2.8 <u>CHESAPEAKE BAY STUDIES</u>

The Calvert Cliffs site is located on the western shore of the Chesapeake Bay approximately at the mid-point of its 195 mile length. The Chesapeake Bay is the largest tidal estuary on the Atlantic Coast, roughly comparable in size to Lake Ontario. Its width ranges from 3 miles to 35 miles. Major tributaries include the Susquehanna, Patapsco, Choptank, Patuxent, Potomac, Rappahannock, York, and James Rivers.

The site is located on the western shore of the Bay, approximately 10 miles north of the Patuxent River, and 25 miles south of the Choptank River which enters from the eastern side of the Bay. At the site, the Bay is approximately 6 miles wide. Water depths up to 110' are found in the main channel of the Bay at the site, with depths of 6, 12, and 18' found at distances of 750, 1200, and 1500' offshore, respectively.

2.8.1 USES OF THE BAY

The Chesapeake Bay in the general vicinity of the site is utilized for fisheries' resources, navigation, and recreation. Shellfish (oysters and clams), crabs, and finfish are taken commercially from the area. A natural oyster bar of 680 acres had extended in front of the site. However, in 1969, BGE relocated approximately 500 acres of the bar to a location in the Patuxent River.

Navigational interests, both ocean-going and local Bay vessels, utilize the Chesapeake Bay extensively. Major shipping channels are situated some 3500' or more from the Calvert Cliffs site.

Recreational use of the Bay in the vicinity of the site is primarily boating and sport fishing. Water-contact recreation at the site location is negligible.

2.8.2 COMPREHENSIVE STUDY PROGRAM

The need to control and minimize adverse effects on the Chesapeake Bay from the construction and operation of the Calvert Cliffs Plant was recognized at the start of the project planning. In keeping with this objective and to assure conformance with the water quality standards of the State of Maryland, shortly after the site was purchased a team of research consultants was assembled to develop the information needed for guiding the design, construction and operation of the plant. The study program and its findings have been discussed frequently with appropriate State and Federal agencies during the course of the work.

The principal consultants were Sheppard T. Powell Associates, Academy of Natural Sciences of Philadelphia, Alden Research Laboratories of Worchester Polytechnic Institute, Dr. John C. Geyer of Johns Hopkins University and NUS Corporation of Rockville, MD. During studies concerning water quality in 1979-1981 Ecological Analysts, Inc. and J. E. Edinger Associates, Inc. were added to the team of consultants.

The effect of the condenser cooling water discharge on temperatures in the Chesapeake Bay was studied by the Alden Research Laboratories through operation of hydraulic models which simulated flows in a 34 mile stretch of the Bay and the areas within a few thousand feet from the plant site. The objective of the studies was to determine the optimum arrangement of the cooling water system to achieve rapid dispersion of effluents and minimize water temperature variations in the area of plant influence. Results of tests on the final design arrangement were reported in December 1969.

In order to provide a baseline for assessment of the effects of plant operation on the aquatic environment, the Academy of Natural Sciences of Philadelphia engaged in a seven-year program of compiling a comprehensive inventory of the population, species,

and condition of the aquatic life in the area, and detailed information on the physical, chemical, and bacteriological characteristics of the Chesapeake Bay near Calvert Cliffs. These studies have been completed for five years of operating conditions.

In accordance with the requirements of the Calvert Cliffs PSAR and the conditions of the Atomic Energy Commission (AEC) construction permits, BGE initiated in 1969 work on the design and development of the environmental radiological monitoring program for Calvert Cliffs. Concurrent with the design, development and operation of the monitoring program, BGE in contract with NUS initiated several studies to assess the potential radiological impact of expected radioeffluents from Calvert Cliffs.

A review of the results of these studies was made in conjunction with other known environmental data. The purpose of this review was to ascertain the significance of the various exposure pathways and to identify the "potential critical pathways" in the area of the facility. The results of this review and the mandatory compliance requirements, based on the AEC limitations on 1971 (proposed 10 CFR Part 50, Appendix I), determined the scope of the monitoring program described in Section 2.9.

In June 1974, BGE received discharge permits from both the Water Resources Administration of the State of Maryland and from the Environmental Protection Agency authorizing the discharge of heated condenser cooling water into the Chesapeake Bay. In June 1976, BGE received a National Pollution Discharge Elimination System (NPDES) permit which consolidated the previous two permits. The NPDES permit is periodically renewed on a schedule established by the Maryland Department of the Environment.

On July 31, 1974, the AEC issued a facility operating license authorizing the power operation of CCNPP in accordance with a set of Environmental Technical Specifications. The Non-Radiological section of the Environmental Technical Specification (Appendix B) was amended by the Nuclear Regulatory Commission (NRC) by deletion of four sections dealing with environmental monitoring on March 25, 1981. Some of the aquatic programs had been completed and the remainder are the responsibility of the NPDES program of the State of Maryland.

The above-mentioned documents require that the plant is to be operated in such a manner as to ensure compliance with the State of Maryland Water Quality Regulations, and also require that monitoring programs are conducted to determine the effects of the operation of the plant on the physical, chemical and biological characteristics of the Chesapeake Bay. In order to implement these requirements, the Academy of Natural Sciences of Philadelphia and Radiation Management Corporation of Philadelphia are continuing the programs initiated before the operation of the plant. Baltimore Gas and Electric Company has performed programs to study specialized areas, such as the impingement of organisms on the traveling screens and the passage of organisms through the condenser cooling water system. The results of these studies indicate the plant meets State mixing zone criteria, the entrainment does not impact a spawning or nursing area of consequence, and the impingement cannot be cost effectively mitigated any further. The PPSP has concurred with these findings.

2.8.3 HURRICANE TIDAL EFFECTS

2.8.3.1 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. In his report (Reference 1) on hurricane tides and tidal flooding in the Chesapeake Bay area, the District Engineer, Baltimore Corps of Engineers District, notes that U.S. Weather Bureau records show at least 80 tropical hurricanes or their

remnants have affected the bay area in the 75 year period since 1889. By far the most destructive hurricane in recent years to affect the Chesapeake Bay region was the hurricane of August 23, 1933. Other notable storms were hurricanes "Hazel" in October 1954, "Connie" and "Diane" in August 1955 (only 5 days apart), and "Donna" in September 1960. The "Great Atlantic Hurricane" of September 1944, which passed some 50 miles offshore of 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. Numerous studies have been made of the more significant hurricanes to have affected the Middle Atlantic and New England States (References 2, 3, 4, 8, 9, and 11) in which their paths, intensities, forward speeds, resulting tides and other associated phenomenon have been well documented. In general, record hurricanes passing over or near Chesapeake Bay have had central pressures of from 27.8 to 28.5"; peak wind speeds over the ocean approaching 100 mph, and maximum winds over the bay area of up to 75 mph. Following recurvature in the middle latitudes 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, which resulted in 4.9’ mean low water (MLW) tide in the lower Potomac River, was about the worst experienced along the Atlantic Coast.

2.8.3.2 Tides and Storm Surges

Normal Tides - Normal tides in the bay area are the semidiurnal type having two highs and lows roughly every 23-1/2 hours, with a higher high and lower low as a daily occurrence. Information contained in Reference 5 shows normal and spring tide ranges at various locations in Chesapeake Bay as follows:

	Mean Tidal Range (ft)	Spring Tidal Range (ft)
Kiptopeke Beach (Ocean)	2.7	3.2
Hampton Roads	2.5	3.0
Cape Charles Harbor (Bay)	2.4	2.8
Point Lookout	1.2	1.4
Cove Point	1.2	1.4
Taylors Island	1.3	1.5
Oxford	1.4	1.6

The mean and spring tide ranges to be expected at the site are 1.2 and 1.4’, respectively. The time occurrence of daily high and low tides within the Chesapeake Bay, related to time of occurrence at Hampton Roads and Baltimore, is also given in Reference 5. From the data given in Table 2 of that reference, it was ascertained that the travel time of high and low tide occurrence from the Bay entrance to the site area is approximately 5 hours.

Storm Surges and Extreme High Tides - Storm surges and extreme high tides have been recorded at numerous locations in Chesapeake Bay and in the various rivers entering the Bay. Plate 2 of Reference 1 shows peak tide elevations above MLW of 8.2’ at Solomons Island near the mouth of Patuxent River and 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 time-frequency curve was developed for the

Chesapeake Bay area in Reference 1 (Plate 3) utilizing observed hurricane surge elevations. A reproduction of that relation is shown on Figure 2.8-1, Generalized Time-Frequency Curve. 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 (Hampton Roads) 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. Analysis of observed hurricane tide hydrographs in References 2 and 3 shows this effect to be quite pronounced. For example, in the August 1949 hurricane, which passed to the west of Chesapeake Bay, below-normal tides were experienced at Hampton Roads and Norfolk. Similarly, in the June 1945 hurricane, which passed east of the bay, a peak tide of 3' was recorded at Hampton Roads, whereas a low tide of over a foot below normal was recorded at Baltimore.

2.8.3.3 Tide and Storm Surge Analysis

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 13).

2.8.3.4 Probable Maximum Hurricane

Parameters describing the maximum probable hurricane were selected from Reference 13 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. The standard project hurricane derived in Reference 6 as hurricane "B" had a pressure anomaly of 2.2" of mercury which would mean a central pressure of about 27.75" of mercury. A probable maximum hurricane (PMH) was derived in Reference 10 for the New York Bay area. The pressure and wind patterns constructed for that storm are shown on Figure 43 of that report. The minimum pressure of that hurricane, when opposite the entrance to Chesapeake Bay, is 27.02" of mercury. A central pressure of 26.94" was selected.

Asymptotic Pressure (P_n) - A value of 30.92" was taken from the envelope curve shown on Figure 6 of Reference 13 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. That value lies between moderate and large radius values recommended in Table 1 of Reference 13.

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 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 plant site. A very slow moving storm would permit the Bay surge to crest at the site 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 2.8-2. 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, and run on a GE 415 Computer. The output of the program can be seen on Tables 2-41 and 2-42. Methods used to derive the PMH conform to those given in Reference 13. Graphical representation of the overwater wind profile, the pressure and pressure effect profiles can be seen on Figure 2.8-3. An isovel pattern was constructed for transposition purposes using data given in Table 2-42. That pattern is shown on Figure 2.8-4.

2.8.3.5 Tidal Surge Computations

General - 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 14). 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. Basic offshore depths, fetch, wind speed data, and Cos c values, together with general map features from wind speed data, and Cos c values, together with general map features from C&GS Chart No. 1222 can be seen on Figure 2.8-5. 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. Data for that storm and its resulting tide can be found in Table 1 and Figure 2 of Reference 6.

Procedures - An offshore bottom profile along the fetch noted on Figure 2.8-5 is plotted on Figure 2.8-6. Average depths offshore along a fetch of about 88 statute miles range from 22' to 800'. The normal tide relations used are as follows:

a. At Hampton Roads:

   Mean Tide Range = 2.5' MLW
   Normal High Tide (NHT) = 1.2' + MLW

b. At Cove Point (near Plant Site):

   Mean Tide Range = 1.2' MLW
   NHT = 0.6' MLW

The basic assumptions made for the surge computations are as follows:

a. PMH surge at bay entrance coincident with NHT at entrance.

b. Beginning elevation of surge computations
   E1 (Mile 105) = NHT + PE
   E1 = 1.2' + 1.5' = 2.7' MLW

c. Five-mile fetch lengths used with miles shown on Tables 2-43 and 2-44 as mid-point.

d. Average depth values, $\bar{d}$, taken from offshore depth profile, Figure 2.8-6, at mid-points of 5-mile reaches.

e. Values of μ (wind speed) from isovel pattern at 5-mile fetch increments.

f. Surge computation procedures from Reference 14 (Formula 1-65, page 140).

g. Pressure effect values taken from PMH parameters, Figure 2.8-3.

h. PMH approach speed = 23 mph. Speed of free wave in Chesapeake Bay for 40 to 50' average bay depth = 24 to 27 mph.

   $\left(v = \sqrt{gD}\right)$

i. Assume PMH forward speed overland increases slightly from 23 mph to speed of free wave in bay. Storm accompanies surge up the bay to plant site.

j. Distance from bay entrance to Calvert Cliffs plant site = 110 miles (statute). At 24-27 mph, the surge would travel from bay entrance to plant site in 4+ to 5 hours.

k. Normal high tide will occur at plant site 4+ to 5 hours after NHT in channel entrance. Coincident peak surge at NHT will thus occur at both locations, with 4+ to 5-hour time difference.

l. Overland reduction in PMH intensity - used factors given in Table 2a, Reference 13; at T+5 hours reduction factor = 80% μ max at site area = 136x.80 = 110 mph.

It was assumed that NHT at shore would occur coincident with the peak hurricane surge. Basic data along the fetch for time T_o are given in Table 2-43; those data were employed in the computational procedures and formula as shown on Table 2-44.

<u>Results</u> - The peak tidal surge elevation that would occur at the Bay entrance was computed to be <u>18.67' MLW</u> (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.

<u>Chesapeake Bay Surge Analysis</u> - A comprehensive analysis of the interrelationships involved in tidal surge movement up Chesapeake Bay was presented in Reference 6. In that report, it was shown that a reduction in ocean surge occurs in its passage 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. The results of that analysis were utilized for prediction purposes. The relationship shown on Figure 15 of that report relates the maximum surge on the open coast to that to be

expected in the southern portion of the Bay. The relation extends within the range of the computed PMH surge elevation. Using the mean prediction curve and the value of 18.67' MLW, the value of 13.2' ± 0.8' would be obtained for the surge Elevation of 14.0' MLW. Movement of the surge up the Bay to the plant site 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 was found in Reference 6 to result in a further minor reduction in surge height in its passage up the Bay. Table IV of that report indicates a factor of 0.96 times the surge elevation in the lower Bay will give the value of the surge elevation to be expected in the vicinity of the plant site. 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 plant 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 NHT at the site, 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. Table 2 of Reference 12 lists the reduction factors to be applied with respect to travel time overland. At T_{+5} hours, a factor of 80% is considered applicable. 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 plant site at the time the peak surge reaches that area. An evaluation of wind speed and direction was made for that condition. Wind speeds of 115 to 120 mph (117 mph average) were found to be applicable for the wind direction and fetch conditions shown on Figure 2.8-7. An effective crosswind of 94 mph (117x0.80) was, therefore, used to compute the additional height of Bay setup. An average bottom profile shown on Figure 2.8-8 was constructed using data from Figure 2.8-7. The total fetch length is approximately 10 Statute miles. Preliminary estimates indicated the node line along the fetch would be at about Mile 4.0 east of the western Bay shore. A summary of setup computations is given in Table 2-45. The computed setup elevation in the vicinity of the plant site 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 site of 16.21' MLW (15.6' MSL).

Wave Analysis - The significant wave height that can be expected to occur in the vicinity of the plant site during the PMH peak surge will be a function of wind speed, water depth, and length of available fetch (Reference 7). Evaluation of average water depth with fetch length in the Bay offshore indicates a 50'-depth for about 7 miles; a 40'-depth for about 9 miles. Using a wind speed of 94 mph and Figures 1-40 and 1-42 of Reference 14, results in a significant wave height of 11.4'; with a corresponding wave period of 9 seconds (Figure 1-43). The wave will break in approximately 14-1/2' 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.

Wave Run-up - The maximum wave run-up elevation at the intake structure was previously calculated to be 28.1' MLW or 27.5' MSL. A series of scale model tests was performed at the University of Florida with an adverse slope on the top of the pump room wall. Six tests were performed to represent still-water levels of 16.2', 17.2' and 18.2', each with and without the baffle wall. Results (Figure 2.8-9), indicate that there will be no overtopping of the intake structure.

The calculated run-up elevations on the slopes north and south of the intake structure are well below the plant grade of Elevation 45'.

2.8.3.6 Wave Run-up at Intake Structure

Introduction - The saltwater cooling pumps, which are essential for safe shutdown of the CCNPP, are housed in the intake structure. Since these are Class I components, it was decided to design the enclosure as a Category I structure for seismic, tornado, and hurricane conditions. The hurricane surge calculations in Section 2.8.3.5 are based on implementation of References 13 and 14. Using a number of conservative assumptions and the results of a series of model wave run-up tests at the University of Florida, it is concluded that the structural integrity of the intake structure will be maintained under PMH conditions. Thus, the saltwater cooling pumps can continue to operate under PMH conditions.

Configuration of the Intake Structure - The intake structure has an open deck at Elevation 10.0' MSL on the Bay side. The deck is about 50' wide and has openings for the trash rakes and racks, stop logs, and traveling screens.

Behind this open deck is an enclosure housing the circulating water pumps and saltwater cooling pumps. The roof of the pump room is at Elevation 28.5' MSL and has watertight hatches to provide access to the pumps for maintenance. An intake structure air supply unit is mounted on each saltwater pump hatch, and an air exhaust vent is mounted on each circulating water pump hatch. To minimize entry of moisture into the pump room, each air supply unit and air exhaust vent housing is provided with louvers designed for high moisture separation efficiency. Similarly, a separate ventilation system draws outside air through the service building (west wall) to minimize water entry. The personnel door located at the north end of the intake structure is of a watertight design.

Model Tests - The configuration of the intake structure is not one of the classic profiles which has been tested in the past. That is, it is not a curved or vertical wall, a stepped wall, or a riprap-covered wall like those shown in Figures 3-6 through 3-10 in Reference 14. However, T. E. Haeussner prepared a report predicting a maximum run-up Elevation of 28.1' MSL based on the curves of Figure 3-6, with an appropriate reduction factor for the case of waves breaking on the front edge of the intake structure.

There were questions on this approach and it was decided to perform two-dimensional model tests at the University of Florida to determine the run-up elevation. These tests were run with a prototype wave period of 9.0 seconds and wave height of 11.4', the significant wave height. Both of these values appear in Section 2.8.3.5. Three still-water Elevations were tested: 16.2', 17.2', and 18.2' MSL. The lowest of these, 16.2' MSL, was 0.6' higher than the value calculated in Section 2.8.3.5, due to confusion between MSL and MLW. The higher still-water elevations were to account for some differences of opinion as to the appropriately-conservative value.

During the tests, considerable overtopping resulted in the early runs, so the adverse slope (upper 5' of pump room sloping out at 20% angle) was added. This adverse slope appeared to eliminate the overtopping. Even with the still-water at 18.2' MSL, an analysis of the test runs indicates that the run-up carries only to Elevation 26.5' MSL, a run-up of 8.3'. Figure 2.8-9 shows the output of the final test runs. A color film was available for viewing. Table 2-46 is a summary of the model test results compared with run-up computed from Figure 3-6 in Reference 14. The highest model/computed ratio is 0.50.

Predicted Wave Run-up - There have been questions as to the conservatism of basing wave run-up on the run-up from the significant wave. Therefore, the results

of the University of Florida tests were used as a predictive tool along with the wave height corresponding to H1, the average of the highest 1% of waves. This is the wave height recommended for design of rigid structures in Reference 14. In Reference 15, C.L. Bretschneider found the expression

$$\frac{H_{max}}{H_s} = \left(145\ \frac{gd}{U^2}\right)^{0.1}$$

where:

H_{max}	=	maximum wave height
H_s	=	significant wave height
g	=	acceleration of gravity, 32.2 ft/sec^2
d	=	depth, in ft
U	=	wind velocity, in ft/sec (138 for Calvert Cliffs)

Solving this expression gives H_{max} = 1.27 H_s for 40' depth, and H_{max} = 1.30 H_s for 50' depth. Fitting these values to a normal curve approximation yields H_1 - 1.23 H_s for 50' 1.23 (11.4') = 14.0. Thus, the design wave for the intake structure is 14.0' high.

As explained previously, the still-water levels tested at the University of Florida were 0.6' high. Using a still-water Elevation of 17.6' MSL, which was calculated by the AEC's consultant, using the 14.0' wave with a period of 9 seconds and using the curves of Reference 14, Figure 3-6 with a reduction factor of 0.50 (the highest model/computed ratio in Table 2-46), the calculated wave run-up is to Elevation 27.1' MSL, 1.4' below the pump house roof.

As a comparison with the approach, the following check was made, again based on model test results:

Run-up with SWL of 17.2' MSL	=	7.3'
Run-up with SWL of 18.2' MSL	=	8.3'
Interpolating, run-up for 17.6' MSL	=	7.7'
Multiplying by H_1/H_s (1.23)	=	9.5' for 14.0' wave
Add still-water level	=	<u>17.6'</u>
Run-up for 14.0' wave	=	27.1' MSL

Analysis was also made of the same conditions with periods of 5 and 12 seconds and resulted in somewhat less run-up. There was a question of model scale effects. The predicted run-up of 9.5' came to 1.4' below the pump house roof, so that a run-up of 10.9' would not overtop the structure. (10.9/9.5) = 1.15. Thus, the structure allows for model scale effects of 15%. This is a greater increase in run-up than predicted from use of the method of effective slope outlined in Reference 14.

<u>Structural Analysis of the Intake Structure</u> - The intake structure has been analyzed for seismic and tornado loadings. In addition, although it is not expected that the pump house portion of the structure will see breaking or broken waves, the intake structure has been analyzed for the following hurricane loading conditions:

a. Nonbreaking wave for water to the top of the roof, Elevation 28.5' MSL; still-water level of 17.6' MSL; and wave periods of 5, 9, and 12 seconds.

b. Broken wave for a wave height of 14.0'; still-water level of 17.6' MSL; and wave periods of 5, 9, and 12 seconds.

c. Breaking wave for the highest wave which could continue unbroken across the front edge of the structure. Since the still-water level is 17.6' MSL and

the deck Elevation is 10.0' MSL, the controlling depth is 7.6'. Thus, the maximum wave height is 0.78x(7.6) or 5.9'. This condition also has been examined for periods of 5, 9, and 12 seconds.

For each of the above loading conditions, the analysis shows that structural integrity will be maintained.

Additional Considerations - Curbs a minimum of 6" high are provided around the roof hatches. The roof and hatch covers are designed for a live loading of 250 psf. The louvered housings for intake structure air supply units and exhaust vents are designed for a live load of 100 psf.

The baffle wall in the intake channel is designed for conditions less than PMH (85 mph wind with a 9-second period, 10.5' high wave).

However, the Florida tests indicate that there would be no overtopping of the intake structure whether or not the baffle wall is in place during the PMH. An analysis showed that even if sections of the wall came loose, they would not damage or block the intake structure. In addition, the saltwater cooling pumps are redundant (two out of three required for each unit) and each can take suction from either of two screen wells.

The concrete stop logs were stored in a recess to the south of the pump house. Thus, they were not considered to be a missile for the intake structure design.

Scour at the front edge of the structure is not expected since there is a very low velocity past this point (about 1 ft/sec), and since the foundation soil is a dense silty sand or sandy silt.

There will be no resonant vibration of the structure due to the waves. The structure's natural frequency is about 3 CPS.

Conclusions - The following conclusions are drawn from the studies performed:

a. The predicted wave run-up is to Elevation 27.1' MSL, 1.4' below the pump room roof elevation.

b. The structural integrity of the intake structure will be maintained during hurricane conditions.

c. The saltwater cooling pumps can continue to operate under hurricane conditions.

2.8.3.7 Extreme Low Tide Considerations

Normal Tides and Tidal Datum - Normal tides in Chesapeake Bay are semidiurnal, or of the mixed type with two highs and two lows occurring daily; and with a higher high and lower low tide level as a daily occurrence. Information available in Reference 5 for Taylors Island, located across the Bay from the site, gives a mean range of 1.3', a spring range of 1.5', and a mean tide level of 0.6'. The latter value indicates that sea level is 0.6' above low water datum. The extreme annual range is approximately 2.3', occurring in December.

Low Tide Considerations - Various factors affect and, to a large extent, control the value of extreme low tide elevation at the site. Essentially, they are as follows:

a. Hurricane wind direction, duration and intensity in storms passing offshore of Chesapeake Bay. Counterclockwise rotating winds from the northeast to

northwest over the Bay will prevail for such a storm path and have the greatest effect in lowering Bay tide levels.

b. The location of the plant site with respect to the total length of the Bay.

c. Depth of water in the Bay, especially along available west-east tide fetches for generation of maximum set-down at shore.

d. General orientation of the Bay, length of the Bay and degree of curvature of the longitudinal axis corresponding to wind streamline curvature of hurricane winds over the Bay.

The general orientation of the Chesapeake Bay is north-south, its length from Baltimore to Norfolk is about 165 miles. The site is about two-thirds of that distance from Norfolk. Records of hurricane tides, shown on path and tide maps in References 2, 3, and 5, indicate that for hurricanes passing offshore of the Bay, maximum drawdown in the Bay occurs at the windward end, i.e., Baltimore, becoming less with distance southward toward the mouth of the Bay. For example, in Hurricane Donna of September 1960 (Figure 3, page 188 of Reference 5), the drawdown at Baltimore was to -2.6' MLW; to -1.5' at Annapolis; to -1.0' at Solomons; and to -0.8' at Portsmouth. Analyses of other hurricanes with similar wind conditions over the Bay, such as the October 1944, September 1947, and October 1954 hurricanes, show much the same variation in tidal drawdown within the Bay. Because of its location, Calvert Cliffs does not experience the maximum effects of Bay drawdown, as is indicted by observed data. The maximum drawdown elevation presumably occurred in Hurricane Donna, and is estimated to have been about -1.2' MLW (1.7' MSL). The extreme low tide elevation occurrence believed possible at Calvert Cliffs is predicated on an occurrence of the PMH on a path offshore of Chesapeake Bay, similar to that of Hurricane Donna. Correlating wind intensity over the Bay of the PMH with that of Donna and the drawdown elevations experienced in Donna, an estimated drawdown Elevation of -3.0' could be expected to occur at Baltimore with a value of -1.6' at the site. With a counterclockwise wind shift from north to west over the Bay, an additional setdown of about 0.5' could be expected to occur, giving an extreme low tide Elevation of -2.1' MLW (-2.7' MSL) at the site.

The predicted extreme low tide Elevation is -3.6' MSL (-3.0' MLW). However, the plant has been designed for -4.0' MSL and can continue to operate with an extreme low water Elevation of -6.0' MSL. The top of the saltwater pump intakes is at Elevation -9.5' MSL.

2.8.4 REFERENCES

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4. Inter-Agency Committee Report, The Resources of the New England - New York Region, Part Two, Chapter XXXIX, Special Subjects Regional, Hurricanes, Volume 4, December 1954

5. Tide Tables, 1967 East Coast, North and South American, U.S. Department of Commerce, ESSA, Coast and Geodetic Survey

6. Miscellaneous Paper No. 3-59, Hurricane Surge Predication for Chesapeake Bay, BEB, September 1959

7. Technical Memorandum No. 83, Reid, R. D, Approximate Response of Water Level on a Sloping Shelf to a Wind Fetch Which Moves Toward Shore, BEB, June 1956

8. N.H.R.P. Report No. 50, part II, Proceedings of the Second Technical Conference on Hurricanes, U.S. Weather Bureau, March 1962 (pp 341-354)

9. N.H.R.P. Report No. 14, B. I. Miller, On the Maximum Intensity of Hurricanes, U.S. Weather Bureau, December 1957

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12. Miscellaneous Publication, Revisions in Wave Forecasting; Deep and Shallow Water, C.L. Bretschneider, BEB, 1957

13. Environmental Science Services Administration Memorandum HUR 7-97, "Interim Report - Meteorological Characteristics of the Probable Maximum Hurricane, Atlantic and Gulf Coasts of the United States"

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TABLE 2-41

BASIC INFORMATION FOR CONSTRUCTING PMH ISOVEL PATTERN

DISTANCE FROM CENTER	OVERWATER WIND PROFILE	PRESSURE EFFECT	PRESSURE
7.5	42.05	4.45	27.01
15.0	81.16	3.92	27.48
22.5	111.92	3.34	27.99
30.0	124.71	2.87	28.40
40.0	110.14	2.39	28.82
50.0	96.07	2.05	29.12
60.0	87.81	1.79	29.35
70.0	81.24	1.58	29.53
80.0	74.47	1.42	29.68
90.0	68.90	1.29	29.79
110.0	62.11	1.08	29.97
130.0	56.48	0.94	30.10
150.0	51.50	0.82	30.20
170.0	47.03	0.73	30.28
190.0	42.96	0.66	30.34
210.0	39.22	0.60	30.39
230.0	35.74	0.55	30.43
250.0	32.48	0.51	30.47
R	T	P_o	P_n
30.00	23.00	26.94	30.92

TABLE 2-42

ANGLES MEASURED FROM LINE OF FORWARD MOTION (USED FOR CONSTRUCTING ISOVEL PATTERN)

DIST.	25	55	85	115	145	175	205	235	265	295	325	355
7.5	42.0	47.8	52.0	53.5	52.0	47.8	42.0	36.3	32.1	30.5	32.1	36.3
15.0	81.2	86.9	91.1	92.7	91.1	86.9	81.2	75.4	71.2	69.7	71.2	75.4
22.5	111.9	117.7	121.9	123.4	121.9	117.7	111.9	106.2	102.0	100.4	102.0	106.2
30.0	124.7	130.5	134.7	136.2	134.7	130.5	124.7	119.0	114.7	113.2	114.7	119.0
40.0	110.1	115.9	120.1	121.6	120.1	115.9	110.1	104.4	100.2	98.6	100.2	104.4
50.0	96.1	101.8	106.0	107.6	106.0	101.8	96.1	90.3	86.1	84.6	86.1	90.3
60.0	87.8	93.6	97.8	99.3	97.8	93.6	87.8	82.1	77.8	76.3	77.8	82.1
70.0	81.2	87.0	91.2	92.7	91.2	87.0	81.2	75.5	71.3	69.7	71.3	75.5
80.0	74.5	80.2	84.4	86.0	84.4	80.2	74.5	68.7	64.5	63.0	64.5	68.7
90.0	68.9	74.7	78.9	80.4	78.9	74.7	68.9	63.2	58.9	57.4	58.9	63.2
110.0	62.1	67.9	72.1	73.6	72.1	67.9	62.1	56.4	52.2	50.6	52.2	56.4
130.0	56.5	62.2	66.4	68.0	66.4	62.2	56.5	50.7	46.5	45.0	46.5	50.7
150.0	51.5	57.2	61.5	63.0	61.5	57.2	51.5	45.7	41.5	40.0	41.5	45.7
170.0	47.0	52.8	57.0	58.5	57.0	52.8	47.0	41.3	37.1	35.5	37.1	41.3
190.0	43.0	48.7	52.9	54.5	52.9	48.7	43.0	37.2	33.0	31.5	33.0	37.2
210.0	39.2	45.0	49.2	50.7	49.2	45.0	39.2	33.5	29.3	27.7	29.3	33.5
230.0	35.7	41.5	45.7	47.2	45.7	41.5	35.7	30.0	25.8	24.2	25.8	30.0
250.0	32.5	38.2	42.4	44.0	42.4	38.2	32.5	26.7	22.5	21.0	22.5	26.7

TABLE 2-43

BASIC DATA - PMH - FETCH

FETCH MILE	μ (mph)	Cos c VALUE	μ Cos c = μ_x	$\overline{\mu\mu_{\bar{x}}}$ (mph)^2	DIST. FOR P_e (miles)	P_e (ft)	ΔP_e (ft)	DEPTH @X (ft MLW)	
X = 0	116	0.42	49	5,684	39	2.42	-.10	0	Hampton Roads
5	122	0.52	63	7,690	37	2.52	-.13	19	
10	127	0.60	76	9,650	34	2.65	-.10	23	
15	131	0.70	92	12,040	32	2.75	-.11	25	
17.5									Bay Entrance
20	133	0.80	106	14,100	30	2.86	0	24	
25	136	0.90	122	16,600	30	2.86	0	32	
30	136	0.93	127	17,300	30	2.86	0	46	
35	136	0.97	132	17,950	30	2.86	0	60	
40	136	0.98	133	18,100	30	2.86	0.11	62	
45	135	0.95	128	17,300	32	2.75	0.10	65	
50	130	0.93	121	15,700	34	2.65	0.13	70	
55	126	0.88	111	14,000	37	2.52	0.10	76	
60	120	0.85	102	12,230	39	2.42	0.14	82	
65	115	0.80	92	10,620	43	2.28	0.11	90	
70	110	0.75	83	9,130	46	2.17	0.12	99	
75	105	0.70	73	7,660	50	2.05	0.12	100	
80	100	0.65	65	6,500	54	1.93	0.08	106	
85	97	0.60	58	5,630	57	1.85	0.05	112	
90	94	0.56	53	4,980	60	1.80	0.13	130	
95	90	0.52	47	4,230	65	1.67	0.09	180	
100	87	0.50	44	3,828	70	1.58	0.07	300	
105	84	0.45	38	3,200	74	1.51	-	800	-Deep Water

TABLE 2-44

PMH SURGE COMPUTATION - OCEAN TO BAY ENTRANCE

$E_1 = 2.7$

χ (Mid Point)	$\bar{d}$ (ft)	ΔPe (ΔS_1) (ft)	$\bar{d} + S_1$ (ft)	$\bar{d}_T$ (ft)	$\overline{\mu\mu_{\bar{x}}}$ 2 (mph)	ΔS_i (ft)	S_2 (ft)	E_2 (ft MLW)
105	800	0.07	800.+	803	32,000	0.024	0.024	2.724'
100	300	0.07	300.+	303	3,828	0.077	0.10	2.80'
95	180	0.09	180.+	183	4,230	0.128	0.23	2.93'
90	130	0.13	130.+	133	4,980	0.227	0.46	3.16'
85	112	0.05	112.+	116	5,630	0.296	0.76	3.40'
80	106	0.08	106.+	110	6,500	0.36	1.12	3.82'
75	100	0.12	100.+	104	7,660	0.45	1.57	4.27'
70	99	0.12	99.+	104	9,130	0.53	2.10	4.80'
65	90	0.11	90.+	95	10,620	0.68	2.78	5.48'
60	82	0.14	83	89	12,230	0.83	3.61	6.31'
55	76	0.10	77	84	14,000	1.01	4.62	7.32'
50	70	0.13	71	79	15,700	1.21	5.83	8.53'
45	65	0.10	66	75+	17,300	1.39	7.22	9.92'
40	62	0.11	62.+	75	18,100	1.46	8.68	11.38'
35	60	0	60.+	74	17,950	1.47+	10.15	12.85'
30	46	0	46.+	61	17,300	1.72	11.87	14.57'
25	32	0	32.+	48	16,600	2.10	13.97	16.67'
20	24	0	24.+	43	14,100	2.00	15.97	18.67'

S_0 (Max.) - Surge Elevation at Bay Entrance (Mile 17.5) - 18.67' MLW or 17.32' MSL.

TABLE 2-45

BAY SETUP COMPUTATIONS AT PLANT SITE

Used Parametric Relationship (Corps of Eng. - Jax. Dist)

Based on Formula: $S = \frac{F_{\lambda}\tau_s}{\lambda D}$ (N factor not included)

SETUP PORTION E_1 = 13.44' + 0.6' = 14.04'

17

Fetch F miles	υav mph	Dav ft	W/T Slope(1) ft/M1.	Setup S ft	Σ_s ft	$D+\frac{\Sigma S}{2}$ ft	Setup S(2) ft	$\sum_s$ ft	E_2 ft MLW
2.70	94	56.4	0.20	+0.54	0.54	56.7	0.51	0.51	14.55'
0.30	94	40.4	0.20	0.06	0.60	40.7	0.07	0.58	14.62'
0.65	94	28.4	0.38	0.25	0.85	28.8	0.24	0.82	14.86'
0.35	94	19.4	0.54	0.19	1.04	19.9	0.19	1.01	15.05'
0.15	94	8.4	1.40	0.21	1.25	9.0	0.16	1.17	15.21'
4.15									

Surge in bay + crosswind effect	=	15.21'
Added wave effect	=	1.00' (est.)
Total Tide	=	16.21' MLW
		(15.6' MSL)

TABLE 2-46

WAVE RUN-UP AT INTAKE STRUCTURE

Comparison of Model and Computer Wave Run-up

	STILL-WATER ELEVATION (MSL)	COMPUTED RUN-UP (T.R. 4, Figure 3-6)	MODEL RUN-UP	MODEL/ COMPUTED RATIO
16.2'	14.8'	6.7'	0.45	
	17.2'	16.2'	7.3'	0.45
	18.2'	16.7'	8.3'	0.50