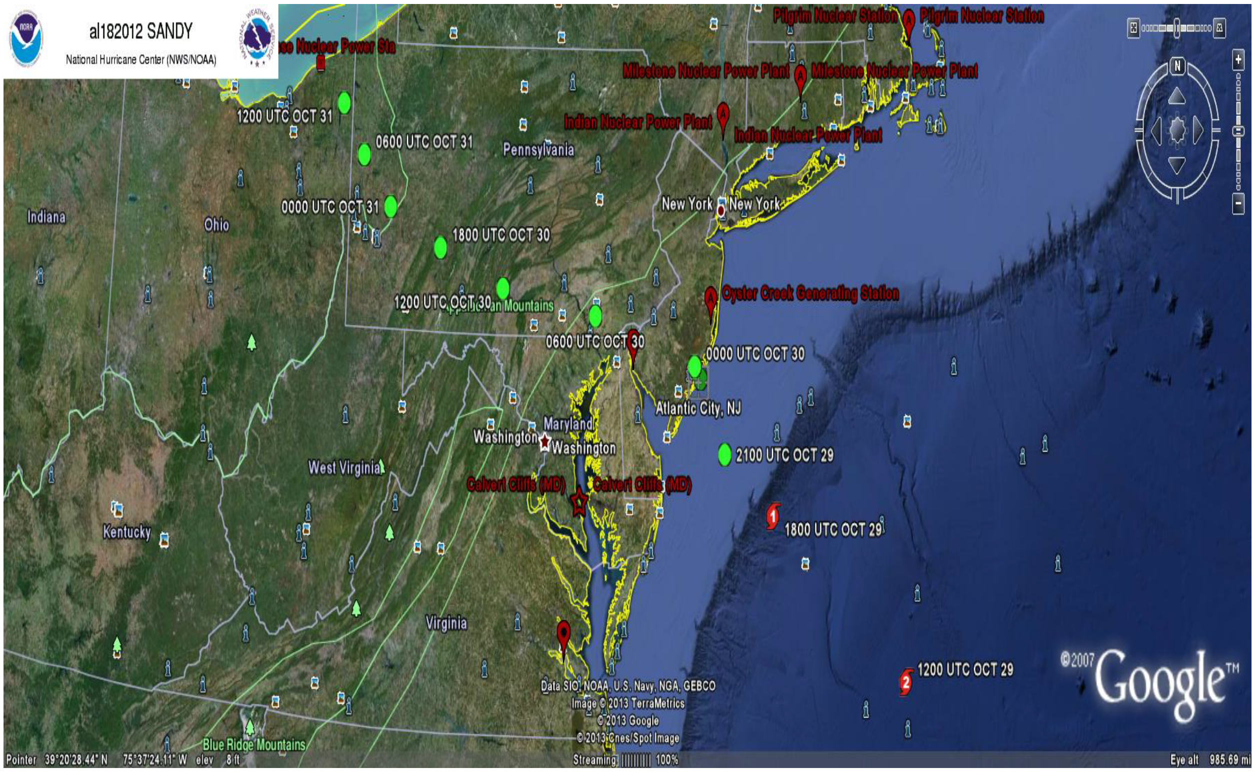

Figure 6. Google map of Hurricane Sandy track as it approached the U.S. coastline.

Storm Surge

The maximum water level observed at OCNGS was 7.4 ft (Table 2) as determined by water level measurements above the base of the service water pumps. **Water levels remained below the service water pump motors and well below the design basis flood height of greater than 22 feet.** This water level was a result of storm surge as noted by the steady rise water level over time. Wind waves would provide a more erratic water level record. However, as previously discussed, the bathymetry of the Bay and intake structure precludes large waves. The OCNGS storm surge analysis estimated wind waves of approximately 1 ft near the intake.

The post-Hurricane Sandy NRC inspection (Reference 2) noted that revision 18 of ABN-32 directed operators to secure all of the service water pumps when the intake level reached 7 ft MSL (e.g., not 6 ft as seen in Table 2). The day shift operating crew identified that the bottom of the service water pump motors was located at approximately 10 ft MSL. Therefore, approximately three feet of available margin existed before the service water pump motors would be impacted. The normal method of decay heat removal from the shutdown cooling and fuel pool cooling systems would therefore remain available.

Table 2. Progression of OCNGS storm surge during Hurricane Sandy

Date (2012)	Time (EST)	Surge Level (MSL)	Remarks
29 OCT	0920	------	Control room operators entered the abnormal operating procedure ABN-32, "Abnormal Intake Level," when intake level downstream of the traveling water screens rose above three feet and the operators began monitoring intake level every four hours.
29 OCT	1346	------	Operators entered ABN-31, "High Winds," due to wind gusts greater than 58 miles per hour.
29 OCT	1847	4.65 ft	Control room operators recognized that intake level had reached the Notice of Unusual Event (NOUE) threshold condition of greater than 4.5 feet.
29 OCT	1655	4.65 ft	The Operations Shift Manager declared an NOUE HU-4.
29 OCT	1954	5.3 ft	Control room operators had to rely on secondary indicators to make emergency action level decisions.
29 OCT	2044	6.25 ft	The operations Shift Manager declared an Alert (HA-4) in response to the report that intake level was greater than 6.0 feet on the intake staff gauge. State and local notifications for the Alert were completed at 2051. **Sandy makes landfall south of plant, near Brigantine, New Jersey with 80 mph winds.**
29 OCT	2311	7.0 ft	The staff gauge is not available above 7 feet
30 OCT	1218	7.4 ft	Max water level observed - determined by water level measurements above the base of the service water pumps. **Water levels remained below the service water pump motors and well below the design basis flood height of greater than 22 feet**
30 OCT	----	----	Intake levels receded below the Alert and NOUE threshold levels at 0629 and 1745, respectively.
31 OCT	----	----	The remnants of Hurricane Sandy weakened over western Pennsylvania.

Conclusion

Hurricane Sandy never exceeded the DBF parameters for OCNGS. The PMH parameters used in the calculation of the 23 ft storm surge is conservative (Table 1) based on the water level observed during Hurricane Sandy (7.4 ft – Table 2) and storm surge studies conducted in 2000 (12 ft - Reference 6) using the Empirical Simulation Technique (EST). The issue for OCNGS is the protection of the intake from storm surge (Reference 11) and the availability of the ultimate heat sink (Reference 10). The NRC post-Hurricane Sandy inspection found that the bottom of the service water pump motors was located at approximately 10 ft MSL. Therefore, approximately three feet of available margin existed before the service water pump motors would be impacted.

Storms like Hurricane Sandy occur late in the hurricane season (September – November) and present no immediate safety concern for OCNGS. In addition, the post Fukushima safety reviews of the current operating nuclear power plants is addressing the site flooding characteristics using the state-of-the-art methodology (Reference 13) as well as emergency procedures.

References

1. Environmental Enforcement Project, Public Justice letter to NRC of November 19, 2012: Emergency 2.206 Petition Regarding Lack of Adequate Protection of Safety at Oyster Creek Nuclear Generating Station Lacy, NJ.

2. NRC letter to Exelon Generation Company, LLC, January 10, 2013: OYSTER CREEK GENERATING STATION - NRC SPECIAL INSPECTION REPORT 05000219/2012009

3. Official Transcript of Proceedings, NUCLEAR REGULATORY COMMISSION: Title: 10 CFR 2.206 Petition Review Board RE Oyster Creek Nuclear Power Plant, Docket Number: 50-219, Location: (teleconference), Thursday, April 18, 2013

4. Oyster Creek Nuclear Power Plant FSAR Revision 16, 2009

5. "Probable Maximum Hurricane Flood Analysis, Oyster Creek Nuclear Unit No. 1," Dames and Moore Inc. Cranford, NJ. 1972

6. Ashok C. Thandani, Director, NRC Office of Nuclear Regulatory Research to Samuel J. Collins, Director, Office of Nuclear Reactor Regulation: Transmittal of Research Information Letter RIL-0001 “Probabilistic Storm Surge Elevations for the Atlantic And Gulf Coasts”

7. Oyster Creek Generating Station FSAR Update (Rev. 0, 1984), Appendix 2.4A (Flood Level Studies)

8. Naval Oceanographic Office, 2001 (Excerpt). Practical Methods for Observing and Forecasting Ocean waves by Means of Wave Spectra and Statistics, HO Pub 603.

9. Dalrymple, Robert A. and Robert G. Dean, 1991. Water Wave Mechanics for Engineers and Scientist. *Advanced Series on Ocean Engineering, Volume 2, World Scientific*.

10. NRC, 1976a, Regulatory Guide 1.27, “Ultimate Heat Sink for Nuclear Power Plants, Revision 2,” U.S. Nuclear Regulatory Commission, January, 1976.

11. NRC, 1976b, Regulatory Guide 1.102, 1976. “Flood Protection for Nuclear Power Plants.” Rev. 1, U.S. Nuclear Regulatory Commission, Washington D.C.

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13. NRC, 2012, Japan Lessons-Learned Project Directorate Interim Staff Guidance (JLD-ISG), JLD-ISG-2012-06, “Guidance for performing a Tsunami, Surge, or Seiche Hazard Assessment.”