Progress Energy

Serial: NPD-NRC-2011-004 10CFR52.79
January 27, 2011

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

LEVY NUCLEAR PLANT, UNITS 1 AND 2
DOCKET NOS. 52-029 AND 52-030
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 095 RELATED TO PROBABLE MAXIMUM SURGE AND SEICHE FLOODING

Reference: Letter from Brian C. Anderson (NRC) to John Elnitsky (PEF), dated October 4, 2010, "Request for Additional Information Letter No. 095 Related to SRP Section 2.4.5 for the Levy County Nuclear Plant, Units 1 and 2 Combined License Application"

Ladies and Gentlemen:

Progress Energy Florida, Inc. (PEF) hereby submits our response to the Nuclear Regulatory Commission's (NRC) request for additional information provided in the referenced letter.

A response to the NRC request is addressed in the enclosure. The enclosure also identifies changes that will be made in a future revision of the Levy Nuclear Plant Units 1 and 2 application.

If you have any further questions, or need additional information, please contact Bob Kitchen at (919) 546-6992, or me at (727) 820-4481.

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

Executed on January 27, 2011.

Sincerely,

John Elnitsky
Vice President
New Generation Programs & Projects

Enclosure/Attachments

cc : U.S. NRC Region II, Regional Administrator
Mr. Brian C. Anderson, U.S. NRC Project Manager

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**Levy Nuclear Plant Units 1 and 2
Response to NRC Request for Additional Information Letter No. 095 Related to SRP Section 2.4.5 for the Combined License Application, dated October 4, 2010**

NRC RAI #	Progress Energy RAI #	Progress Energy Response
02.04.05-10	L-0876	Response enclosed – see following pages

NRC Letter No.: LNP-RAI-LTR-095

NRC Letter Date: October 4, 2010

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.04.05-10

Text of NRC RAI:

In RAI 2.4.5-09 (RAI ID 4629, Question 17567) , the staff requested the applicant to provide the following information: (a) an analysis of the probable maximum storm surge (PMSS) event using a technically sound and conservative approach such as that predicted by a storm surge model (e.g., Sea, Lake, and Overland Surges from Hurricanes (SLOSH)) with input from appropriate Probable Maximum Hurricane (PMH) scenarios, (b) an estimate of sea level rise accounting for current climatic predictions, and (c) if factored into the PMSS analysis (i.e., application of margins), a detailed description of the process for determining uncertainty estimations.

The applicant's response, dated June 18, 2010, does not appear to describe an estimation of PMSS at and near the LNP site using PMH scenarios input into a currently-accepted hydrodynamic storm surge model. NRC requests that the applicant:

(1) utilize a set of plausible PMH scenarios consistent with National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Report 23 (NWS 23) as input to a currently-accepted storm surge model (such as SLOSH)
(2) use initial open-water conditions that are consistent with current understanding of long-term sea-level rise and are valid for the life of the proposed plant
(3) provide estimates of coincident wind wave runup
(4) maps of highest PMSS water surface elevation at and near the LNP site, and
(5) provide updates to FSAR Section 2.4.5 including descriptions of data, methods, model setup, PHM scenarios and how they are consistent with NWS 23, treatment of uncertainty in the analysis, and available margins.

PGN RAI ID #: L-0876

PGN Response to NRC RAI:

In Subsection 2.4.5.2.3 of the LNP FSAR, PMH surge water level at the LNP site was estimated based on extrapolation of surge water levels for the hurricane categories 1 through 5. To respond to this RAI, a confirmatory Sea, Lake, and Overland Surges from Hurricanes (SLOSH) computer model analysis was performed.

As requested in the RAI, the following considerations are used to estimate the PMH surge at the LNP site and are described in the RAI response and also in the updates to FSAR Subsection 2.4.5.

1. Different PMH scenarios based on PMH parameters obtained from National Oceanic and Atmospheric Administration (NOAA), National Weather Services (NWS) Report 23 (Reference 1) were utilized as input to the SLOSH storm surge model.

2. Initial water level consistent with the long term sea level rise valid for the life of the plant together with the 10% exceedance high tide was used.

3. Estimates of coincident wind wave setup and runup were developed.

4. Maps of highest PMH surge water surface elevation at LNP site are provided.

5. Updates to FSAR Subsection 2.4.5 are provided.

SLOSH Computer Model

SLOSH is a two-dimensional finite difference code that uses an adaptive curvilinear, polar coordinate grid for regions along the Gulf and Atlantic coasts. SLOSH assumes uniform friction to solve the equations of motion for reference basins. A geographical region with known values of topography and bathymetry is called a SLOSH basin.

The SLOSH computer model is developed and maintained by the National Weather Services (NWS) and is used to generate real time forecasting of hurricane storm surge on continental shelves, along coastlines and across inland water bodies. A detailed discussion of the model is presented in the FSAR Subsection 2.4.5.2.3. SLOSH computer program Version 3.95 (v3.95) was used for the estimation of PMH surge water level at the LNP site. The SLOSH computer program was obtained from NWS and is the version currently used by the NWS for hurricane prediction for the region where the LNP site is located.

CEDAR Key Basin Grid

For purposes of modeling the coastline of Gulf of Mexico the NWS generated multiple SLOSH basin grids. The project site falls within the Apalachicola, Tampa and Cedar Key SLOSH basin grids (Figure RAI 2.4.5-10-1). The Cedar Key basin grid best represents the conditions specific to the project site and this basin was used for the PMH surge computation.

The basin grid, topographic and bathymetric data provided with SLOSH input files by NWS was used in the computation. In the examination of the LiDAR coverage used by NWS in the Cedar Key SLOSH basin, it was observed that the state LiDAR coverage did not encompass the area around the site. Thus, the highest elevation assigned by the NWS in the Cedar Key grid is 36 feet NAVD88 and serves as a default maximum height of any grid cell.

A LiDAR topographic survey was performed for the LNP site area with the vertical datum NAVD88. This LiDAR data and processed topographic contours for site area were incorporated into the state LiDAR data used by the NWS in the original Cedar Key grid. These new contours were then averaged for specific grids where the NWS assigned elevation did not correctly represent the topography. Subsequently, at each grid point, the existing grid elevation was compared with the average elevation obtained from the LiDAR data for the site. When a difference was noted, the existing grid elevation was modified based on this additional LiDAR data set. Grid cells outside the project area were also checked against elevations from South Florida Water Management District (SFWMD) USGS topographic information (Reference 2) to ensure that the elevations in the NWS grid were correctly represented. This revised grid data file was used for the SLOSH PMH simulations.

The SLOSH v3.95 FORTRAN code provided by NWS also contained a limitation wherein grid cells with elevations greater than 35 feet NAVD88 were removed from the flooding computation (i.e. these cells could never be flooded). It was confirmed from NWS that the 35 feet limit for surge in the SLOSH program is historical and does not pose any particular problems when it is relaxed. Since the LNP site is located at elevation greater than 35 feet, the code was modified to allow flooding for any grid with elevations less than 56 feet, where surge elevations were greater than the elevation of the cell, including those near the site. Once the code was modified, a new executable file was compiled. The SLOSH program code was validated with and without the changes in the code to determine that the changes in the code were effective and accurate in allowing flooding at elevations greater than 35 feet. The validation for the SLOSH program was performed by comparing the same hurricane scenario for each code. The revised code was then validated against historical High Water Mark (HWM) data points for locations within Cedar Key Data Grid from a published FEMA report (Reference 3) for Hurricane Frances (2004) with the surge elevations computed using the SLOSH model.

PMH Parameters for LNP Site

NOAA Technical Report NWS 23 defines the PMH as a hypothetical steady state hurricane, with a specific combination of five meteorological parameters that will generate the highest sustained wind speed that can probably occur at a specified coastal location. The five meteorological parameters are central pressure, P_o; peripheral pressure, P_w; radius of maximum winds, R; forward speed, T; and track direction, Θ.

It is determined that the location of the LNP site is at approximately nautical mile marker 1125 in the NWS Report 23 (Reference 1). Using this location the PMH parameters were extracted from Reference 1. The peripheral pressure P_w for a PMH for the site is fixed at 1020 mb. As the Central Pressure, P_o, increases, the pressure deficit ($P_w - P_o$) decreases and consequently, the PMH induced surge will decrease with increasing P_o. For the evaluation of maximum surge at site, the PMH is assumed to be a steady state PMH and the value of Central Pressure, P_o, is taken to be the minimum specified value in NWS 23. Table 1 is a compilation of the selected PMH values, which are the same as the PMH parameters presented in the FSAR Table 2.4.5-203, except for minor variations in central pressure (P_o), forward speed (T) and lower limit of the Track Direction (**Θ**). However, the track directions for maximum surge producing cases are well within the range of the values presented in Table 1.

Table 1. PMH Parameters from NWS 23 Used for SLOSH Model Simulations

Parameter	Lower	Upper	Unit
Central Pressure, P_O	890	890	Millibars
Peripheral Pressure, P_W	1020	1020	Millibars
Pressure Deficit, $\Delta_p = P_W - P_O$	130	130	Millibars
Radius of maximum winds, R	7.5	26	Statute miles
Forward speed, T	16.4	23	Miles/hour
Maximum wind speed*	152	155	Miles/hour
Track Direction, Θ	215	245	Degrees from North

(* Reference 1 contains several wind speed values. Shown here are those defined in Reference 1 as the maximum gradient wind speed.)

Antecedent Water level

For the computation of PMH surge water level at the LNP site using the SLOSH model, the initial open water level at the coast was determined by adding the long term sea level rise to the 10% exceedance high tide estimated based on observed tide data for this region. For the period from 1983 to 2010, the monthly extreme tide values were obtained from Reference 4. The spring high tide values were sorted from high to low and converted from the local station datum to NAVD88. The percent exceedance was tabulated from the sorted data. The 10% exceedance spring high tide elevation is calculated to be 3.23 feet NAVD88.

NOAA has evaluated sea level rise trends for each tide station. Figure RAI 2.4.5-10-2 provides the data for the mean sea level trend at the Cedar Key tide gauge, station 8727520. The mean sea level trend has been calculated by NOAA to be +1.80 millimeters/year with a 95% confidence interval of +/- 0.19 mm/yr based on monthly mean sea level data from 1914 to 2006. This is equivalent to a mean sea level rise of 0.59 feet in 100 years. The sea level rise of 0.59 feet in 100 years as evaluated by NOAA at the Cedar Key tide gauge station is appropriate for use as the sea level rise rate for the LNP site. Combining the initial water level of 3.23 feet NAVD88, corresponding to the 10% exceedance spring high tide, with long term sea level rise of 0.59 feet, an initial water level of 3.82 feet NAVD88 was used for all the SLOSH model runs.

Preliminary SLOSH Model runs

A set of preliminary runs (matrix of 576 cases), as presented in Table 2, were input into the SLOSH model. The matrix of simulations representing the lower and upper limits of the PMH as listed in the table encompassed 16 landfall locations within 27 miles north and 6.5 miles south of the project site, 3 radii of maximum winds, 3 forward speeds, and 4 directions for the storm track. For the preliminary simulations, the pressure deficit was fixed at 130 mb at all times during the storm simulation. These preliminary runs were used to narrow the range of parameters which had the greatest effect on surge values at the site.

Figure RAI 2.4.5-10-3 provides a map of the landfall locations examined. As seen in Figure RAI 2.4.5-10-3, most of the landfall locations are north of the project site. This is because the northeast quadrant of a hurricane (north being the axis of the hurricane track) will produce the greatest surge due to the counter clockwise rotation of the wind field; therefore, it would be expected that landfalls north of the project site will produce the greatest surge. This was confirmed from the preliminary run results.

Table 2. PMH Parameters for SLOSH Preliminary Runs

Landfall Location	Radius of Maximum Winds (miles)	Forward Speed (mph)	Direction of Storm Track with Respect to North (degrees)
16 locations	7.5 17 26	16 20 23	215
			225
			235
			245

Table 3 provides a summary of the minimum and maximum surge values calculated for each of the landfall locations (Figure RAI 2.4.5-10-3). For all combinations of landfall locations, and forward speed, with the radius of maximum winds set at 7.5 miles or 17 miles, no surge is produced at the site. Only simulations that used a radius of maximum winds of 26 miles produced surge this far inland at the site.

Table 3. Minimum and Maximum Surges for each Landfall Location From Preliminary Runs.

Landfall Location	Preliminary Run #	Forward Speed, V (mph)	Track Direction, Θ (degrees)	Radius of Maximum Winds (miles)	Surge Elevation at Site (feet NAVD88)	Comment
				7.5	DRY	
				17	DRY	
1		No Surge Calculated				Northernmost Landfall
2	513	23	215	26	42.20	
	522	23	225	26	41.1	
3	495	23	235	26	41.00	
	477	23	215	26	42.60	
	486	23	225	26	42.60	
4	468	23	245	26	41.20	
	441	23	215	26	44.40	
5	402	20	215	26	41.00	
	405	23	215	26	44.80	
6	393	20	245	26	41.00	
	378	23	225	26	46.10	
7	357	20	245	26	41.20	
	351	23	235	26	46.30	
8	321	20	245	26	41.40	
	306	23	225	26	47.00	
9	285	20	245	26	41.30	
	270	23	225	26	46.90	
10	249	20	245	26	41.20	
	225	23	215	26	46.10	
	234	23	225	26	46.10	
11	213	20	245	26	41.00	
	198	23	225	26	46.20	
12	177	20	245	26	41.30	
	162	23	225	26	47.40	
13	141	20	245	26	42.30	
	126	23	225	26	46.90	
14	105	20	245	26	42.60	
	90	23	225	26	47.50	Highest Surge in Prelim. Runs
15	69	20	245	26	42.70	
	54	23	225	26	47.10	
16	33	20	245	26	41.50	Southernmost Landfall
	18	23	225	26	46.50	

Pressure Deficit Scenarios

Data and studies demonstrate that a constant pressure deficit is not representative of the normal evolution of a large hurricane as it approaches and makes landfall. As hurricanes reach landfall, central pressure begins to rise resulting in an exponential decay of pressure deficit with time (Reference 5). After the preliminary simulations were completed, the pressure deficit for each storm simulation was varied in the matrix of cases for the final simulations. Reference 5 provides a method for calculating the pressure deficit decay for hurricanes making landfall on the peninsula of Florida. The calculated change in pressure deficit at 6, 12, 18, and 24 hours after landfall is shown in Table 4.

Table 4. Pressure Deficit Decay After Landfall.

Time After Landfall (hours)	Pressure Deficit (mb)
0	130
6	86
12	57
18	38
24	25

Three scenarios for the change in pressure were selected to examine the effect of a change in pressure deficit with respect to the time of landfall. Table 5 describes each scenario and Figure RAI 2.4.5-10-4 provides a graph of the change in pressure deficit with time for the three scenarios. Figure RAI 2.4.5-10-4 also provides a comparison with pressure data from significant hurricanes that made landfall along the Gulf of Mexico. It is seen that as the storms approach landfall (at time=0 hours) the pressure deficit increases with the maximum occurring before or at landfall. Figure RAI 2.4.5-10-4 shows that most of the storms also show a nearly linear ramp up of pressure deficit prior to landfall with an exponential decay after landfall. The decay after landfall follows the calculation of decay provided by Reference 5.

Table 5. Scenarios for the Change in Pressure Deficit with Respect to Landfall.

Scenario	Pressure Deficit Profile
1	Pressure Deficit ΔP = 130mb constant
2	Pressure Deficit remains at maximum until landfall then decays exponentially after landfall according to the rate calculated in Table 4.
3	• 80% of Maximum: Until 12 hours before landfall (Start to -12 hours) • Maximum from 12 hours before landfall to Landfall (-12 to 0 hr) • Decays exponentially per Table 4 after landfall (> 0 hr)

Final SLOSH Model Runs

It was determined from the preliminary runs that storms from the 13 most northern landfall locations produced the greatest surge when combined with a radius of maximum winds of 26 miles, and forward speed of 23 mph. These parameters were used to generate the matrix of simulations for the final computations of PMH surge.

For the final runs, as shown in Table 6, 182 SLOSH simulations were performed for each scenario, at 26 landfall locations spaced approximately a mile apart. These 26 landfall locations were chosen within the range of the 13 landfalls short listed from the preliminary runs. The radius of maximum winds and forward speed were fixed at 26 miles and 23 mph respectively.

At each landfall location, the storm approach direction was varied, at 5° intervals, within the track direction range of 215°N-245°N PMH outlined in Table 1. Consequently for each of the 26 landfall locations seven storm directions were modeled resulting in 182 SLOSH simulations for each scenario. Figure RAI 2.4.5-10-5 shows the storm parameters for a single landfall location, used for the final simulations.

Table 6. PMH Parameters for Final SLOSH Model Runs

Landfall Location	Radius of Maximum Winds (miles)	Forward Speed (mph)	Direction of Storm Track with Respect to North (degrees)
26 locations	26	23	215
			220
			225
			230
			235
			240
			245

For each of the scenarios, 182 simulation runs were preformed. From these simulations for each of the scenarios the highest surge elevation at the LNP site was extracted. Table 7 provides a listing of the storm parameters and the corresponding maximum surge for each pressure deficit scenario.

Table 7. Storm Parameters Producing the Maximum Surge for Different Scenarios.

Scenario	Radius of Maximum Winds (miles)	Forward Speed (mph)	Direction of Storm Track with Respect to North (degrees)	Surge at Site (feet NAVD88)
1	26	23	225	47.7
2	26	23	225	47.3
3	26	23	230	46.8

Figures RAI 2.4.5-10-6 through RAI 2.4.5-10-11 provide the SLOSH display screenshots and maps displaying the surge at the time of the peak surge for the site, for Scenarios 1, 2, and 3, shown in Table 7.

Scenario 1 (constant Δp) produces marginally higher surge value than the other two pressure deficit cases. This result was expected and represents the most conservative of the final simulations.

For all scenarios, the time variations of surge elevation, wind speed, and wind direction follow the pattern shown in Figure RAI 2.4.5-10-12. The maximum surge condition of 47.7 feet for scenario 1, Run 101, is depicted in Figure RAI 2.4.5-10-12. The cells that include the site have an average elevation of 42 feet; the cell remains dry until the surge elevation exceeds 42 feet. The peak surge elevation occurs at the site for a narrow time frame, one time step, of ten minutes. Water enters the cell at one time step (10 minutes) prior to the peak. Peak winds of 180 mph are felt for about one hour with the peak surge occurring 20 minutes after the winds have begun to decline below 180 mph. Wind direction is northwesterly (onshore) as the hurricane makes landfall, clocking around to an easterly direction (offshore) over a five hour period as the hurricane passes, consistent with the typical dynamics of hurricanes.

Wind Wave Set-up and Run-up

Waves near the LNP site generated by the PMH design storm, as they propagate from the deep water of the Gulf, are influenced by gently sloping continental shelf. The winds continue to add energy into the wave field, however, energy dissipation due to bottom friction is significant and plays a major role in controlling and reducing the height of the waves as they approach the coast and then pass over the flooded landscape.

Based on Reference 6 and Reference 7 the wave setup at LNP site is conservatively estimated as 0.6 feet.

For computation of wave runup, the elevation of the top of structure was chosen as the plant grade elevation of 50 feet NAVD88 for Units 1 and 2. The elevation at the toe of structure was determined based on the grade at the toe of the fill slope for Units 1 and 2. The depth of water at the toe of structure was based on the water level (PMH surge + Wave setup) of 48.31 feet. The slope of the earthen structure (embankment) for all scenarios was assumed to be 3H:1V. The nearshore slope for all scenarios was calculated from station 300 to station 1300 as shown in Figure RAI 2.4.5-10-13.

The wave runup at the plant buildings was estimated as 1.48 feet due to a breaking wave of approximately 1 foot with a period of 1.96 sec. This breaking wave is generated based on the local depth from the maximum surge for the short time during which the peak surge elevation occurs.

PMH Surge Water Surface Elevation Using SLOSH Computer Model

Table 8 provides a summary of the total PMSS at the site with the considerations from the maximum PMH surge value at the site as well as contributions from wave setup and wave runup. For all scenarios, the maximum water level remains below the plant floor elevation of 51 feet NAVD 88 for Units 1 and 2.

Table 8 Total PMH Surge Elevation at LNP Site Including Wave Effects.

Component	Units	Scenario		
		1	2	3
LNP Grade Elevation	FEET NAVD88	50	50	50
10% Exceedance Spring High Tide Elevation	FEET NAVD88	3.23	3.23	3.23
Sea Level Rise	FEET	0.59	0.59	0.59
SLOSH Surge Elevation	FEET NAVD88	47.70	47.30	46.80
Total Wave Setup	FEET	0.60	0.50	0.40
Wave Runup	FEET	1.48	0.90	0.23
TOTAL PMSS including wave effects	**FEET NAVD88**	**49.78**	**48.70**	**47.43**

Consistent with the purpose and scope, plausible scenarios for the PMH were input into SLOSH. The maximum PMH surge was calculated to be 47.7 feet which is the most conservative of all of the peak simulation scenarios (Δp is constant) and includes the initial open-water condition of the 10% exceedance spring high tide and the published sea level rise for the next 100 years taken for the nearest tide gauge. Realistic values for wind wave setup have been calculated and take into consideration realistic values for bed friction. Runup was generated based on the specific conditions at the LNP site.

The computed surge elevation of 47.7 feet NAVD88 combined with wave setup of 0.6 foot and wave runup of 1.48 feet, results in a maximum water level of 49.78 feet NAVD88. This PMH surge elevation is below the plant floor elevation of 51 feet NAVD88.

The estimated PMH surge level together with 10% exceedance high tide, long term sea level rise, and the wind wave effect presented in FSAR Subsection 2.4.5.3.3 and Table 2.4.5-215 is 49.52 feet NAVD88 which agrees closely with the confirmatory PMH surge elevation of 49.78 feet NAVD88 presented in this RAI response. Therefore the PMH surge elevation of 49.52 feet NAVD 88 presented in the FSAR will be used as the elevation for external flooding due to PMH surge at LNP site.

References:

1 National Oceanic and Atmospheric Administration, National Weather Service, "Meteorological Criteria for Standard Project Hurricane and Probable Maximum Hurricane Windfields, Gulf and East Coasts of the United States," NOAA Technical Report NWS 23, September 1979.

2 Web site of Southwest Florida Water Management District (SFWMD), topographic data, http://www.swfwmd.state.fl.us/data/gis/libraries/physical_dense/usgstopo.htm accessed in December 2010.

3 FEMA Region IV. Hurricane Frances Rapid Response Florida Coastal High Water Mark (CHWM) Collection. Report No: FEMA-1545-DR-FL. January 2005.
4 Website of National Oceanic and Atmospheric Administration (NOAA), tides and currents online, http://tidesandcurrents.noaa.gov/geo.shtml?location=8727520 accessed in December 2010.
5 M. Powell et al. "State of Florida hurricane loss projection model: Atmospheric science component," Journal of Wind Engineering and Industrial Aerodynamics. 93:651–674. 2005.
6 Longuet-Higgins, M.S. Journal of Fluid Mechanics. Vol. 527, pp. 217–234, 2005.
7 Dean, R.G. and Dalrymple, R.A., 1984, Water Wave Mechanics for Engineers and Scientists, Prentice Hall, 353 pp.

Associated LNP COL Application Revisions:

The following changes will be made in a future revision to Part 2, FSAR of the LNP COLA:

1. LNP FSAR Rev. 2 will be revised to add Tables 2.4.5-216 through 2.4.5-223 as shown in Attachment 02.04.05-10-A.

2. LNP FSAR Rev. 2 will be revised to add Figures 2.4.5-234 through 2.4.5-246 as shown in Attachment 02.04.05-10-B.

3. Subsection 2.4.5.4 will be renumbered as Subsection 2.4.5.5

4. Subsection 2.4.5.5 will be renumbered as Subsection 2.4.5.6

5. No existing FSAR tables or figures in Subsection 2.4.5 are revised or deleted.

6. Subsection 2.4.5.4 will be added as follows:

2.4.5.4 Confirmatory Analysis for PMH Surge Using SLOSH Computer Model

A confirmatory Sea, Lake, and Overland Suges from Hurricanes (SLOSH) computer model analysis was performed for different PMH scenarios based on PMH parameters obtained from National Oceanic and Atmospheric Administration (NOAA), National Weather Services (NWS) Report 23 (Reference 2.4.5-205). The highest surge elevation at the LNP site including 10% exceedance high tide and long term sea level rise was computed. To this computed surge elevation, corresponding wind-wave setup and wind-wave runup was added to obtain the maximum surge level at the LNP site.

2.4.5.4.1 SLOSH Computer Model

SLOSH is a two-dimensional finite difference code that uses an adaptive curvilinear, polar coordinate grid for regions along the Gulf and Atlantic coasts. SLOSH assumes uniform friction to solve the equations of motion for reference basins. A geographical region with known values of topography and bathymetry is called a SLOSH basin.

The SLOSH computer model is developed and maintained by the National Weather Services (NWS) and is used to generate real time forecasting of hurricane storm surge on continental shelves, along coastlines and across inland water bodies. A detailed discussion of the model is presented in the Subsection 2.4.5.2.3. SLOSH computer program Version 3.95 (v3.95) was used for the estimation of PMH surge water level at the LNP site. The SLOSH computer program was obtained from NWS and is the version currently used by the NWS for hurricane prediction for the region where the LNP site is located.

2.4.5.4.2 CEDAR Key Basin Grid

For purposes of modeling the coastline of Gulf of Mexico, the NWS generated multiple SLOSH basin grids. The project site falls within the Apalachicola, Tampa and Cedar Key SLOSH basin grids (Figure 2.4.5-234). The Cedar Key basin grid best represents the conditions specific to the project site and this basin was used for the PMH surge computation.

The basin grid, topographic and bathymetric data provided with SLOSH input files by NWS was used in the computation. In the examination of the LiDAR coverage used by NWS in the Cedar Key SLOSH basin, it was observed that the state LiDAR coverage did not encompass the area around the site. Thus, the highest elevation assigned by the NWS in the Cedar Key grid is 10.7 m (35 ft.) NAVD88 and serves as a default maximum height of any grid cell.

A LiDAR topographic survey was performed for the LNP site area with the vertical datum NAVD88. This LiDAR data and processed topographic contours for site area were incorporated into the state LiDAR data used by the NWS in the original Cedar Key grid. These new contours were then averaged for specific grids where the NWS assigned elevation did not correctly represent the topography. Subsequently, at each grid point, the existing grid elevation was compared with the average elevation obtained from the LiDAR data for the site. When a difference was noted, the existing grid elevation was modified based on this additional LiDAR data set. Grid cells outside the project area were also checked against elevations from South Florida Water Management District (SFWMD) USGS topographic information (Reference 2.4.5-220) to ensure that the elevations in the NWS grid were correctly represented. This revised grid data file was used for the SLOSH PMH simulations.

The SLOSH v3.95 FORTRAN code provided by NWS also contained a limitation wherein grid cells with elevations greater than 10.7 m (35 ft.) NAVD88 were removed from the flooding computation (i.e. these cells could never be flooded). It was confirmed from NWS that the 10.7 m (35 ft.) limit for surge in the SLOSH program is historical and does not pose any particular problems when it is relaxed. Since the LNP site is located at elevation greater than 10.7 m (35 ft.), the code was modified to allow flooding for any grid with elevations less than 17.1 m (56 ft.), where surge elevations were greater than the elevation of the cell, including those near the site. Once the code was modified, a new executable file was compiled. The SLOSH program code was validated with and without the changes in the code to determine that the changes in the code were effective and accurate in allowing flooding at elevations greater than 10.7 m (35 ft.) The validation for the SLOSH program was performed by comparing the same hurricane scenario for each code. The revised code was then validated against historical High Water Mark (HWM) data points for locations within Cedar Key Data Grid from a published FEMA report (Reference 2.4.5-221) for Hurricane Frances (2004) with the surge elevations computed using the SLOSH model.

2.4.5.4.3 PMH Parameters for LNP Site

NOAA Technical Report NWS 23 (Reference 2.4.5-205) defines the PMH as a hypothetical steady state hurricane, with a specific combination of five meteorological parameters that will generate the highest sustained wind speed that can probably occur at a specified coastal location. The five meteorological parameters are central pressure, P_o; peripheral pressure, P_w; radius of maximum winds, R; forward speed, T; and track direction, Θ.

It is determined that the location of the LNP site is at approximately nautical mile marker 1125 in the NWS Report 23 (Reference 2.4.5-205). Using this location the PMH parameters were extracted from Reference 2.4.5-205. The peripheral pressure P_w for a PMH for the site is fixed at 1020 mb. As the Central Pressure, P_o, increases, the pressure deficit ($P_w - P_o$) decreases and consequently, the PMH induced surge will decrease with increasing P_0. For the evaluation of maximum surge at site, the PMH is assumed to be a steady state PMH and the value of Central Pressure, P_o, is taken to be the minimum specified value in NWS 23. Table 2.4.5-216 is a compilation of the selected PMH values, which are the same as the PMH parameters presented in the Table 2.4.5-203, except for minor variations in central pressure (P_o), forward speed (T) and lower limit of the Track Direction (Θ). However, the track directions for maximum surge producing cases are well within the range of the values presented in Table 2.4.5-216.

2.4.5.4.4 Antecedent Water level

For the computation of PMH surge water level at the LNP site using the SLOSH model, the initial open water level at the coast was determined by adding the long term sea level rise to the 10% exceedance high tide estimated based on observed tide data for this region. For the period from 1983 to 2010, the monthly extreme tide values were obtained from Reference 2.4.5-222. The spring high tide values were sorted from high to low and converted from the local station datum to NAVD88. The percent exceedance was tabulated from the sorted data. The 10% exceedance spring high tide elevation is calculated to be 1.0 m (3.23 ft.) NAVD88.

NOAA has evaluated sea level rise trends for each tide station. Figure 2.4.5-235 provides the data for the mean sea level trend at the Cedar Key tide gauge, station 8727520. The mean sea level trend has been calculated by NOAA to be +1.80 millimeters/year with a 95% confidence interval of +/- 0.19 mm/yr based on monthly mean sea level data from 1914 to 2006. This is equivalent to a mean sea level rise of 0.2 m (0.59 ft.) in 100 years. The sea level rise of 0.2 m (0.59 ft.) in 100 years as evaluated by NOAA at the Cedar Key tide gauge station is appropriate for use as the sea level rise rate for the LNP site. Combining the initial water level of 1.0 m (3.23 ft.) NAVD88, corresponding to the 10% exceedance spring high tide with long term sea level rise of 0.2 m (0.59 ft.), an initial water level of 1.2 m (3.82 ft.) NAVD88 was used for all the SLOSH model runs.

2.4.5.4.5 Preliminary SLOSH Model runs

A set of preliminary runs (matrix of 576 cases), as presented in Table 2.4.5-217, were input into the SLOSH model. The matrix of simulations representing the lower and upper limits of the PMH as listed in the table encompassed 16 landfall locations within 27 miles north and 6.5 miles south of the project site, 3 radii of maximum winds, 3 forward speeds, and 4 directions for the storm track. For the preliminary simulations, the pressure deficit was fixed at 130 mb at all times during the SLOSH simulation. These preliminary runs were used to narrow the range of parameters which had the greatest effect on surge values at the site.

Figure 2.4.5-236 provides a map of the landfall locations examined. As seen in Figure 2.4.5-236, most of the landfall locations are north of the project site. This is because the northeast quadrant of a hurricane (north being the axis of the hurricane track) will produce the greatest surge due to the counter clockwise rotation of the wind field; therefore, it would be expected that landfalls north of the project site will produce the greatest surge. This was confirmed from the preliminary run results.

Table 2.4.5-218 provides a summary of the minimum and maximum surge values calculated for each of the landfall locations (Figure 2.4.5-236). For all combinations of landfall locations, and forward speed, with the radius of maximum winds set at 7.5 miles or 17 miles, no surge is produced at the site. Only simulations that used a radius of maximum winds of 26 miles produced surge this far inland at the site.

2.4.5.4.6 Pressure Deficit Scenarios

Data and studies demonstrate that a constant pressure deficit is not representative of the normal evolution of a large hurricane as it approaches and makes landfall. As hurricanes reach landfall, central pressure begins to rise resulting in an exponential decay of pressure deficit with time (Reference 2.4.5-223). After the preliminary simulations were completed, the pressure deficit for each storm simulation was varied in the matrix of cases for the final simulations. Reference 2.4.5-223 provides a method for calculating the pressure deficit decay for hurricanes making landfall on the peninsula of Florida. The calculated change in pressure deficit at 6, 12, 18, and 24 hours after landfall is shown in Table 2.4.5-219.

Three scenarios for the change in pressure were selected to examine the effect of a change in pressure deficit with respect to the time of landfall. Table 2.4.5-220 describes each scenario and Figure 2.4.5-237 provides a graph of the change in pressure deficit with time for the three scenarios. Figure 2.4.5-237 also provides a comparison with pressure data from significant hurricanes that made landfall along the Gulf of Mexico. It is seen that as the storms approach landfall (at time=0 hours) the pressure deficit increases with the maximum occurring before or at landfall. Figure 2.4.5-237 shows that most of the storms also show a nearly linear ramp up of pressure deficit prior to landfall with an exponential decay after landfall. The decay after landfall follows the calculation of decay provided by Reference 2.4.5-223.

2.4.5.4.7 Final SLOSH Model Runs

It was determined from the preliminary runs that storms from the 13 most northern landfall locations produced the greatest surge when combined with a radius of maximum winds of 26 miles, and forward speed of 23 mph. These parameters were used to generate the matrix of simulations for the final computations of PMH surge.

For the final runs, as shown in Table 2.4.5-221, 182 SLOSH simulations were performed for each scenario, at 26 landfall locations spaced approximately a mile apart. These 26 landfall locations were chosen within the range of the 13 landfalls short listed from the preliminary runs. The radius of maximum winds and forward speed were fixed at 26 miles and 23 mph respectively.

At each landfall location, the storm approach direction was varied, at 5° intervals, within the track direction range of 215°N-245°N PMH outlined in Table 2.4.5-216. Consequently for each of the 26 landfall locations seven storm directions were modeled resulting in 182 SLOSH simulations for each scenario. Figure 2.4.5-238 shows the storm parameters for a single landfall location, used for the final simulations.

For each of the scenarios, 182 simulation runs were preformed. From these simulations for each of the scenarios the highest surge elevation at the LNP site was extracted. Table 2.4.5-222 provides a listing of the storm parameters and, the corresponding maximum surge for each pressure deficit scenario.

Figures 2.4.5-239 through 2.4.5-244 provide the SLOSH display screenshots and maps displaying the surge at the time of the peak surge for the site, for Scenarios 1, 2, and 3, shown in Table 2.4.5-222.

Scenario 1 (constant Δp) produces marginally higher surge value than the other two pressure deficit cases. This result was expected and represents the most conservative of the final simulations.

For all scenarios, the time variations of surge elevation, wind speed and wind direction follow the pattern shown in Figure 2.4.5-245. The maximum surge condition of 14.5 m (47.7 ft.) for Scenario 1, Run #101, is depicted in Figure 2.4.5-245. The cells that include the site have an average elevation of 12.8 m (42 ft.); the cell remains dry until the surge elevation exceeds 12.8 m (42 ft.). The peak surge elevation occurs at the site for a narrow time frame, one time step, of ten minutes. Water enters the cell at one time step (10 minutes) prior to the peak. Peak winds of 180 mph are felt for about one hour with the peak surge occurring 20 minutes after the winds have begun to decline below 180 mph. Wind direction is northwesterly (onshore) as the hurricane makes landfall, clocking around to an easterly direction (offshore) over a five hour period as the hurricane passes, consistent with the typical dynamics of hurricanes.

2.4.5.4.8 Wind Wave Set-up and Run-up

Waves near the LNP site generated by the PMH design storm, as they propagate from the deep water of the Gulf, are influenced by gently sloping continental shelf. The winds continue to add energy into the wave field, however, energy dissipation due to bottom friction is significant and plays a major role in controlling and reducing the height of the waves as they approach the coast and then pass over the flooded landscape.

Based on Reference 2.4.5-224 and Reference 2.4.5-225, the wave setup at LNP site is conservatively estimated as 0.2 m (0.6 ft.).

For computation of wave runup, the elevation of the top of structure was chosen as the plant grade elevation of 15.2 m (50 ft.) NAVD88 for Units 1 and 2. The elevation at the toe of structure was determined based on the grade at the toe of the fill slope for Units 1 and 2. The depth of water at the toe of structure was based on the water level (PMH surge + Wave setup) of 14.7 m (48.31 ft.). The slope of the earthen structure (embankment) for all scenarios was assumed to be 3H:1V. The nearshore slope for all scenarios was calculated from station 300 to station 1300 as shown in Figure 2.4.5-246.

The wave runup at the plant buildings was estimated as 0.5 m (1.48 ft.) due to a breaking wave of approximately 0.3 m (1 ft.) with a period of 1.96 sec. This breaking wave is generated based on the local depth from the maximum surge for the short time during which the peak surge elevation occurs.

2.4.5.4.9 PMH Water Surface Elevation Using SLOSH Computer Model

Table 2.4.5-223 provides a summary of the total PMSS at the site with the considerations from the maximum PMH surge value at the site as well as contributions from wave setup and wave runup. For all scenarios, the maximum water level remains below the plant floor elevation of 15.5 m (51 ft.) NAVD88 for Units 1 and 2.

Consistent with the purpose and scope, plausible scenarios for the PMH were input into SLOSH. The maximum PMH surge was calculated to be 14.5 m (47.7 ft.) which is the most conservative of all of the peak simulation scenarios (Δp is constant) and includes the initial open-water condition of the 10% exceedance spring high tide and the published sea level rise for the next 100 years taken for the nearest tide gauge. Realistic values for wind wave setup have been calculated and take into consideration realistic values for bed friction. Runup was generated based on the specific conditions at the LNP site.

The computed surge elevation of 14.5 m (47.7 ft.) NAVD88 combined with wave setup of 0.2 m (0.6 ft.) and wave runup of 0.5 m (1.48 ft.), results in a maximum water level of 15.2 m (49.78 ft.) NAVD88. This PMH surge elevation is below the plant floor elevation of 15.5 m (51 ft.) NAVD88.

The estimated PMH surge level together with 10% exceedance high tide, long term sea level rise, and the wind wave effect presented in Subsection 2.4.5.3.3 and Table 2.4.5-215 is 15.1 m (49.52 ft.) NAVD88 which agrees closely with the PMH surge water level of 15.2 m (49.78 ft.) NAVD88, estimated based on the confirmatory analysis using SLOSH computer model.

7. Revise subsection 2.4.16 References to add:

2.4.5-220 Southwest Florida Water Management District (SFWMD), topographic data, Website, http://www.swfwmd.state.fl.us/data/gis/libraries/physical_dense/usgstopo.htm , accessed in December 2010.

2.4.5-221 FEMA Region IV. Hurricane Frances Rapid Response Florida Coastal High Water Mark (CHWM) Collection. Report No: FEMA-1545-DR-FL. January 2005.

2.4.5-222 National Oceanic and Atmospheric Administration (NOAA), tides and currents online, Website, http://tidesandcurrents.noaa.gov/geo.shtml?location=8727520, accessed in December 2010.

2.4.5-223 M. Powell et al. “State of Florida hurricane loss projection model: Atmospheric science component,” Journal of Wind Engineering and Industrial Aerodynamics. 93:651–674. 2005.

2.4.5-224 Longuet-Higgins, M.S. Journal of Fluid Mechanics. Vol. 527, pp. 217–234, 2005.

2.4.5-225 Dean, R.G. and Dalrymple, R.A., 1984, Water Wave Mechanics for Engineers and Scientists, Prentice Hall, 353 pp.

Attachments/Enclosures:

Attachment 02.04.05-10-A: New FSAR Tables 2.4.5-216 through 2.4.5-223

Attachment 02.04.05-10-B: Figures RAI 2.4.5-10-1 through RAI 2.4.5-10-13 (New FSAR Figures 2.4.5-234 through 2.4.5-246, respectively)

Attachment 02.04.05-10-A

New Tables 2.4.5-216 through 2.4.5-223

(6 pages attached)

LNP COL 2.4-2

Table 2.4.5-216
PMH Parameters from NWS 23 Used for SLOSH Model Simulations

Parameter	Lower	Upper	Unit
Central Pressure, P_O	890	890	Millibars
Peripheral Pressure, P_W	1020	1020	Millibars
Pressure Deficit, $\Delta_p = P_W - P_O$	130	130	Millibars
Radius of maximum winds, R	7.5	26	Statute miles
Forward speed, T	16.4	23	Miles/hour
Maximum wind speed*	152	155	Miles/hour
Track Direction, Θ	215	245	Degrees from North

* NWS 23 contains several wind speed values. Shown here are those defined in NWS23 as the maximum gradient wind speed.

LNP COL 2.4-2

Table 2.4.5-217
PMH Parameters for SLOSH Preliminary Runs

Landfall Location	Radius of Maximum Winds (miles)	Forward Speed (mph)	Direction of Storm Track with Respect to North (degrees)
16 locations	7.5 17 26	16 20 23	215 225 235 245

LNP COL 2.4-2

Table 2.4.5-218 (Sheet 1 of 1)
Minimum and Maximum Surges for Each Landfall Location From Preliminary Runs

Landfall Location	Preliminary Run #	Forward Speed, V (mph)	Track Direction, Θ (degrees)	Radius of Maximum Winds (miles)	Surge Elevation at Site (ft NAVD88)	Comment
				7.5	DRY	
				17	DRY	
1			No Surge Calculated			Northernmost Landfall
2	513	23	215	26	42.20	
	522	23	225	26	41.1	
3	495	23	235	26	41.00	
	477	23	215	26	42.60	
	486	23	225	26	42.60	
4	468	23	245	26	41.20	
	441	23	215	26	44.40	
5	402	20	215	26	41.00	
	405	23	215	26	44.80	
6	393	20	245	26	41.00	
	378	23	225	26	46.10	
7	357	20	245	26	41.20	
	351	23	235	26	46.30	
8	321	20	245	26	41.40	
	306	23	225	26	47.00	
9	285	20	245	26	41.30	
	270	23	225	26	46.90	
10	249	20	245	26	41.20	
	225	23	215	26	46.10	
	234	23	225	26	46.10	
11	213	20	245	26	41.00	
	198	23	225	26	46.20	
12	177	20	245	26	41.30	
	162	23	225	26	47.40	
13	141	20	245	26	42.30	
	126	23	225	26	46.90	

LNP COL 2.4-2

Table 2.4.5-218 (Sheet 2 of 2)
Minimum and Maximum Surges for Each Landfall Location From Preliminary Runs

Landfall Location	Preliminary Run #	Forward Speed, V (mph)	Track Direction, Θ (degrees)	Radius of Maximum Winds (miles)	Surge Elevation at Site (ft NAVD88)	Comment
14	105	20	245	26	42.60	
	90	23	225	26	47.50	Highest Surge in Preliminary Runs
15	69	20	245	26	42.70	
	54	23	225	26	47.10	
16	33	20	245	26	41.50	Southernmost Landfall

LNP COL 2.4-2

Table 2.4.5-219
Pressure Deficit Decay After Landfall

Time After Landfall (hours)	Pressure Deficit (mb)
0	130
6	86
12	57
18	38
24	25

LNP COL 2.4-2

Table 2.4.5-220
Scenarios for the Change in Pressure Deficit with Respect to Landfall

Scenario	Pressure Deficit Profile
1	Pressure Deficit ΔP = 130mb constant
2	Pressure Deficit remains at maximum until landfall then decays exponentially after landfall according to the rate calculated in Table 4.
3	80% of Maximum: Until 12 hours before landfall (Start to -12 hours) Maximum from 12 hours before land fall to Landfall(-12 to 0 hr) Decays exponentially as per Table 4 after landfall (> 0 hr)

LNP COL 2.4-2

Table 2.4.5-221
PMH Parameters for SLOSH Final Runs

Landfall Location	Radius of Maximum Winds (miles)	Forward Speed (mph)	Direction of Storm Track with Respect to North (degrees)
			215
			220
			225
26 locations	26	23	230
			235
			240
			245

LNP COL 2.4-2

Table 2.4.5-222
Storm Parameters Producing the Maximum Surge for Different Scenarios

Scenario	Radius of Maximum Winds (miles)	Forward Speed (mph)	Direction of Storm Track with Respect to North (degrees)	Surge at Site (ft NAVD88)
1	26	23	225	47.7
2	26	23	225	47.3
3	26	23	230	46.8

LNP COL 2.4-2

Table 2.4.5-223
Total PMH Surge Elevation at LNP Site Including Wave Effects

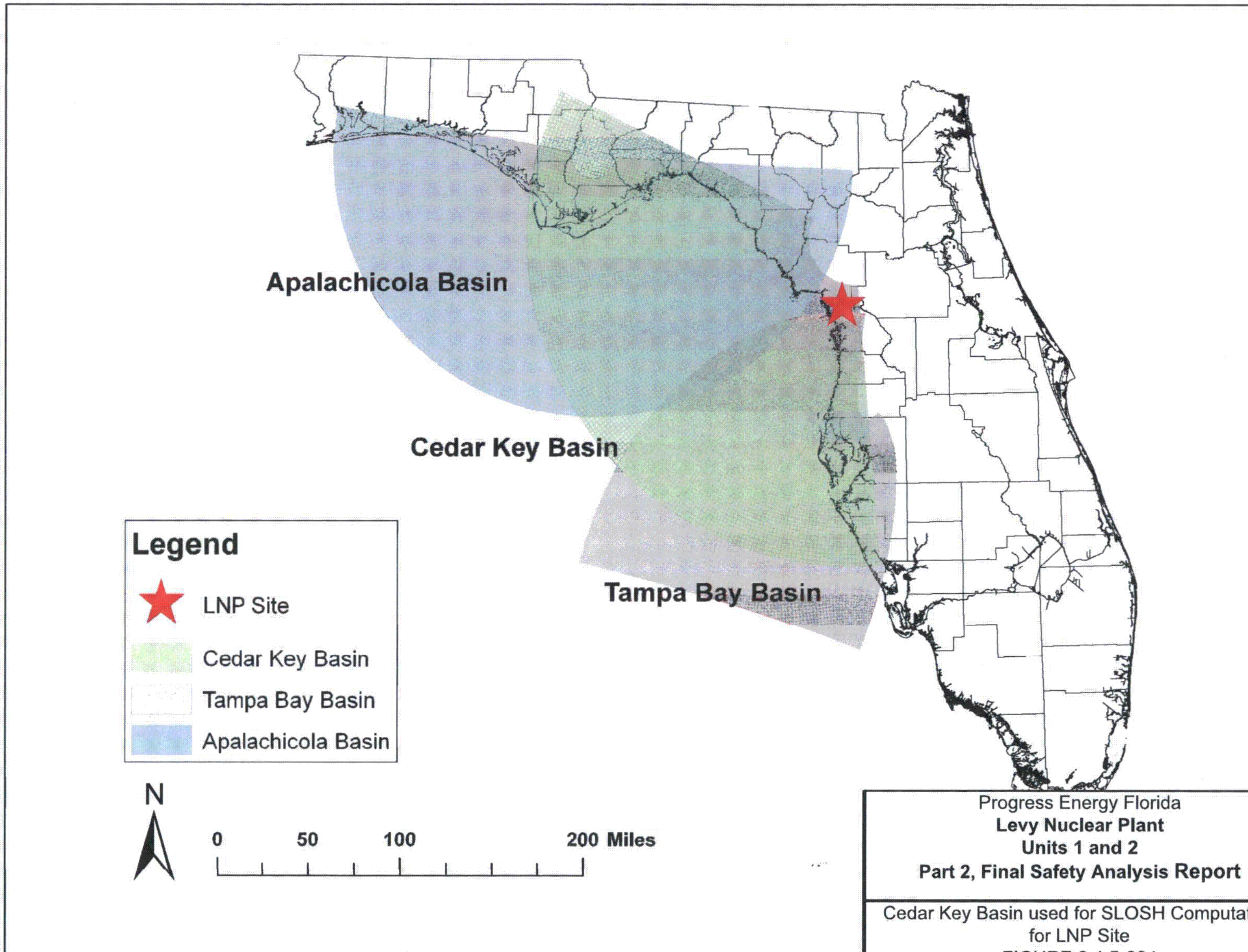
Component	Units	Scenario		
		1	2	3
LNP Grade Elevation	FT NAVD88	50	50	50
10% Exceedance Spring High Tide Elevation	FT NAVD88	3.23	3.23	3.23
Sea Level Rise	FT	0.59	0.59	0.59
SLOSH Surge Elevation	FT NAVD88	47.70	47.30	46.80
Total Wave Setup	FT	0.60	0.50	0.40
Wave Runup	FT	1.48	0.90	0.23
TOTAL PMSS including wave effects	**FT NAVD88**	**49.78**	**48.70**	**47.43**

Attachment 02.04.05-10-B

Figures RAI 2.4.5-10-1 through RAI 2.4.5-10-13
(New FSAR Figures 2.4.5-234 through 2.4.5-246, respectively)

(13 pages attached)

LNP COL 2.4-2



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Cedar Key Basin used for SLOSH Computation for LNP Site
FIGURE 2.4.5-234

Rev 3

Figure RAI 2.4.5-10-1

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sea level trends

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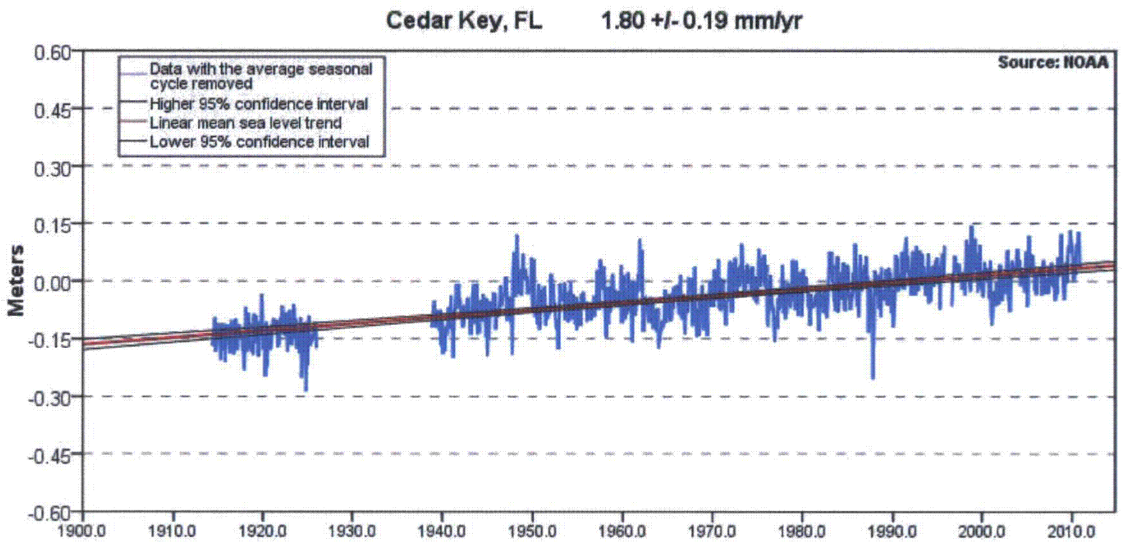
Mean Sea Level Trend
8727520 Cedar Key, Florida



The mean sea level trend is 1.80 millimeters/year with a 95% confidence interval of +/- 0.19 mm/yr based on monthly mean sea level data from 1914 to 2006 which is equivalent to a change of 0.59 feet in 100 years.

The plot shows the monthly mean sea level without the regular seasonal fluctuations due
winds, atmospheric pressures, and ocean currents. The long-term linear trend is also sho
The plotted values are relative to the most recent Mean Sea Level datum established by
stations are available as a table in millimeters/year or a table in feet/century (0.3 meters

If present, solid vertical lines indicate times of any major earthquakes in the vicinity of th
any periods of questionable data.

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Mean Sea Level Trend at Cedar Key, Florida
(Station: 8727520)
FIGURE 2.4.5-235

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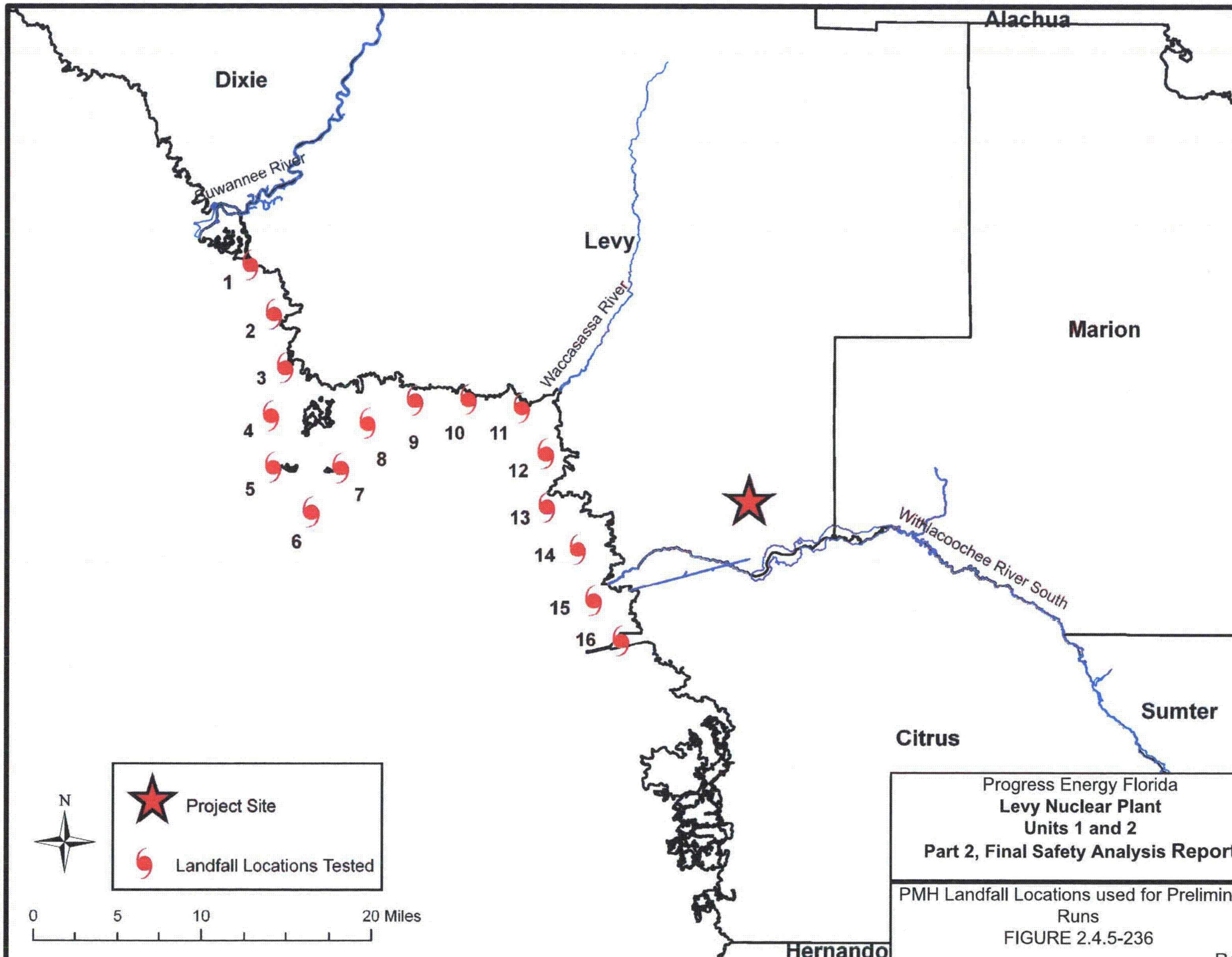
Figure RAI 2.4.5-10-2

LNP COL 2.4-2



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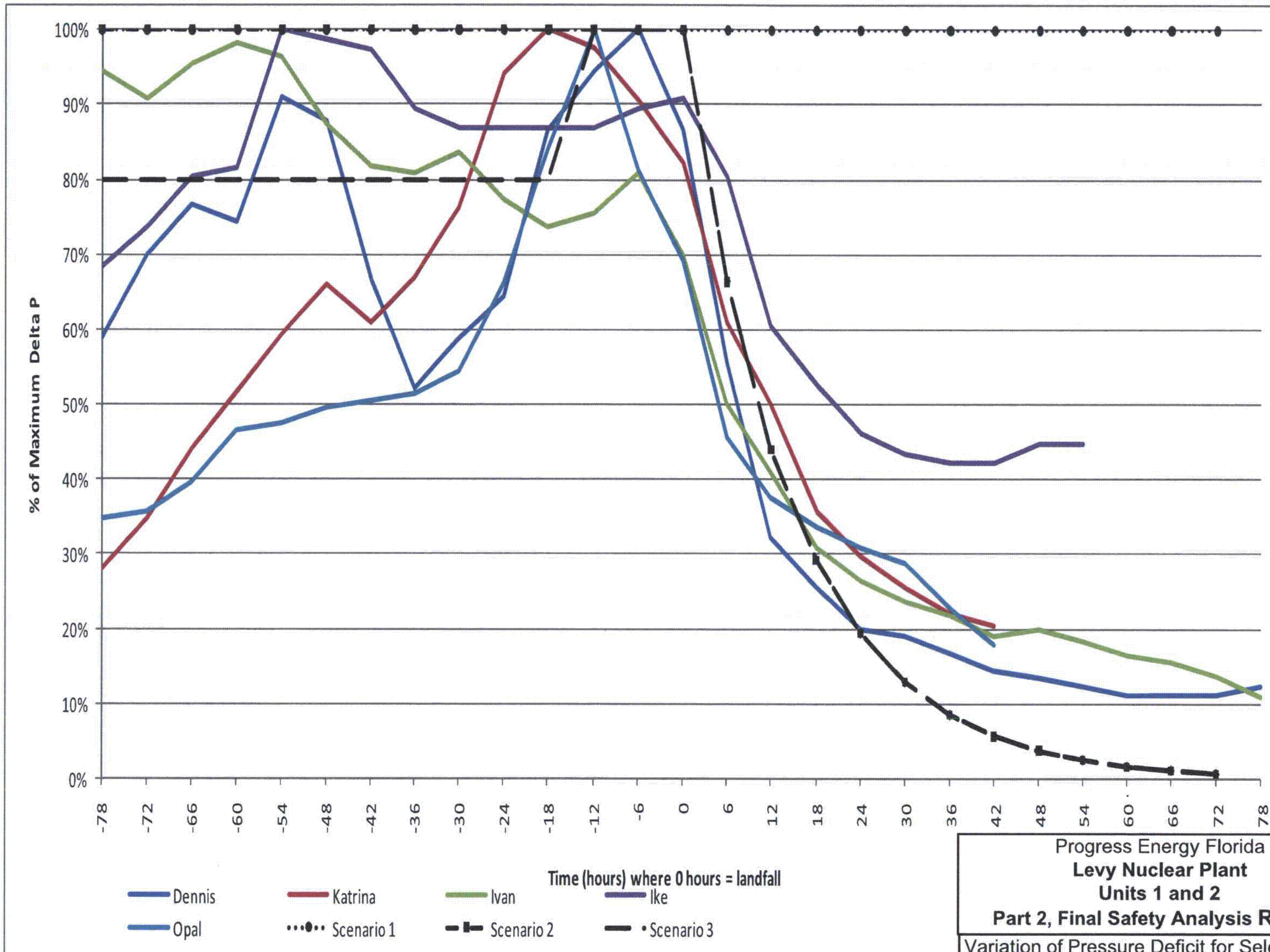
PMH Landfall Locations used for Preliminary Runs
FIGURE 2.4.5-236

Rev 3

Figure RAI 2.4.5-10-3

LNP COL 2.4-2



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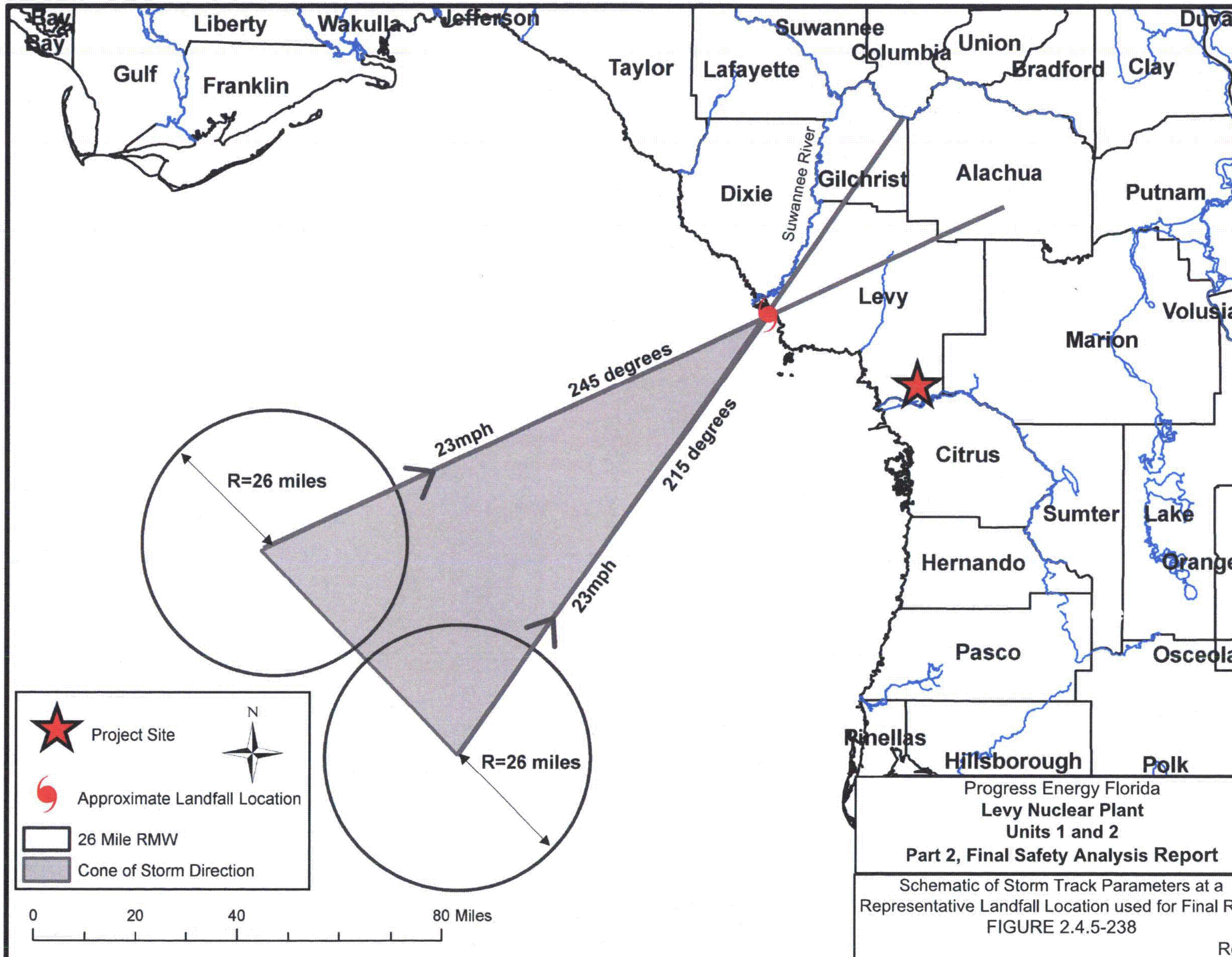
Variation of Pressure Deficit for Selected Gulf of Mexico Hurricanes and the Three PMH Scenarios
FIGURE 2.4.5-237

Rev 3

Figure RAI 2.4.5-10-4

LNP COL 2.4-2



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Schematic of Storm Track Parameters at a Representative Landfall Location used for Final Runs
FIGURE 2.4.5-238

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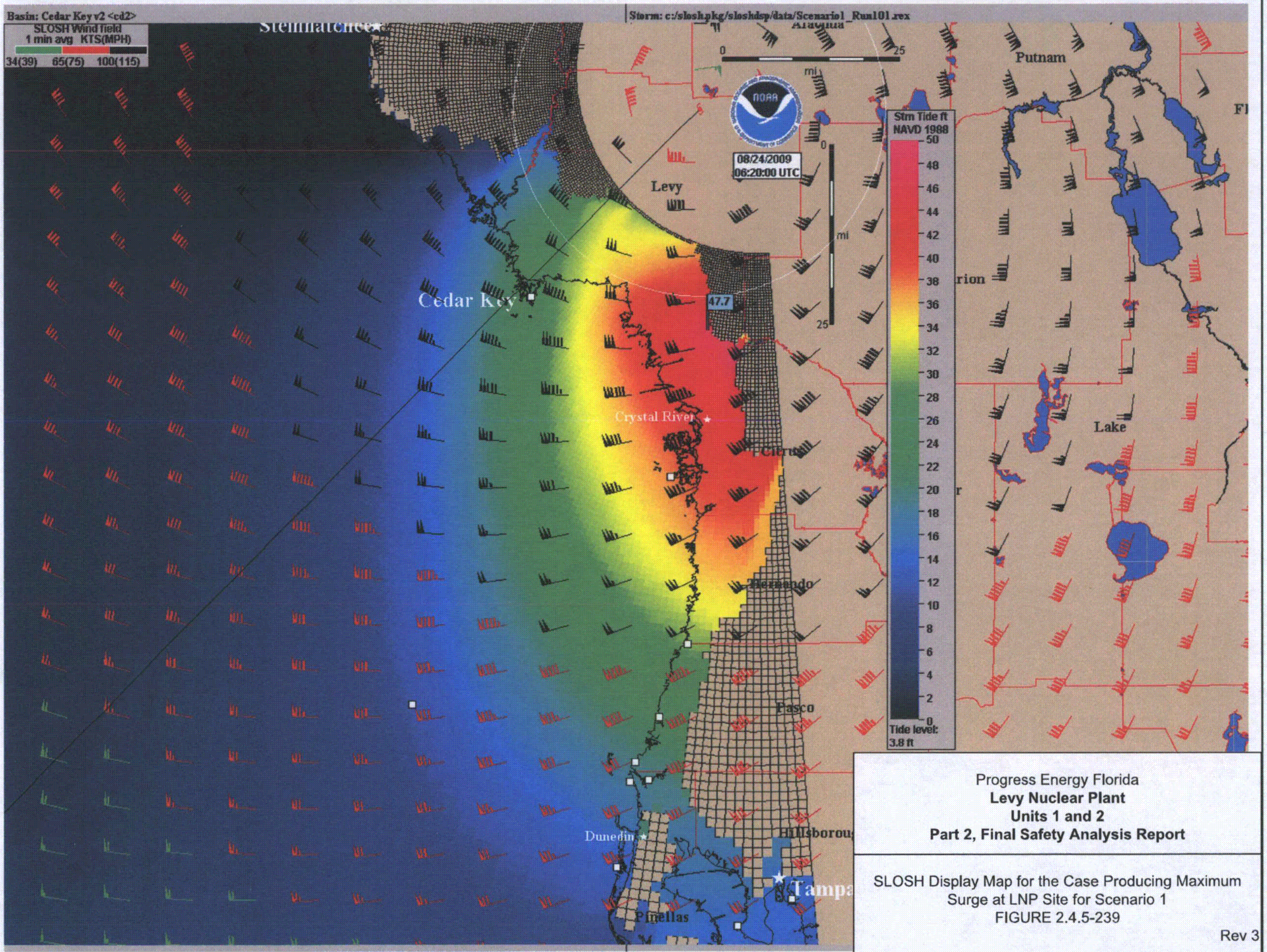
Figure RAI 2.4.5-10-5



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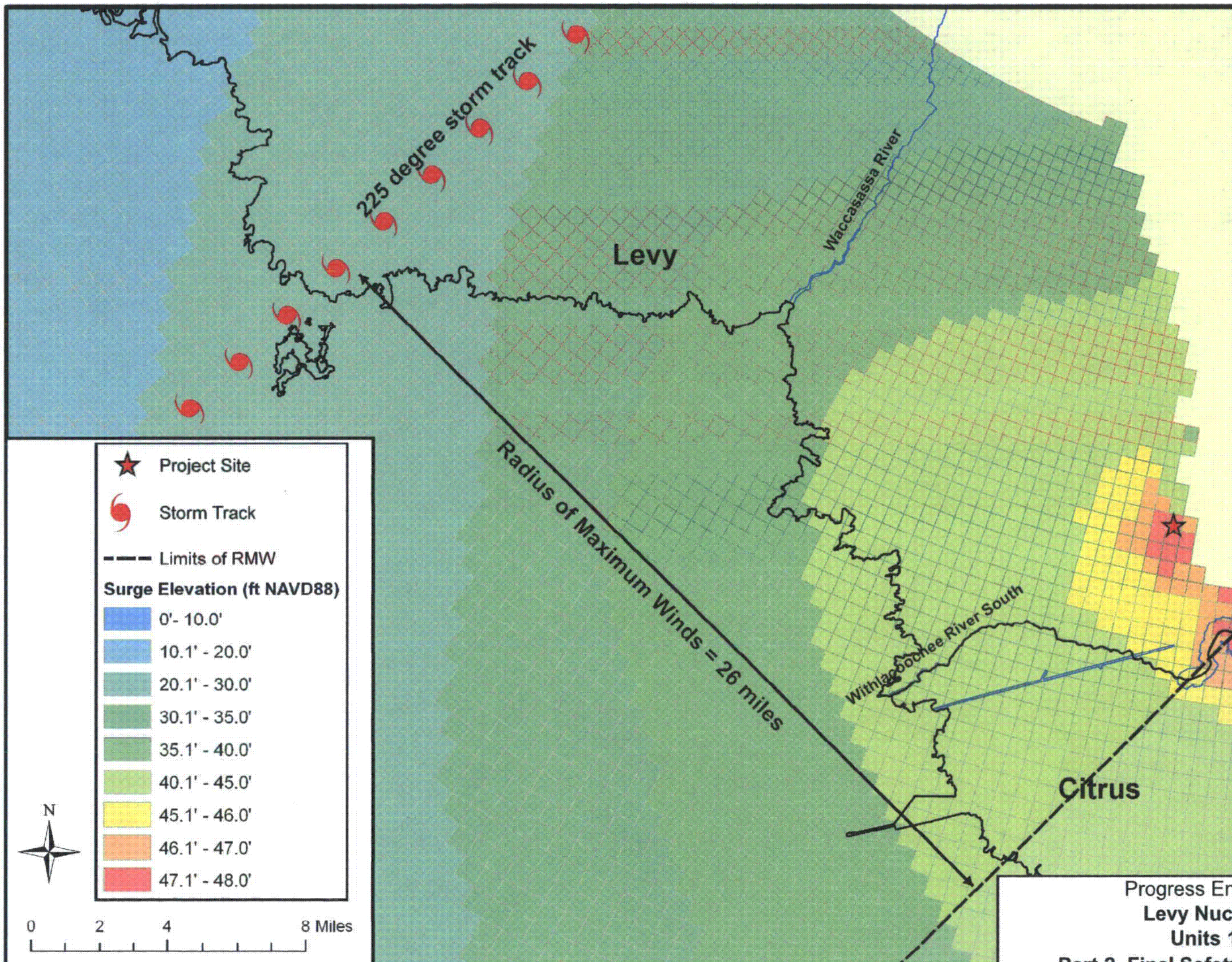
SLOSH Display Map for the Case Producing Maximum Surge at LNP Site for Scenario 1
FIGURE 2.4.5-239

Rev 3

Figure RAI 2.4.5-10-6

LNP COL 2.4-2



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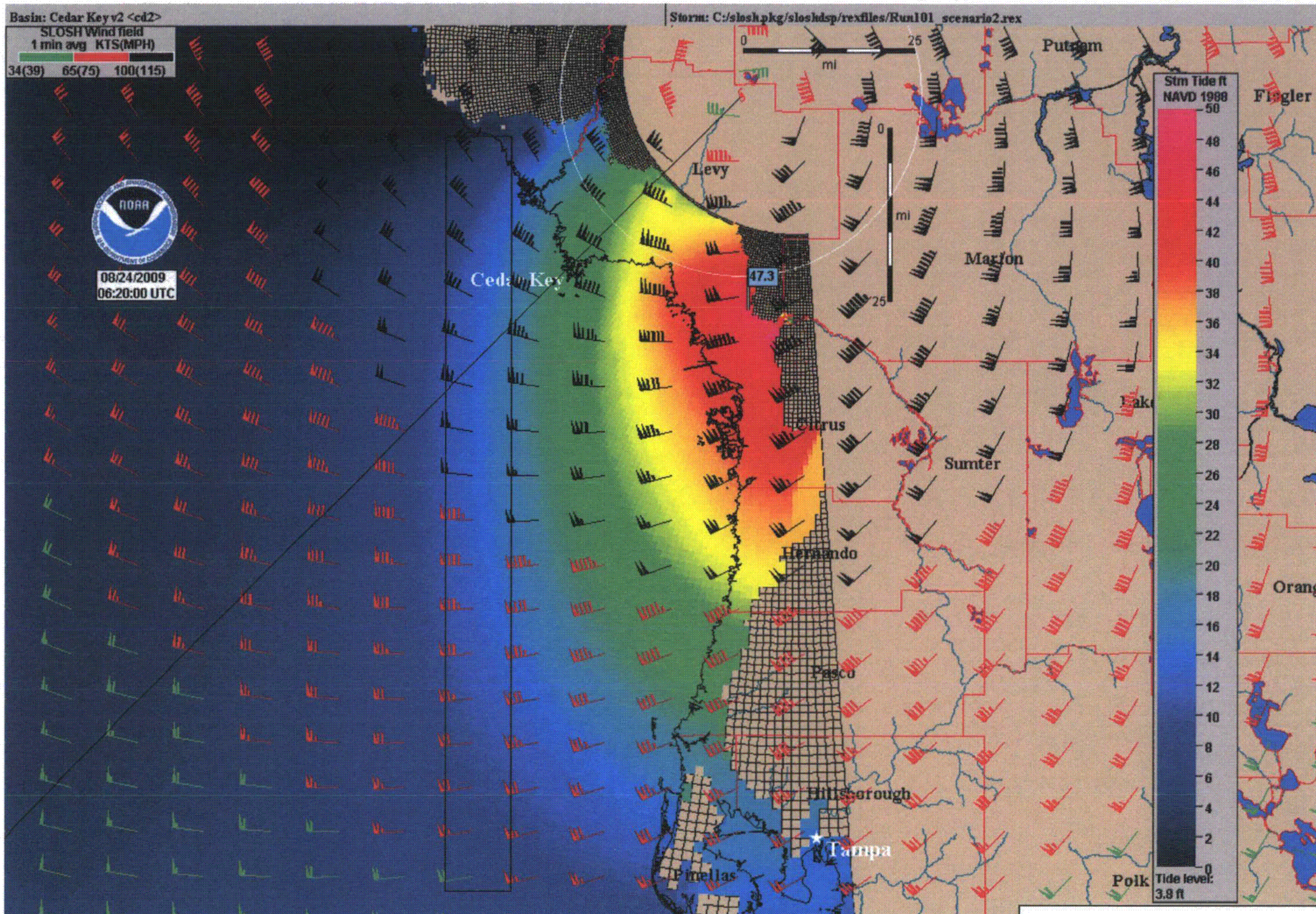
PMH Parameters and Maximum Surge at LNP Site for Scenario 1
FIGURE 2.4.5-240

Rev 3

Figure RAI 2.4.5-10-7



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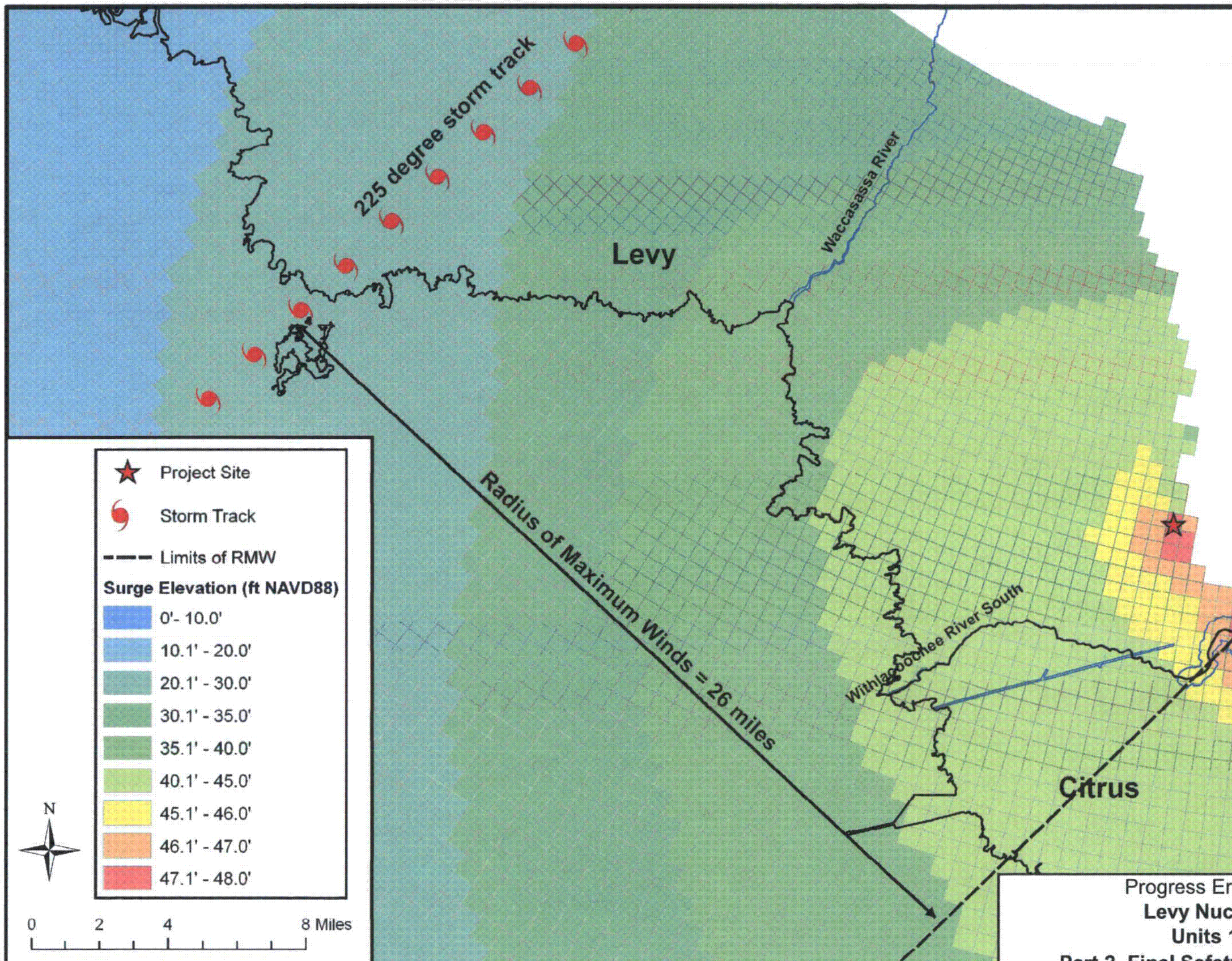
SLOSH Display Map for the Case Producing Maximum Surge at LNP Site for Scenario 2
FIGURE 2.4.5-241

Rev 3

Figure RAI 2.4.5-10-8



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PMH Parameters and Maximum Surge at LNP Site for Scenario 2
FIGURE 2.4.5-242

Rev 3

Figure RAI 2.4.5-10-9

LNP COL 2.4-2

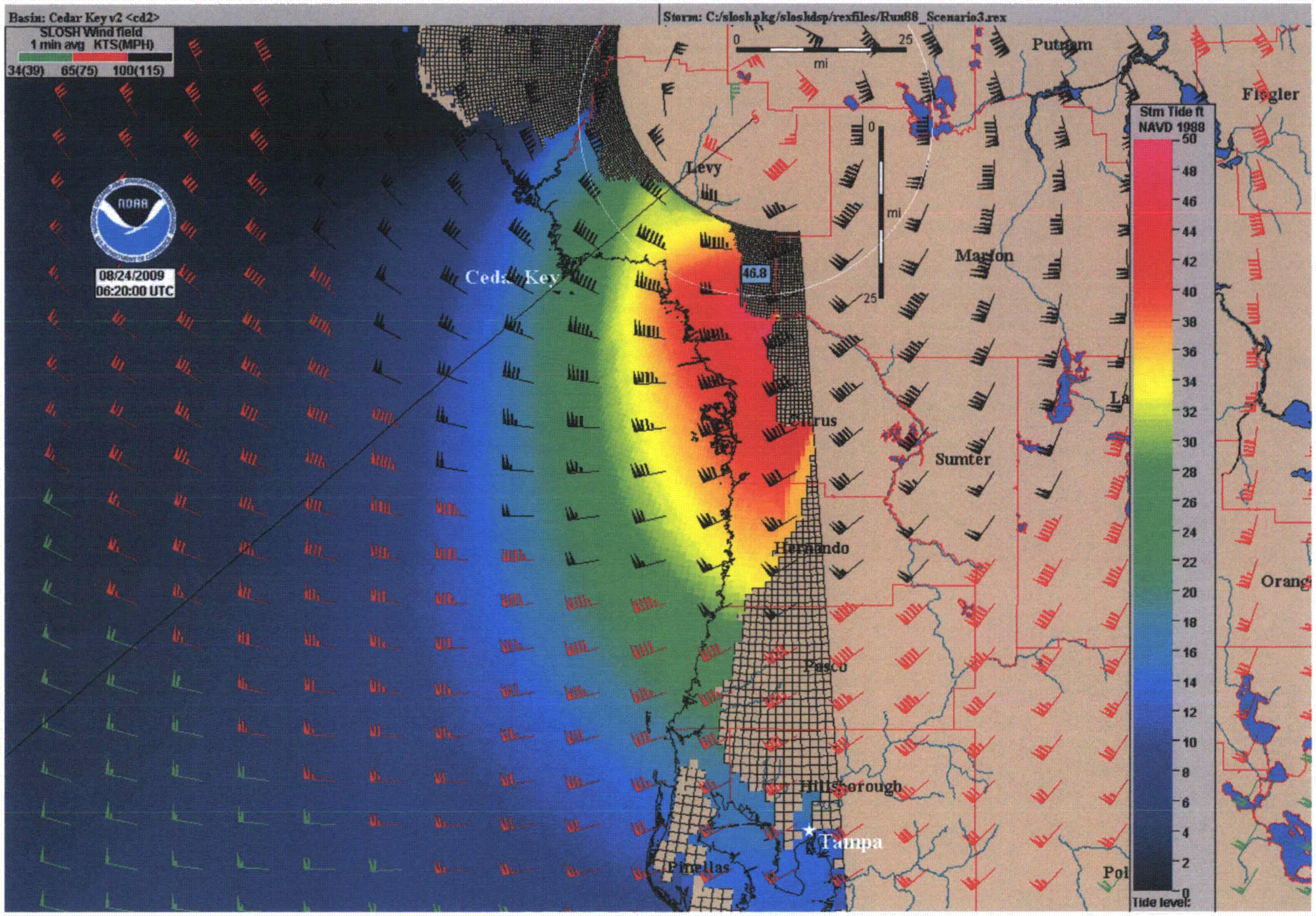

Figure RAI 2.4.5-10-10

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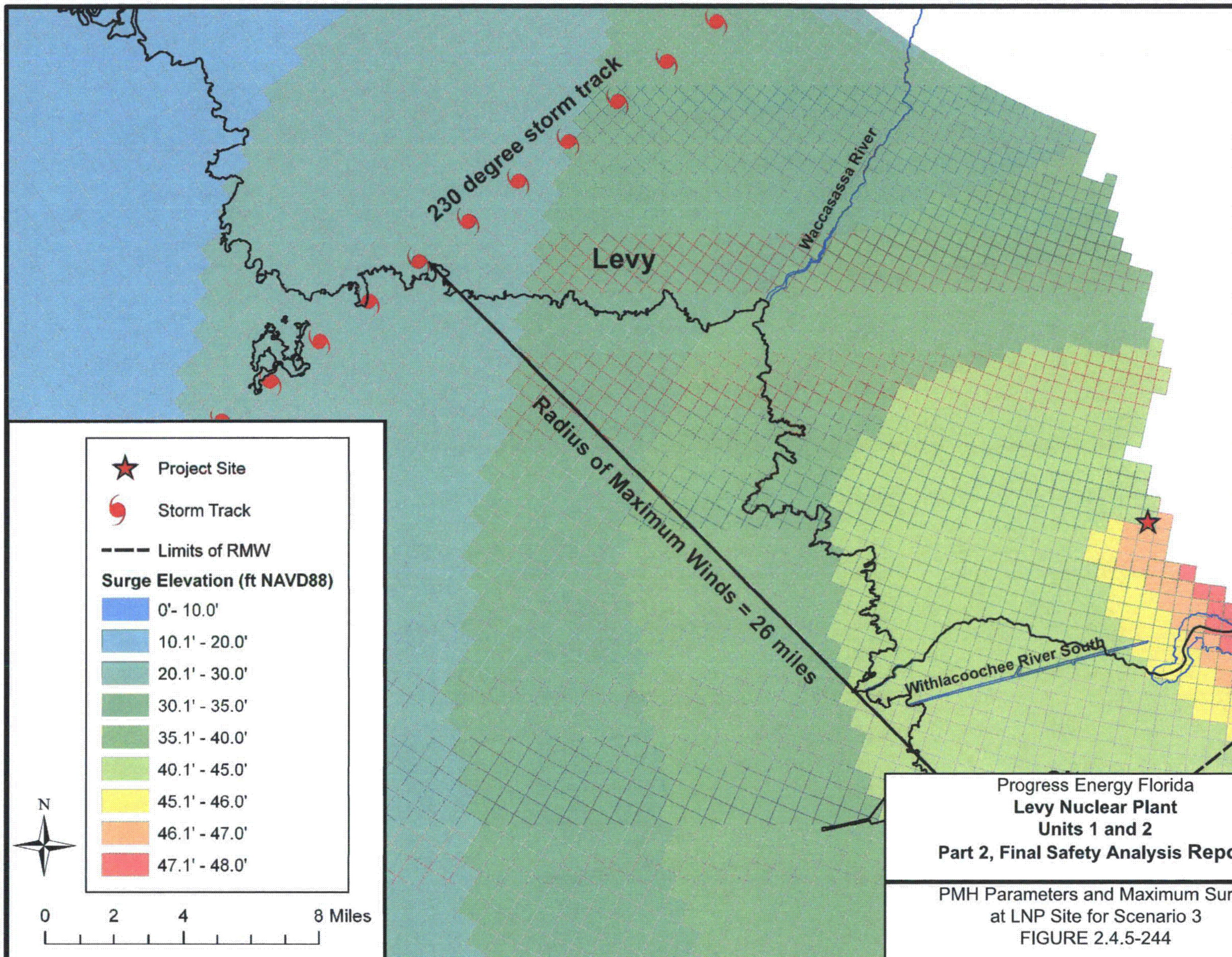
SLOSH Display Map for the Case Producing Maximum Surge at LNP Site for Scenario 3
FIGURE 2.4.5-243

Rev 3

LNP COL 2.4-2



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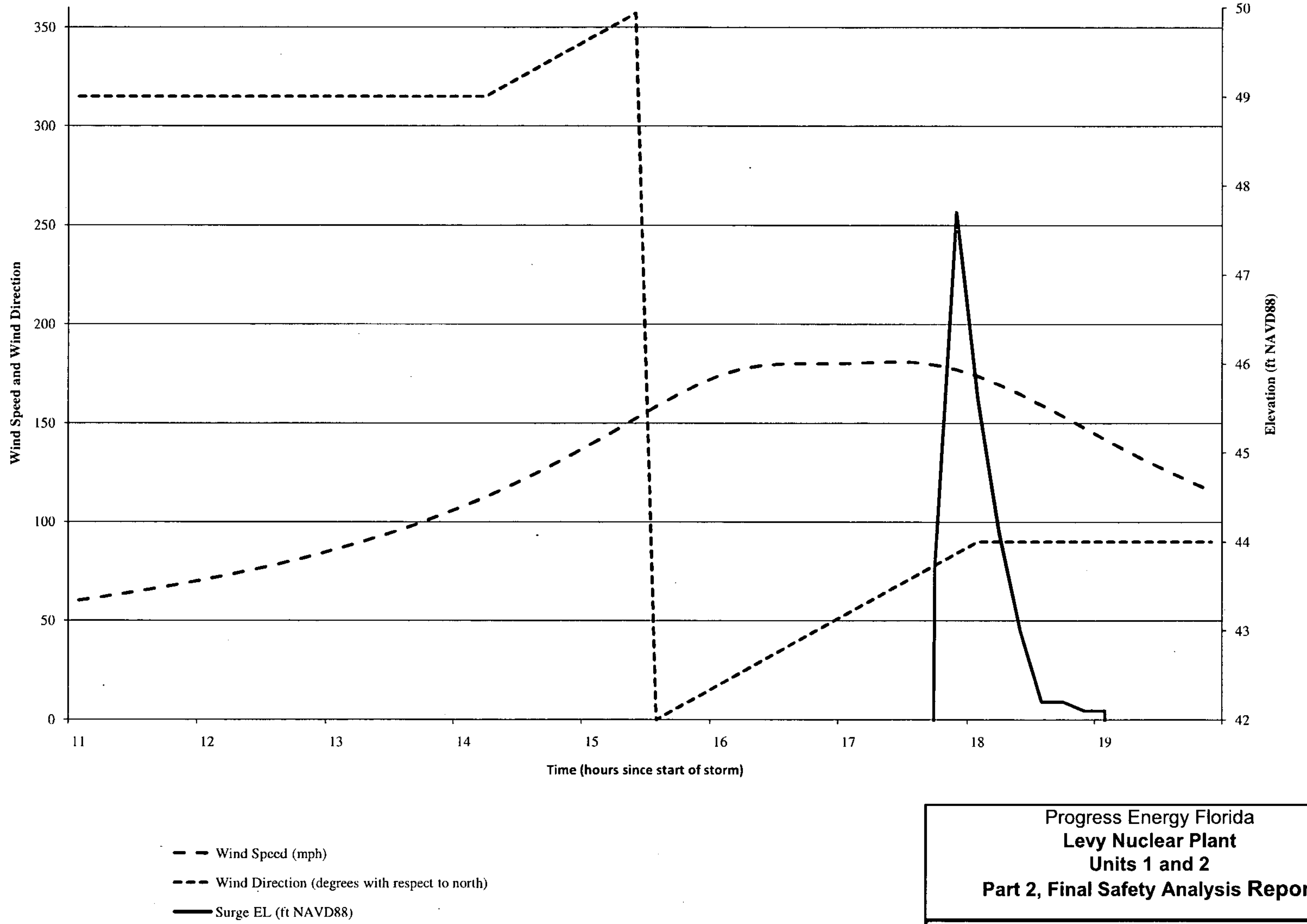
PMH Parameters and Maximum Surge
at LNP Site for Scenario 3
FIGURE 2.4.5-244

Rev 3

Figure RAI 2.4.5-10-11

LNP COL 2.4-2



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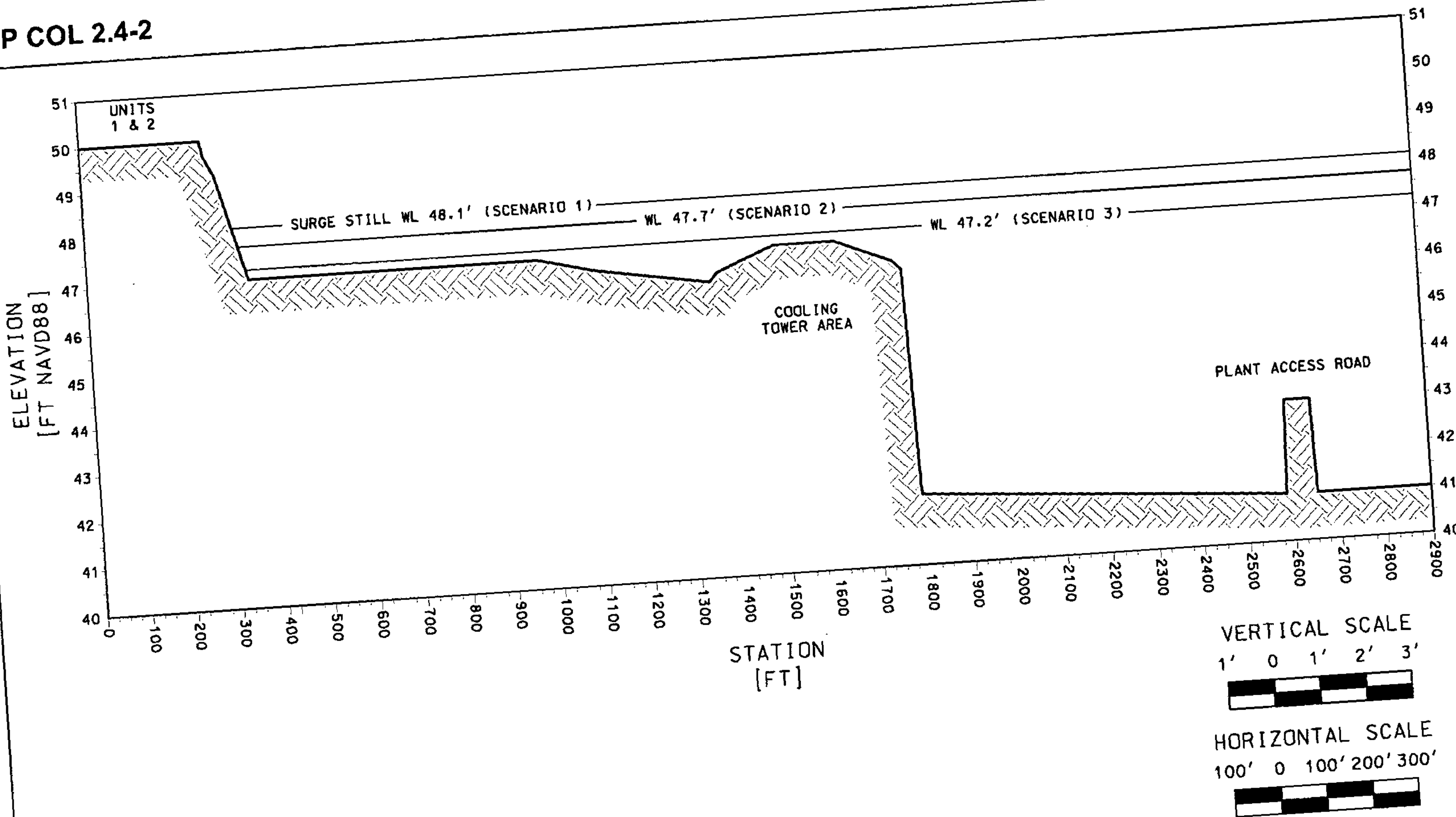
PMH Surge Elevation, Wind Speed, and Wind Direction versus Time (Run 101, Scenario 1)
FIGURE 2.4.5-245

Rev 3

Figure RAI 2.4.5-10-12

LNP COL 2.4-2



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Cross Section Along Transect with Proposed Grades used for Wave Runup Calculation
FIGURE 2.4.5-246

Rev 3

Figure RAI 2.4.5-10-13