UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	Docket # 50-293
Entergy Corporation	
Pilgrim Nuclear Power Station	
License Renewal Application	March 4, 2011

PILGRIM WATCH FINDINGS OF FACT CONCLUSIONS OF LAW
SAMA REMAND

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INTRODUCTION

1. Pilgrim Watch filed its *Request For Hearing and Petition To Intervene By Pilgrim Watch* on May 25, 2006 ("Hearing Request"). That Hearing Request set forth four Contentions. Contentions 1, 2 and 4 were rejected by the Board and Commission. Contention 3 is the subject of this remand hearing.

2. Contention 3 now before this Board is different from Contention 3 as originally set forth in Pilgrim Watch's Hearing Request. As stated in Pilgrim Watch's Hearing Request, Pilgrim Watch's Contention 3 was (Hearing Request p 26):

> **Contention 3:** The Environmental Report is inadequate because it ignores the true off-site radiological and economic consequences of a severe accident at Pilgrim in its Severe Accident Mitigation Alternatives (SAMA) analysis
>
> **Contention** The Environmental Report inadequately accounts for off-site and economic costs in the SAMA analysis of severe accidents. By using probabilistic modeling and incorrectly inputting certain parameters into the modeling software, Entergy has downplayed the consequences of a severe accident at Pilgrim and this has caused it to draw incorrect conclusions about the costs versus benefits of possible mitigation alternatives.

3. In its October 16, 2006 Memorandum And Order (Ruling on Standing and Contentions of Petitioners Massachusetts Attorney General and Pilgrim Watch), this Board did not accept Pilgrim Watch's original Contention 3. The amended Contention 3 that this Board did admit, and that remains before the Board, is

> Applicant's SAMA analysis for the Pilgrim plant is deficient in that the input data concerning (1) evacuation times, (2) economic consequences, and (3) meteorological patterns are incorrect, resulting in incorrect conclusions about the costs versus benefits of possible mitigation alternatives, such that further analysis is called for.

4. In its October 30, 2007 Order Granting Summary Disposition with respect to Contention, a majority of the Board stated its understanding of how the amended Contention had narrowed the scope of this proceeding.

> Not at issue here, as discussed below in more depth, because these matters were raised and eliminated at the contention admissibility stage, are issues related to: (1) the adequacy of the computer code (MACCS2) used to perform the SAMA computations; (2) the use for SAMA analyses of probabilistic (as opposed to deterministic) methodologies; and (3) the health effects of low doses of radiation.

5. On March 26, 2010 the Commission reversed the Board's grant of summary disposition and remanded Contention 3 to the Board for the consideration of some issues.

6. The Board's Order of September 23, 2010 identified the issues it would consider and the manner in which the remand hearing would be conducted:

> Contention 3 will be bifurcated, to the following extent:
> If the Board decides in favor of Intervenors on the primary and threshold issue of *whether the meteorological modeling in the Pilgrim SAMA analysis is adequate and reasonable to satisfy NEPA, and whether accounting for the meteorological patterns/issues of concern to Pilgrim Watch could, on its own, credibly alter the Pilgrim SAMA analysis conclusions on which SAMAs are cost-beneficial to implement* (hereinafter referred to as "the meteorological

modeling issues"), the hearing will proceed to consideration of whether, and the extent to which, additional issues as set forth below will be heard

7. Now before the Board is the "primary and threshold issue." In deciding that issue, the Board has kept three things in mind:

a. Entergy is seeking a 20 years extension of its operating license and bears the burden of proof.

b. As admitted by this Board, Contention 3 only requires Pilgrim Watch to show that "further analysis is required." It does not require Pilgrim Watch to conduct that analysis or to show what its results might be.

c. Consistent with both of these, the question now before this Board, as stated in its September 23, 2010 Order, is whether Entergy has met its burden of proving that its meteorological modeling does adequately and reasonably satisfy NEPA, and that "the meteorological pattens/concerns of concern to Pilgrim Watch, on its own, could [not] credibly alter the Pilgrim SAMA analysis."

8. **The Board finds, based on the facts and legal principles set forth below, that Pilgrim Watch has shown that "further analysis is required," and that Entergy has not met its burden.**

FINDINGS OF FACT

I. Introduction

9. Under NRC Regulations, SAMAs are a Category 2 (site specific), and not a Category 1 (generic), issue. Table 9.1 of NUREG 1437 lists both Category 1 and Category 2 issues, and

identifies SAMAs as Category 2. Entergy agrees SAMAs are Category 2.[1] Pilgrim Watch's challenge is site-specific: "Applicant's SAMA analysis *for the Pilgrim plant* is deficient..."

10. The Gaussian plume model used by Entergy does not take the complex site specific conditions at PNPS into account. The site specific conditions that the Gaussian plume model used by Entergy does not take into account, and is not capable of taking into account, include the sea breeze effect, the behavior of plumes over water, storms, precipitation, fog, or geographical varations, all of which we discuss below. (Egan, PWA00001)

11. As we also discuss below, the evidence before us shows that a variable plume model could take all of these into account, and thus could provide a much more accurate analysis. (Ibid)

12. Entergy did not meet its burden of proof. They should have conducted analyses that compared both models, rather than presenting analyses that are based on only Entergy's straight-line Gaussian plume model. (Ibid)

II. Meteorological Modeling Overview

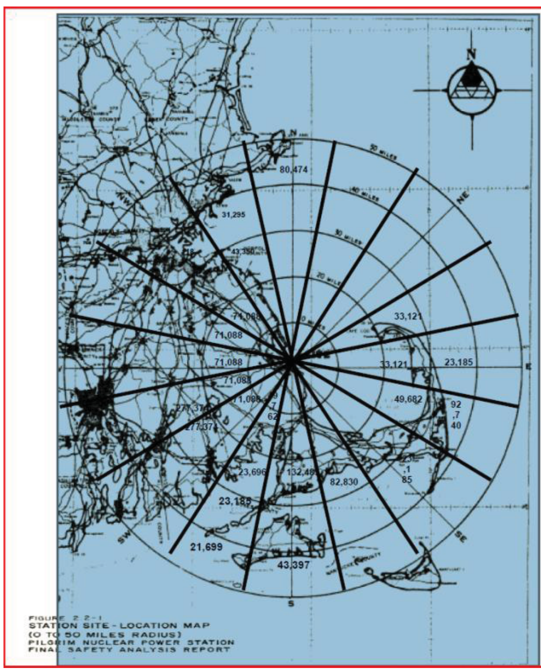
13. What meteorolgical model is used will determine the area likely to be impacted and the deposition within that area. The need for accuracy in the meteorological model is particularly important where the economic costs of mitigation measures are being calculated. (Egan, PWA00023, pg.,2)

[1] PNPS Applicant's Environmental Report Operating License Renewal Stage, 4.21.4 says,"…severe accidents are a Category 2 issue for plants that have not performed a site-specific consideration of severe accident mitigation and submitted that analysis for Commission review.[Reference Section 5.5.2.5,US NRC, NUREG-1437, GEIS, Volumes 1 and 2, May 1996]

14. It is critical that the meteorological data input is representative of the air flow conditions throughout the source area and the locations of interest where air pollutant concentrations are being calculated. (Egan, PWA00001,pg.3)

15. The selection of a dispersion model depends decisively upon the complexity of the meteorology and terrain influencing a release from a source and at what downwind distances reliable concentration projections are needed. (Ibid)

16. As shown in the table below, the Pilgrim site is located along the coast of Cape Cod Bay, "approximately 60% of the area within the 50-mile radius is open water." (FEIS, pg., 7) Not surprisingly, population densities are much higher in some directions than in others.



Pilgrim Nuclear Power Station
Applicant's Environmental Report
Operating License Renewal Stage

E.1.5.2.1 Projected Total Population by Spatial Element

The total population within a 50-mile radius of PNPS was estimated for the year 2032, the end of the proposed license renewal period, for each spatial element by combining total resident population projections with transient population data obtained from Massachusetts and Rhode Island. Table E.1-13 shows the estimated population distribution.

Table E.1-13
Estimated Population Distribution within a 50-mile Radius

Sector	0-10 Miles	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	50-Mile Total
N	0	0	0	0	80474	80474
NNE	3	0	0	0	0	3
NE	3	0	0	0	0	3
ENE	3	0	33121	0	0	33124
E	5	0	33121	23185	0	56311
ESE	23	0	49682	92740	0	142445
SE	950	9936	115925	23185	0	149996
SSE	13289	69555	82803	0	0	165647
S	23695	99364	132485	84383	43397	383324
SSW	23695	49762	23696	23185	21699	142037
SW	23695	71088	277374	349491	114546	836194
WSW	23695	71088	277374	349491	183037	904685
W	22818	71088	277374	388324	286370	1045974
WNW	16494	71088	118481	303450	390150	899663
NW	11269	71088	195075	1529212	405561	2212205
NNW	5599	35544	43350	31295	321894	437682
Total	165236	619601	1659861	3197941	1847128	7489767

The 2000 U.S. Census Bureau data, together with Massachusetts and Rhode Island population projection data, was used to project county-level resident populations to the year 2032. Seasonal peak transient population was conservatively used to establish a transient/resident population ratio for each county within the 50-mile radius. The ratio was found to be decreasing over time. For purposes of this study, the total county level population values were estimated by

Figure 2: Radial grid overlay to 50 miles ENT00004) **LRA, E-161 showing 1990 population per grid (FEIS 1972)**

17. The "coastline orientation and topography strongly influence wind patterns (the frequency, direction, and strength of onshore winds.) Predominantly, in the summer and spring, a sea breeze on-shore component is observed along the Massaachusetts coast. The dominant sea breeze components are east and east-southeast for Boston-Logan, easterly for Plymouth, northeast and east-northeast for the Canal site, and east-southeast for the Pilgrim Plant. The finding suggests that wind speed and direction at one coastal site should not be used as a surrogate for other coastal sites." (Spengler, PWA00011, pg.,1)

18. The topography is characterized by gently rolling hills, forests, beaches, dunes, tidal marshes, ponds, lakes, swamps and clusters of buildings in towns and cities - unlike the flat grassland plains of Kansas, as shown below. Entergy's description of the PNPS site says that the "[t]opography consists of rolling forested hills interspersed with urban areas.

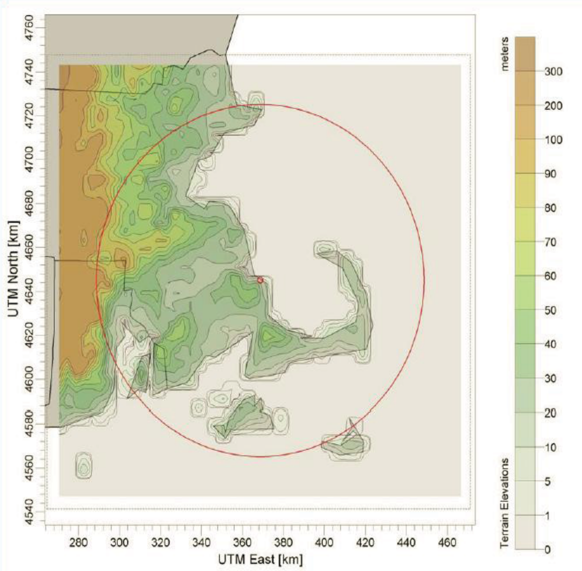


Figure 5. Terrain elevations in the CALMET modeling domain. The Pilgrim Station and the 50 mi radius circle around the Pilgrim Station are shown in red.

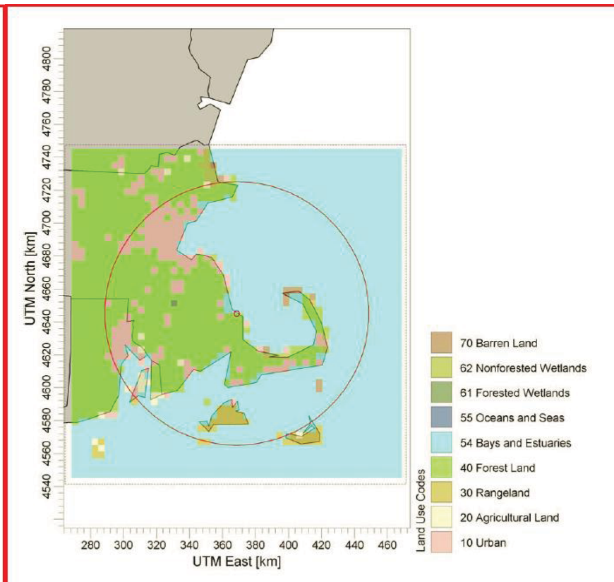


Figure 6. Land use categories in the CALMET modeling domain. The Pilgrim Station and the 50 mi radius circle around the Pilgrim Station are shown in red.

Figure 6: Land use categories in the CALMET modeling domain. The Pilgrim Station And the 50 mi radius circle around the Pilgrim Station is shown in red. (ENT00004, pg., 19)

19. NRC regulations are clear that the SAMA cost –benefit analysis is a Cateogry II issue (site specific). Therefore the meteorological model must take into consideration the site specific chacteristics of Pilgrim's location in order to properly model contaminant transport.

A. Straight-Line Gaussian Plume Model

20. The MACCS2 code used by Applicant is based upon a straight-line Gaussian plume model.

> The MAACS2 code is based upon a straight line, steady state Gaussian plume equation that assumes that meteorological conditions are steady in time and uniform spatially across the study region for each time period of simulation. <u>It does not allow consideration for the fact that the winds for a given time period may be spatially varying.</u> For example, the wind speeds and directions over the ocean and over the land near the Pilgrim Nuclear Power Station (PNPS) are assumed to be the same. Thus the presences of sea breeze circulations which dramatically alter air flow patterns are ignored by the model. As discussed later, the nearby presence of the ocean greatly affect atmospheric dispersion processes and is of great importance to estimating the consequences in terms of human lives and health effects of any radioactive releases from the facility. (Egan, PWA0001, §9) (Emphasis added)

21. The Gaussian plume model assumes that a released radioactive plume travels in a steady-state straight-line [Egan, PWA00001, pg., 9], i.e., the plume functions much like a beam from a flashlight.

22. The Gaussian model provides a "snapshot" that " makes a projection based on an initial set of conditions, persisted without change. (PWA00019, NRC La Vie, slide 4, 9)

23. The essential conditions of the gaussian model are: non-zero wind speed; wind direction constant over time and downwind area; release rate constant over time for the duration of the release; atmospheric stability contstant over time and downwind area. Because of these conditions: Gaussian assessment is a straight-line 'snapshot;' (and the) gaussain model is not temporal nor spatial." (Ibid, slide 22) These conditions are not characteristic of Pilgrim's coastal site. (Egan, PWA00001)

24. "The most limiting aspect of the basic Gaussian model is its inability to evaluate spatial and temporal differences in model inputs." (LaVie, PWA00019, Ibid, slide 28)

25. In Gaussian models, "[t]he impact of terrain on plume transport is not addressed. Straight-line models can not "curve" a plume…Advanced models can address terrain impact on plume transport." (Ibid, slide 33) As shown above (§ 18), Pilgrim's site specific topography is characterized by gently rolling hills, forests, beaches, dunes, tidal marshes, ponds, lakes, swamps and clusters of buildings in towns and cities - unlike the flat grassland plains of Kansas where gaussian models have been compared to variable models.[2]

26. In flat terrain settings with homogeneous surface characteristics (e.g., surface roughness, albedo and Bowen ratio) and relatively evenly distributed populations of interest, the simple straight-line Gaussian plume model algorithm is often appropriate. However, Pilgrim's 50-mile radius is not charaterized by flat terrain.

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[2] Mollenkamp et al (2004) compared several codes for recorded data in the Midwest, NUREG/CR-6853, discussed herein at page 37

Segmented Gaussian Plume Model:

27. Entergy said that it "uses a Gaussian plume segment model, not a standard straight line model." (ENT0001,Answers 14, 33) This model updates some of the meteorological governing plume dispersion on an hour-by-hour basis, but it remains a straight line model. (Egan, PWA00023, pg., 2). The key point is that the wind direction, i.e., the direction of the straight line in which the plume travels, always remains the same. It does not capture variability.

28. Pilgrim Watch's expert, Dr. Egan's comments regarding the plume segment model:

> The responses by Drs Hanna and O'Kula to questions 14 and 33 describe how the ATMOS module within the MACCS2 model simulates transport and dispersion with a "plume segment" algorithm. Their description states that the plume segment model is more than the straight-line Gaussian plume model in that it is "able to account for hour to hour changes in atmospheric stabilities, wind speed, and precipitation during plume travel. Noticeably absent are hourly changes in wind direction, a key concern for the PNPS site. It is a straight-line Gaussian model. The associated reference to the plume segment model refers to a section of NRC Regulatory Guide 1.111 entitled "Plume Element Models". The reference to this section is misleading as it has only one equation that is for a "puff" model. No equations are provided for the plume segment model. Reference to the plume segment model is in a following single paragraph that states that the plume segment model uses **spatial and temporal** (emphasis added) variations of wind direction, wind speed and atmospheric stability to define the transport and diffusion of each element. The next and final paragraph in Regulatory Guide 1.111 essentially states what we have being advocating: "The effectiveness of the meteorological input data in defining atmospheric transport and diffusion conditions is dependent on the representativeness of these data and the complexity of the topography in the site region; therefore a detailed discussion of the applicability of the model and input data should be provided." The plume segment model as has been applied to the PNPS uses temporal but not spatial variations of meteorological conditions. Spatial

variations would require the use of simultaneous meteorological data. My understanding is that the application at PNPS did not use multiple station data in this context. (Egan, PWA00023, pg.,2) (Emphasis, underlining, added)

B. Variable Plume or Advanced Diffusion Models

29. Dispersion models rely upon the adequacy of the input meteorological data to represent the important air flow regimes. The field of dispersion modeling has developed rapidly; however, "[s]imilar improvements to the model parameterizations have not been required for models used by the NRC for applications to the permitting of nuclear power plants while other government agencies and the air dispersion modeling communtiy agree that the straight-line gaussian plume models cannot account for the effects of complex terrain on the dispersion of pollutants from a source." (Egan, PWA00001, §7-9)

30. History Model Improvements (Dr. Egan)

The field of dispersion modeling has developed rapidly since models were first routinely used in regulatory applications in the 1960's and early 1970s. The Clean Air Act Amendments of 1977 created further reliance on atmospheric dispersion models for the establishment of emission limits for new industrial sources seeking licenses and permits under the Clean Air Act. The US EPA and other groups initiated research programs to improve the science of dispersion models and the US EPA began to establish performance measures for models and to provide guidance and recommendations for the testing and adoption of improved models in permit applications. The result was further advancement in modeling methods that have persisted to the current decade. Specifically, very significant improvements have been made in the parameterization of the atmospheric boundary layer wind profiles, temperature profiles and variations of turbulent mixing rates with height above the ground surface. As a result of the Clean Air Amendments of 1977, The US EPA has been instrumental in encouraging and supporting the development of improved models including those defined as guideline models AERMOD and CALPUFF (EPA, 2005). AERMOD includes highly sophisticated algorithms for including spatial variations of the ground surface parameters of roughness lengths, surface albedo and the Bowen ratio into the parameterizations of wind and turbulence levels as a function of height. CALPUFF has the added features of allowing spatially variable wind fields. These models are now routinely used for regulatory applications and for risk assessments.

Even more advanced prognostic dispersion models have been developed for other applications including forecasting of sports events and real time model for weather forecasting and air quality predictions. For example, the MM5 meteorology model was used as a real time forecast model for predicting wind and dispersion conditions in last years winter Olympics. (PWA00001, §7-9)

31. The **CALPUFF** model is an example of a variable plume model that is appropriate for simulating transport and dispersion in wind fields that change with space and time (Scire,et al, 2000a) It is often coupled to CALMET (Scire, et al, 2000b), a model that computes the needed wind and dispersion fields from meteorological data. CALPUFF may also be coupled to a full mesoscale meteorological flow model such as MM5. (PWA00001, §7-9, 11)

32. CALPUFF has benefited from advances in the parameterization of wind fields and turbulent dispersion over the past four decades. CALPUFF is routinely used in both simple and complex terrain settings to estimate ambient air concentrations at distances beyond the recommended 50 kilometer upper limit of AERMOD (EPA, 2005).

33. The air flow fields used by CALPUFF generally use data from more than one meteorological station in order to estimate concentrations at large distances from a source.

Straight line Gaussian plume models, like ATMOS, do not have the capability to simultaneously use meteorological data from several different sources. (PWA00023, pg.,2)

C. Straight-Line vs. Variable Plume Models

34. A variable model that takes into account the manner in which winds vary spatially over time and location is fundamentally different from Entergy's Gaussian plume model, which assumes and is limited to meteorological conditions steady in time and uniform spatially [Egan, PWA00001,§ 9]. Such a variable plume model also is fundamentally different from the "relatively simple" atmospheric models used in Entergy's MACCS2 code which cannot account for variations at Pilgrim's site and in which "'[r]eleased material is assumed to travel downwind in a straight line." [NUREG/CR-6853 (October 2004), 5].

35. The simplicity of the ATMOS straight-line model's assumptions make the model unreliable for use at Pilgrim's coastal location and varied terrain. Because of its inherent limitations, the straight-line model therefore cannot accurately predict the geographic dispersion and concentration of a radionuclide release from that site. A proper valiable plume model is much more likely to reliably predict geographic dispersion and concentration of a release from a reactor at Pilgrim's coastal location. (PWA00001, §7-9, 11)

36. From a meteorological air flow perspective, the presence of the ocean, nearby terrain features and non-homogeneous ground surface features, all affect the overall air flow patterns, which in turn affect the rates of vertical and horizontal mixing of any pollutants released from the plant. (PWA00001, § 9)

37. A proper variable plume model can take these into account; a straight line model cannot.

38. The straight line model's ATMOS can only use data from one meteorological location at a time, cannot predict the wind speed and direction accurately from the meteorological data measured by that tower because wind speeds and directions offsite are unlikely to be representative of the larger scale flow patterns that carry contaminants from the plant to the surrounding areas. It is important that atmospheric dispersion modeling of the effluents from the plant consider these factors in order to provide a reliable basis for estimating ground level concentrations and corresponding estimates of potential exposures to the surrounding population. A proper variable plume model is far more likely to do so. (PWA00023, pg.,2)

39. The consensus in the scientific community of meteorologists that create and use air dispersion models, and government agencies that rely on them, is that a simple straight-line Gaussian plume model, such as ATMOS, is scientifically unreliable when applied to the complex terrain in which Pilgrim is located and cannot accurately predict the dispersion and concentrations of radionuclides in a 50 mile radius of the Station. (Ibid)

40. For that reason, and as Pilgrim Watch has shown, "the assumption of a … straight-line plume are inappropriate when complex inhomogeneous wind flow patterns happen to be prevailing in the affected region," [PWA00001 § 11; Rothstein, 2] such as the affected region of PNPS.

41. All of the evidence presented by Entergy is based on a straight line Gaussian plume model. A major issue before this Board is whether this evidence is sufficient to carry Entergy's

burden of showing that its use of the Gaussian plume reasonably satisfy NEPA, and that a variable plume model that accounted for site specific meteorological conditions at PNPS could not credibly alter the SAMA analysis. We have concluded that it does not.

42. To prove its contention, that use of a variable plume model (as opposed to a straight-line Gaussian model) would make no significant difference in the area impacted or the deposition within that area, Entergy should have run both its segmented straight line model and also a proper variable plume model, to find out how, among other things, whether use of a site-appropriate variable plume model could result in significant changes in the areas that would be affected by a serious accident at PNPS, and then should have compared the results. Although the importance of this issue has been apparent since Pilgrim Watch filed its Request for Hearing in 2006, Entergy has not done this. The segmented plume model used by Entergy does not model spatial variations, as required for this site. (Egan, PWA00023, pg., 2) It is the responsibility of the Applicant, not the petitioner, to do the required "further analysis." (Burden of Proof, herein at § 250-260)

43. Because of these deficiencies, and because of the wide variations in population density within the 50 mile radius, Pilgrim's SAMA analysis may have significantly underestimated the area and hence the number of people and property exposed in a severe accident and the concentration of the doses received.

44. Pilgrim Watch has presented evidence showing that that the use of a variable trajectory model could materially affect whether additional SAMAs may be cost-beneficial.[3] Entergy used a straight-line Gaussian plume model, and in determining what SAMAs might be beneficial,

[3] Pilgrim Watch Answer Opposing Entergy's Motion for Summary Dispostion of Pilgrim Watch Contnetion 3, June 29, 2007, Tables pages, 42-43

assumed that the majority of the winds head N, NNE, NE, ENE, E, and ESE. Entergy essentially ignored the other 43.7% of the winds (ENT00001, Ans.100), even though the impact of that 43.7% is more than ten times of the off-shore winds. (Ibid A96).

Entergy's own tables are set forth below.

Table 6. Comparison of annual 2001 wind direction frequencies from the CALMET trajectory analysis (500 m elevation trajectories, at a distance of 50 miles from the Pilgrim Station), with wind direction frequencies from the 33 ft level of the Pilgrim meteorological tower (used in the SAMA analysis).

Wind Direction (blowing towards) Compass Direction	CALMET Trajectory 500 m (1,640 ft) Elevation and 50 mile Distance	Pilgrim 33 ft	Difference
N	11.0%	8.8%	2.2%
NNE	13.7%	16.1%	-2.4%
NE	9.4%	12.0%	-2.6%
ENE	9.0%	10.1%	-1.1%
E	8.9%	9.3%	-0.4%
ESE	6.7%	6.5%	0.2%
SE	6.2%	4.5%	1.7%
SSE	5.1%	3.1%	2.0%
S	5.1%	3.7%	1.4%
SSW	4.8%	5.2%	-0.4%
SW	3.2%	3.8%	-0.6%
WSW	2.3%	3.6%	-1.3%
W	2.2%	3.6%	-1.4%
WNW	3.6%	3.2%	0.4%
NW	4.4%	3.7%	0.7%
NNW	4.5%	2.6%	1.9%

Next by multiplying the population by spatial element projected to 2032 provided in the LRA (E.1.5.2.1) by Entergy's sensitivity cases (Entergy Motion for Summary Disposition, May 17, 2007, Material Facts 16-18,50-57, referencing O'Kula WSMS 2007 Report), it shows by multiplying population per spatial element by Entergy's own sensitivity analyses that Entergy essentially ignores the 46% of the time winds blow in other directions (variability) that would result if considered in approximately 15 times more damage.

Table: Population Per Geographic Sector Multiplied By Sensitivity Case I&2 Costs

Sector	Total Population 0-10 miles	Pop x $135,187.77/per person 1st sensitivity	Pop x $189,041/person 2nd sensitivity
N	0	0	0
NNE	3	$405,563.31	$567,123.00
NE	3	$405,563.31	$567,123.00
ENE	3	$405,563	$567,123
E	5	$675,939	$945,2050
ESE	23	$3,109,319	$4,347,943
SE	950	$128,428,381	$179,588,950
SSE	13,289	$17,883,854,906	$2,512,165,849
S	23,695	$3,203,274,210	$4,479,326,495
SSW	23,695	$3,203,274,210	$4,479,326,495
SW	23,695	$3,203,274,210	$4,479,326,495
WSW	23,695	$3,203,274,210	$4,479,326,495
W	22,818	$3,084,714,536	$4,313,537,538
WNW	19,494	$2,635,350,388	$3,685,165,254
NW	11,269	$1,523,430,980	$2,130,303,029
NNW	5,599	$756,916,324	$1,058,440,559

III. Site Specific Conditions Not Properly Accounted For In Entergy's Analyses

45. Entergy's Gaussian plume model assumes, and is only capable of making its calculations based on, meterological conditions measured at a single point (not where the plume might be) and assumes that those conditions at any point in time are uniform spatially across the study region. (Egan, PWA00001, § 9; Egan, PWA00023, pg., 2)

46. Entergy's model does not take into consideration changes in wind direction once the plume leaves the site (Testimony Hanna and O'Kula, January 3, 2011), or that winds at various points in the study region may for any given time period be spatially varying.

47. Entergy's Gaussian plume model also uses meterological inputs (e.g., wind speed, wind direction, atmospheric stability and mixing heights) that are limited to data collected by

Applicant at a <u>single,</u> <u>on-site</u> anemometer, plus precipitation data from Plymouth airport, some 5 or so miles inland [ENT00001, Answer 39; Application ER, E.1.5.2.6]; and Entergy inputs data from only one year. (Ibid)

A. Sea Breeze Effect

48. Sea breeze is a critical feature to consider when seeking to determine the potential effects of a radiological release at Pilgrim's coastal location (Egan, PWA0001,§ 10)

49. Dr. Spengler's report to the Commonwealth said that "[t]hese flow reversals and stagnations documented here at our coast result in an increased area impacted, increased concentration of the plume and ultimate cost. (Spengler, PWA00011, pg., 3)

50. Dr. Eagan description of the sea breeze says that,

> The sea breeze circulation is well documented (Slade, 1968, Houghton, 1985, Watts, 1994, Simpson, 1994).The pressure differences that result in the development of a sea breeze essentially start over the land area well after sunrise. Along a coast, the sun heats the land surfaces faster than water surfaces. The warmer air above the land is more buoyant and initially rises vertically. The resulting lower pressure over the land draws air horizontally in from surrounding areas. Near a coast, the air over the water is cooler and denser and is drawn in to replace the rising air. This horizontal flow represents the advent of the sea breeze. The air starting to flow over the land is cooler than the air aloft and like any dense gas tends to resist upward vertical motions and prefers to pass around a terrain obstacle rather than up and over it. The density difference also suppresses turbulence that would mix the air vertically. As

this air flows over the rougher and warmer land, an internal boundary layer is created which grows in height within the land bound sea breeze flow. Further inland the flow slows and warms and creates a return flow aloft which flows much more gently back out over the ocean to complete the overall circulations. Thus, the presence of a sea breeze circulation changes the wind directions, wind speeds and turbulence intensities both spatially and temporally through out its entire area of influence. The classic reference *Meteorology and Atomic Energy*, (Section 2-3.5) (Slade, 1968) succinctly comments on the importance of sea breeze circulations as "The sea breeze is important to diffusion studies at seaside locations because of the associated changes in atmospheric stability, turbulence and transport patterns. Moreover its almost daily occurrence at many seaside locations during the warmer seasons results in significant differences in diffusion climatology over rather short distances." (Egan, PWA00001,§10)

51. "While the sea breeze can occur throughout the year, it occurs *most frequently* during the spring and summer months. On average, Pilgrim experiences about 45 sea breeze days during these two seasons. Typically the onshore component commences around 10 AM and can persist to about 4 PM." (Spengler and Keeler, pg., 1) Seasonal wind distributions can vary greatly from one year to the next" (Ibid, pg., 22)

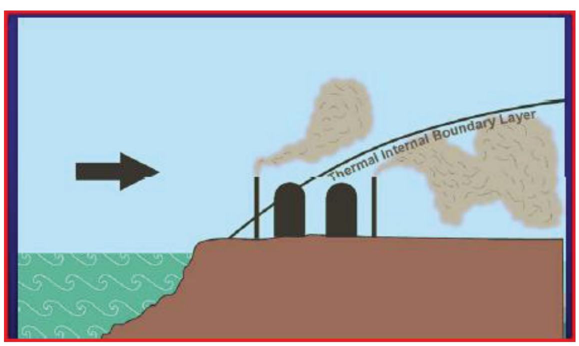
52. However the annual frequency of the sea breeze effect and the "hot spot" effect cannot be known without reviewing data from multiple weather stations and over a 5-year period. This is the "further analysis" that is properly the responsibility of the Applicant, not the Petitioner. Data

is available for example Entergy's expert used 18 meteorological stations within the 50 miles radius in their CALMET Modeling (ENT 00004).

53. Climate change during license renewal is likely to increase the number of days sea breezes occur due to Global warming predictions.

Impact of Sea Breeze:

54. Impact sea breeze: A sea breeze can cause a plume to penetrate farther inland, or to different locations, and thus increase the area impacted. (PWA00019, NRC, LaVie, slide 2 44) Because the air over the water is cooler and stable, as the sea breeze forms, the stable air flows over the unstable air mass at the shore. The boundary between the stable and unstable air in known as the thermal internal boundary alayer (TIBL). Because the air below the TIBL is unstable, there is turbulance and mixing, drawing the plume to ground level thereby increasing dose. (Ibid)



55. Spengler and Keeler, 1988 showed that the sea breeze at Pilgrim's coastal location increases doses on communities inland to an approximate 15 Km (9.3 miles). [Spengler; see also Egan, 12]

56. Subsequent studies have shown penetration can extend inland to an approximate 30 miles along Massachusetts' coast. (PWA00010, Jennifer Thorpe, pg.,5)

57. Entergy's experts agreed that penetation inland could pentrate a considerable distance inland. "On days with significant sea breezes, they average about 5 to 10 miles inland penetration, with occasional larger values of up to 30 miles or so." (ENT00001, Ans., 74). Prior to that, Entergy's expert (O'Kula WSMS Report, pg., 21) said that sea breezes are sometimes recognized to be able to penetrate long distances inland. Simpson (1994) shows evidence of sea breeze penetrations up to 300 km inland over a period of 15 hrs in Australia. Although not all coastal locations will experience such a large inland penetration, Simpson (1994) noted that penetrations on the south coast of England up to 100 km inland. Buckley and Kurzeja (1997) found evidence of sea breeze penetration over 100 km on the South Carolina coast.

E**ntergy's model did not and inherently could not account for the sea breeze effect**.

58. Entergy's expert, Dr. O'Kula incorrectly said that the sea breeze effect was accounted for in Entergy's analysis (Egan PWA0001, §13, refering to Entergy's Motion for Summary Disposition, O'Kula Decl., 10)

59. Dr. Egan showed that Entergy's analysis could not account for the sea breeze effect. Therefore Entergy's analysis minimized the area likely to be impacted and deposition within that

area during the spring and summer months when the sea breeze effect occurs. Dr Egan explained that,

> [Mr. O'Kula's] statement that the meteorological data collected at the PNPS site would reflect the occurrence of the sea breeze in terms of wind speeds and direction is not necessarily true.
>
> A measurement at a single station tower, 220 feet, will not provide sufficient information to allow one to project how an accidental release of a hazardous material would travel.[4] Measurement data from one station will definitely not suffice to define the sea breeze. (Egan, PWA 0001,§ 13, replying to O'Kula's declaration, item 10)

Entergy misunderstands the significance of the sea breeze in increasing dose to the population

60. Entergy's cost-benefit analysis is based on its contention that the sea breeze is "generally beneficial in dispersing the plume and in decreasing doses." (Ibid, O'Kula Decl., Item 10) Dr. Egan explains otherwise. He said that,

> [Mr. O'Kula's] statement reflects a misconception that the sea breeze is "generally a highly beneficial phenomena that disperses and dilutes the plume concentration and thereby lowers the projected doses downwind from the release point." If the same meteorological conditions (strong solar insolation, low synoptic-scale winds) that are conducive to the formation of sea breezes at a coastal site occurred at a non coastal location, the resulting vertical thermals developing over a pollution source would carry contaminants aloft. In contrast, at a coastal site, the sea breeze would draw

[4] License Application 2.10 Meteorology and Air Quality at 2-31; and at Attachment E, E.1.5.2.6 at E.1-63]

contaminants across the land and inland subjecting the population to potentially larger doses. (Ibid, 13 Comment on O'Kula's declarations, Item 20)

61. The Staff's expert, Dr. Bixler, agrees with PW and Dr. Egan, and says that "*the effect of sea breeze is not taken into account"* in Entergy's studies.

> 10. (NEB) Material Fact number 19 states that the effect of sea breeze is taken into account in the Pilgrim site meteorological data. *Although the wind speed and direction of a sea breeze may be included in the actual PNPS meteorological data, the effect of sea breeze is not taken into account.* The effect that is not taken into account is that the *complex flow pattern under sea breeze conditions differs substantially from the straight-line pattern used in the MACCS2 analyses*. The sea breeze occurrences are typically diurnal events, occurring during daylight hours and during warmer seasons. (Emphasis added) (PWA00017, §10)

Entergy's claim that sea breezes will not make a difference (See Entergy Dir. at A73-A81)

62. Entergy's experts say that merely changing meteorological inputs to account for coastal breezes will not make any difference because Entergy has "averaged out" the effects of any differences in meteorology. Entergy (ENT00001, A.79) explains that, "SAMA cost benefit analysis sums (takes a mean average of) population dose and economic consequences across a 50 mile radius based on one-year's worth of hourly meteorological data; (and) Coastal sea and land breezes occur only about forty or fifty days per year, very roughly about 10 to 15% of the year, and for a limited duration of about 6 hours on each day." Therefore sea breeze has no impact if a mean average is used.

63. PW disputes the use of the mean average; and will include this in its appeals. The meteorological issue is the threshold issue. How meteorological inputs are computationally dealt with while inside the MACCS2, as an input, is properly within scope of the accepted contention that limited the contention to meteorological inputs. The MACCS2 OUTPUT file (that is INSIDE the code and performs the mathematical computations with the data) shows a cumulative distribution frequency that includes for example the mean, 90 and 95th percentile. The user chooses what average to use. In order to accurately account for an important site specific characteristic, the sea breeze, it is wrong and deceptive to choose the mean to wash away the effect of an important site-specific occurance, the sea breeze effect. For example, "on days with significant sea breezes, they average about 5 to 10 miles inland penetration, with occasional larger values of up to 30 miles or so" (Entergy A.74). Therefore the sea-breeze would contaminate more densely populated areas where long term health effects and requirements for cleanup would significantly affect cost. The same argument applies to the materiality of the so-called "hot Spot" effect. (PW ANS, at 46)

64. Further, Dr. Egan explains that "the choice of meteorological model does not depend upon the averaging time over which the meteorological variations occur." (Egan PWA00023, pg., 4)

He explained that,

> From a computational point of view, the key difference between the modeling needs of SAMA analyses and applications to emergency response is the fact that, as constructed, the SAMA analyses focus on evaluating only long term average consequences. The short term averages are not needed. For emergency response, the short term predictions are essential. However, the difference between these needs from an air quality modeling computational standpoint essentially reduces to the

averaging of the results and how the data is manipulated in post processors. The core elements of the RASCAL model described by Mr. Ramsdell are used to calculate 1 hour values that could be averaged to produce the long term averages needed for a SAMA. With today's computers, the computer time in unlikely to be an issue. We think such advances could improve the reliability and credibility of ATMOS because improvements to the model made to the 1-hour predictions would improve the reliability of the annual average values.

And

The comments that the US EPA 's requirements to address National Ambient Air Quality Standards (NAAQS) with short term averaging times (one hour, 3 hour, 24 hour averages) is the reason that EPA uses more advanced models are not correct. The averaging times for the National Ambient Air Quality Standards (NAAQS) range for one hour to annual averages. The EPA has guidance for selecting the most appropriate dispersion model for use in different applications (40 CFR Part 51 Appendix W. Guideline ion Air quality models). The criteria are based on a combination of appropriate recent science and model validation. With these criteria, there is no issue of different dispersion modeling techniques for modeling short term averages versus long term averages. Three criteria pollutants have annual average standards: SO2, NO2, and particulate matter. The same models used for estimating short averaging time impacts are used for the annual averages. The modeling requirements for demonstrating compliance with the NAAQS for Nitrogen Dioxide are an example. The initial standard set for NO_2 was for annual average concentrations. On the basis of revised findings of health effects, EPA in 2010, set a new standard with a one hour averaging time. The dispersion modeling methods recommended for compliance demonstrations for both the annual averages and the one hourly values did not change. The choice of model does not depend upon the averaging time over which meteorological variations occur.

B. Behavior of Plumes Over Water –the so-called "Hot Spot" Effect

65. The "Hot-Spot" effect is another important feature to consider when seeking to determine the potential effects of a radiological release at Pilgrim's coastal location. (PWA00002, Beyea 11-12; and others[5])

66. Entergy's Gaussian plume model assumed that plumes blowing out to sea would have no impact. PW showed that a plume over water, rather than being rapidly dispersed, will remain tightly concentrated due to the lack of turbulence. The marine atmospheric boundary layer provides for efficient transport. Because of the relatively cold water, offshore transport occurs in stable layers. Wayne Angevine's (NOAA) research of the transport of pollutants on New England's coast concluded that major pollution episodes along the coast are caused by efficient transport of pollutants from distant sources. "The transport is efficient because the stable marine boundary layer allows the polluted air masses or plumes to travel long distances with little dilution or chemical modification. The sea-breeze or diurnal modulation of the wind, and thermally driven convergence along the coast, modify the transport trajectories." Therefore a

[5] Listing of references: *Angevine*, Wayne*; Senff,* Cristoph; *White,Allen; Williams, Eric; Koermer,James; Miller,Samuel T.K.; Talbot,Robert, Johnston,Paul; McKeen,Stuart,* Coastal Boundary Layer Influence on Pollutant Transport in New England, http://journals.ametsoc.org/doi/full/10.1175/JAM2148.1;Angevine WM, Tjernstrom M, Zagar M., "Modeling of Coastal Boundary Layer and Pollutant Transport in New England," J. of Applied Meterorology & Climatology, 45:137-154, 2006;Beyea, Jan, PhD.,"Report to The Massachusetts Attorney General On The Potential Consequences Of A Spent Fuel Pool Fire At The Pilgrim Or Vermont Yankee Nuclear Plant," May 25, 2006, The Massachusetts Attorney General's Request for a Hearing and Petition for Leave to Intervene With respect to Entergy Nuclear Operations Inc.'s Application for Renewal of the Pilgrim Nuclear Power Plants Operating License and Petition for Backfit Order Requiring New Design features to Protect Against Spent Fuel Pool Accidents, Docket No. 50-293, May 26, 2006; Miller, Samule T.K.; Keim, Barry; Synoptic-Scale Controls on the Sea Breeze of the Central New England Coast**, AMS Journal Online,** Volume 18, Issue 2 (April 2003); Thorp, Jennifer E., Eastern Massachusetts Sea Breeze Study, Thesis Submitted to Plymouth State University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Applied Meteorology, May 2009.

plume will remain concentrated until winds blow it onto land. (Zager et al.; Angevine et al. 2006[6]) (Angevine, PWA00006)

67. If Angevine's research found this to be true for contaminants that result in smog then why would it not hold true for radionuclides? The meteorological phenomena would be the same and the only difference would be factoring in the half-lives of released radionuclides, many of which are long lived.

68. Dr. Beyea said that this effect can lead to hot spots of radioactivity in places along the coast, certainly to Boston. [Beyea, PWA00002, pg.,11) The compacted plume also could be blown ashore to Cape Cod, directly across the Bay from Pilgrim and heavily populated in summer. An alternative model that Entergy did not use, CALPUFF, could account for reduced turbulence over water and could be used for sensitivity studies. (Ibid, pgs., 11-12)

69. Dr. Egan observed (PWA00023, pg., 6) that:

> In the discussion about wind over the ocean, I found Dr. Hanna's response to Question 85 to be out of context with the potential accidental configurations at the PNPS and therefore leading to an erroneous implication about the role of overwater transport. Dr. Hanna states that "a factor of 2 greater wind speed over the ocean would, by itself, contribute to a reduction of maximum concentrations by approximately a factor of two". This would strictly be true only if the source were also within the airflow over the ocean. As Dr. Hanna correctly states in response to question 28, the dilution effect of wind speed and the inverse wind speed relationship to concentration only applies to the initial dilution of the emission source. What

[6] **Angevine, Wayne; Tjernström, Michael; Žagar, Mark,** Modeling of the Coastal Boundary Layer and Pollutant Transport in New England, Journal of Applied Meteorology and Climatology 2006; 45: 137-154, Exhibit 6

often does happen with an onshore flow, since the air over the water is often more stable than that over land, is that a fumigation type event occurs. This is associated with the fact that the surface roughness change and the warm land surface create more turbulence in the surface layer that would mix plume material from an elevated plume down to the surface, resulting in increased ground level concentrations.

Both the sea breeze and behavior of plumes over water (the so-called hot spot effect) will change the area of impact and concentration within that area.

C. Storms – Precipitation – Fog

Storms:

70. Storms along the New England coast are important. "The storm cycle consists generally of northeasters in the winter and spring (and) [h]urricanes sometimes occur in the late summer and fall." [Applicant's LA Appendix E, 2-31]. The accompanying strong and variable winds would carry a plume to a considerable distance. Coastal storms are an intricate combination of events that impact a coastal area. A coastal storm can occur any time of the year and at varying levels of severity; common to coastal storms are high winds, erosion, heavy surf and unsafe tidal conditions, and fog.[7] Massachusetts is susceptible to high wind from several types of weather events, including, hurricanes and tropical storms, tornados, and Nor'easters. High winds move the plume more quickly over an area and to more densely populated areas. Therefore higher concentrations of deposition can be expected at greater distances because there is a shorter time frame for radioactive decay to occur. Dr. Egan explained that,

[7] Commonwealth of Massachusetts -State Hazard Mitigation Plan, 2007http://www.mass.gov/Eeops/docs/mema/disaster_recovery/state_plan_2007_rvn4.pdf at 1.2 Natural hazards

> [T]he travel time of a plume will determine the fractionof radioactive decay that will occur in the near vs. far field of a release.(PWA00023, pg., 5)

71. High winds will result in re-suspension of contaminants, increasing the area of impact. Resuspension is ignored in Pilgrim's analysis. The MACCS2 Guidance Report, June 2004,[8] is even clearer that Entergy's inputs to the code do <u>not</u> account for variations resulting from *site-specific* conditions such as those present at PNPS. (1)The "code does not model dispersion close to the source (less than 100 meters from the source);" thereby ignoring resuspension of contamination blowing offsite, especially in high winds..

Storm events are predicted to increase in number and severity over the license renewal period due to the effects of global warming on climate change. Data from one year of meteorology, 2001, could not capture the increase in these events.

<u>Precipitation and Fog</u>

72. Entergy failed to properly account for another site specific characteristic in Pilgrim's coastal location - precipitation, moisture, fog – that affects dispersion (concentration) and hence the cost-benefit analysis. Dispersion (concentration) is affected by precipitation that, like wind flow, is highly complex. Fog varies along the coast and also in the interior, affected by bogs and ponds. Fog with low inversion layer and constant easterly winds could result in less dispersion of the plume. Because fog patches and precipitation can be highly localized, precipitation data from one location at Plymouth Airport 5 or so miles inland is inadequate. [PW Motion to Intervene, 3.3.3.1.c]

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[8] MACCS2 Guidance Report June 2004 Final Report page 3-8:3.2 Phenomenological Regimes of Applicability

73. Dr. Spengler said that, "[the] worst case scenario of exposure from a release at the Pilgrim Plant may (be)… drizzly, foggy day with a low inversion layer and constant easterly winds (because they) could potentially have less dispersion." (Spengler, Decl., pg., 35)

D. Geographical Variations, Terrain Effects, and Distance

74. PW showed that topography of a coastal environment plays an important role in the sea breeze circulation, and can alter the typical flow pattern expected from a typical sea breeze along a flat coastline. (Spengler, PWA00011, pg., 40)

75. But, the MACCS2 Guidance Report, June 2004,[9] is clear that Entergy's inputs to the code do not account for variations resulting from *site-specific* conditions such as variations in terrain. "Gaussian models are inherently flat-earth models, and perform best over regions where there is minimal variation in terrain."

76. Entergy's description of the PNPS site says that the, "[t]opography consists of rolling forested hills interspersed with urban areas." "The Station proper is on the Bay side of the northeast end of the Pine Hills, a ridge of low hills about four miles long and (lying) in a north-south direction. These hills reach a maximum height of 365 feet. (FEIS, 1972, page 9) But, the 2001 meteorological data came from Pilgrim's onsite meteorological tower with only 33-ft and 220-ft levels, 145 feet lower than the Pine Hills. (Attachment E – License Application 2.10 Meteorology and Air Quality at 2-31) The plume cannot go straight through the hills.

[9] MACCS2 Guidance Report June 2004 Final Report page 3-8:3.2 Phenomenological Regimes of Applicability

The topography within the 50-miles is characterized by gently rolling hills, forests, beaches, dunes, tidal marshes, ponds, lakes, swamps and clusters of buildings in towns and cities - unlike the flat grassland plains of Kansas

77. Drs. O'Kula and Hanna say, in response to Question 60, that the three models (ATMOS, AERMOD and CALPUFF) are likely to produce similar results is because the <u>topography of the region modeled were simple, flat terrain</u>, the only setting that the ATMOS model is designed for. We would expect <u>significant differences would be modeled in other topographic settings such as in complex terrain and in coastal settings</u> where terrain elevations, surface parameters and rainfall precipitation rates vary with location. (ENT00001, A.60)

However Entergy's expert's topographical and land us maps do not show that the area within 50 miles is simple flat terrain; nor one devoid of cluster of buildings to change the direction of a plume. (ENT00004, pg., 19)

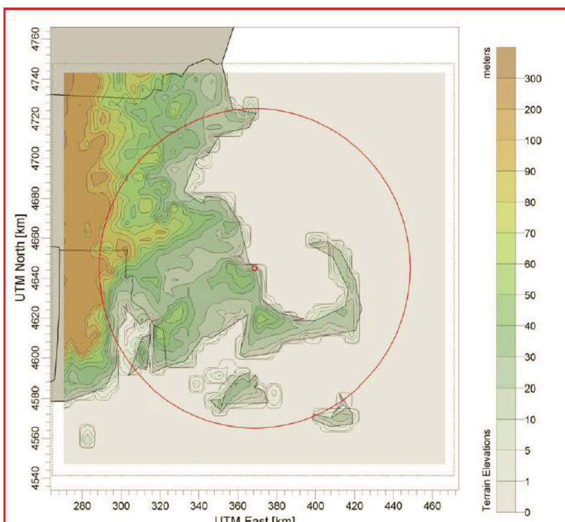

Figure 5. Terrain elevations in the CALMET modeling domain. The Pilgrim Station and the 50 mi radius circle around the Pilgrim Station are shown in red.

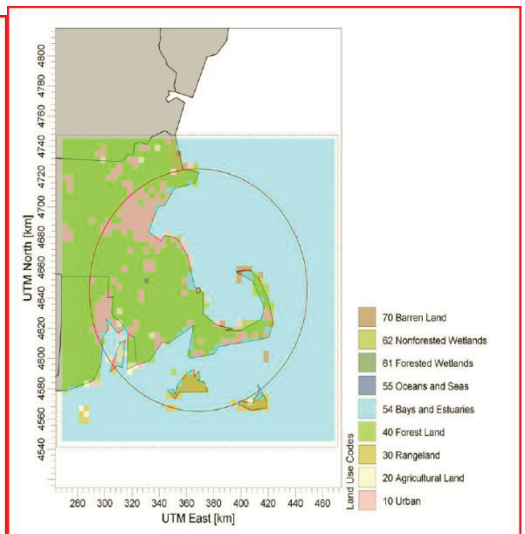

Figure 6. Land use categories in the CALMET modeling domain. The Pilgrim Station and the 50 mi radius circle around the Pilgrim Station are shown in red.

E. Spatial Variations

78. Entergy's straight-line, steady-state Gaussian plume model does not allow consideration for the fact that the winds for a given time period may be spatially varying, and it ignores the presence of sea breeze circulations which dramatically alter air flow patterns. Because of these model failings, PW showed that the Gaussian plume model does not allow consideration of the fact that the winds for a given time period may be spatially varying. (PWA00023, Egan, pg.,5; PWA00001, § 9)

79. Entergy's experts, Drs Hanna and O'Kula, agreed. He acknowledges that the "MACCS2 does not model spatial variation in weather conditions." (ENT00001, Answer 33)

80. The EPA has recognized that "geographical variations can generate local winds and circulations, and modify the prevailing ambient winds and circulations" and that "a*ssumptions of steady-state straight-line transport both in time and space are inappropriate.*"[EPA Guidelines on Air Quality Models (Federal Register Nov. 9, 2005, Section 7.2.8, Inhomogeneous Local Winds, italics added EPA's November 9, 2005 modeling Guideline (Appendix A to Appendix W) lists EPA's "preferred model;" the Gaussian plume model used by Entergy (ATMOS) is not on the list. EPA recommends that CALPUFF, a non-straight-line model, be used for dispersion beyond 50 Km.[10]

81. Regarding the model's ability to take into account meteorological conditions as a function of time, Dr, Egan established that,

[10] Appendix A to Appendix W to 40 CFR Part 51, EPA Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule, November 9, 2005. http://www.epa.gov/ scram001/guidance/guide/appw_05.pdf.

> [Entergy's expert, O'Kula's] declaration seems to state that randomly chosen meteorological conditions would give the same results as inputting meteorological conditions as a function of time. This is an erroneous concept with real meteorology which does not generally behave in a random manner. In order to take into account meteorological conditions 'as a function of time' a model must process the meteorological data sequentially with time. A common phenomena in weather data analysis is the role of persistence of combinations of meteorological events over periods of hours to many days. The probability that the next hour's meteorology will be similar to the previous hour's or that tomorrows weather will be like today's is fairly high and certainly not random or independent of what happened in the previous time period . It also matters from an air quality point of view if winds are very low and dispersion very small for several hours in a row. To accommodate the real role of persistence in dispersion modeling EPA requires sequential modeling for all averaging times from 3 hour averages to annual averages. (PWA00001, Egan Decl., § 13, Comments on O'Kula's declarations, item 16)

82. The essential difference between the models that EPA recommends for dispersion studies and the two-generation-old Gaussian plume model (ATMOS) used by Entergy and the NRC is more than determining where a plume will likely to go. Major improvements in the simulation of vertical dispersion rates have been made in the EPA models by recognizing the importance of surface conditions on turbulence rates as a function of height above the ground (or ocean) surfaces. We know that turbulence rates and wind speeds vary greatly as a function of height above a surface depending upon whether the surface is rough or smooth (trees versus over water transport) (Roughness), how effectively the surface reflects or absorbs incoming solar radiation (Albedo) and the degree that the surface converts latent energy in moisture into thermal energy (Bowen ratio). These parameters are included in the AERMOD and CALPUFF models and

determine the structure of the temperature, wind speed and turbulent mixing rate profiles as a function of height above the ground. Entergy's ATMOS model does not include these parameters. This is an especially important deficiency when modeling facilities located along coastlines, such as Pilgrim. (Egan, PWA00001§ 7)

83. Dr. Egan explained that,

> The reference made by Entergy's experts to the plume segment model refers to a section of NRC Regulatory Guide 1.111 entitled "Plume Element Models.. The reference to this section is misleading as it has only one equation that is for a "puff" model. No equations are provided for the plume segment model. Reference to the plume segment model is in a following single paragraph that states that the plume segment model uses **spatial and temporal** (emphasis added) variations of wind direction, wind speed and atmospheric stability to define the transport and diffusion of each element. The next and final paragraph in Regulatory Guide 1.111 essentially states what we have being advocating: "The effectiveness of the meteorological input data in defining atmospheric transport and diffusion conditions is dependent on the representativeness of these data and the complexity of the topography in the site region; therefore a detailed discussion of the applicability of the model and input data should be provided." The plume segment model as has been applied to the PNPS uses temporal but not spatial variations of meteorological conditions. Spatial variations would require the use of simultaneous meteorological data. My understanding is that the application at PNPS did not use multiple station data in this context. [Emphasis added] (PWA00023, pg., 2)

84. An example of a systematic bias in the ATMOS application at the PNPS that is especially important at large distances from the PNPS is the use of only the seasonally averaged afternoon mixing depths. Because the afternoon mixing depths are generally much larger than morning mixing depths, and because at large distances from a source, ground level concentrations will be lower with increased mixing depth, this is not a conservative. (Egan, PWA00023, pg., 6)

F. Limited Meteorological Data – single station, one year

85. The meterological input used by Entergy was limited to Pilgrim Station's weather tower for wind direction and speed and to Plymouth Airport for precipitation data. (Application ER, E.1.5.2.6; ENT00001, Ans., 39)

86. PW demonstrated (PW Response to CLI pages 8-9) that basing wind direction on the single on-site meteorological tower data ignores "shifting wind patterns away from the Pilgrim Plant including temporary stagnations, re-circulations, and wind flow reversals that produce a different plume trajectory." (Motion to Intervene, Pg., 36; Rothstein, Town of Plymouth Nuclear Matters Committee Recommendation to Selectmen, Appendix A Meteorology, 13)

87. The simple fact is that measurements from a single 220' high anemometer will not provide sufficient information to project how an accidental release of a hazardous material would travel. [PWA00001, Egan, §13] For cases when the sea breeze was just developing and for cases when the onshore component winds do not reach entirely from the ground to the anemometer height. The occurrence of a sea breeze would not be identified. The anemometer would likely indicate an offshore wind indication. Further PW demonstrated that basing wind direction on the single on-site meteorological tower data ignores "shifting wind patterns away from the Pilgrim

Plant including temporary stagnations, re-circulations, and wind flow reversals that produce a different plume trajectory." (Rothstein, Town of Plymouth Nuclear Matters Committee Recommendation to Selectmen, Appendix A Meteorology, 13) **(**Egan, PW00023, pg.,8; Egan, PW00001,§ 13). Also as pointed out above, the on-site meteorological tower is considerably lower than the height of the Pine Hills, located to the west (Bay side)of the reactor. These hills reach a maximum height of 365 feet. (FEIS, 1972, page 9) but the 2001 meteorological data came from Pilgrim's onsite meteorological tower with only 33-ft and 220-ft levels - 332 to 145 feet lower than the Pine Hills depending on which level of data Entergy entered into the model. We understand that the 220 foot level was relied upon for the majority of entries. (Attachment E – License Application 2.10 Meteorology and Air Quality at 2-31) However, the plume cannot go straight through the hills; therefore reliance on only the onsite data could not properly characterize plume behavior at the site.

88. A measurement at a single station tower, 220 feet, will not provide sufficient information to allow one to project how an accidental release of a hazardous material would travel.[11] Measurement data from one station will definitely not suffice to define the sea breeze. (Egan, PW0001,§13)

89. **"S**ince the 1970s, the USNRC has historically documented all the advanced modeling technique concepts and potential need for multiple meteorological towers especially in coastal regions." [Rothstein, June 24, 2006 letter, 2] NRC Regulatory Guide 123 (Safety Guide 23) On Site Meteorological Programs 1972, states that, "at some sites, due to complex flow patterns in non-uniform terrain, additional wind and temperature instrumentation and more comprehensive

[11] License Application 2.10 Meteorology and Air Quality at 2-31; and at Attachment E, E.1.5.2.6 at E.1-63]

programs may be necessary."[Ibid., cited in Appendix 1]; and an EPA 2000 report, Meteorological Monitoring Guidance for Regulatory Model Applications, EPA-454/R-99-005, February 2000, Sec 3.4 points to the *need for multiple inland meteorological monitoring sites.* See also Raynor, G.S.P. Michael, and S. SethuRaman, 1979, Recommendations for Meteorological Measurement Programs and Atmospheric Diffusion Prediction Methods for Use at Coastal Nuclear Reactor Sites. NUREG/CR-0936.

90. The meterological data was also limited to data from 2001, a **single year**. (Application ER, E.1.5.2.6; ENT00001,Ans., 61)

91. Revised Chapter 4, *Meteorological Monitoring*, of Guide DOE/EH-0173T (PWA00021) says that the joint-frequency distribution and choices of meteorological conditions for the accident analyses should be based on a minimum of 5 years of hourly-averaged data acquired by a meteorological program that meets the objectives and principles of ANSI/ANS-3.11-2000 and EPA-454/R-99-005.

92. Spengler and Keeler Report, Page 22, (Exhibit 1) says that, "Seasonal wind distributions can vary greatly from one year to the next."

93. NRC's own document, NRC Regulatory Guide 1.194, 2003, "*The NRC staff considers 5 years of hourly observations to be representative of long-term trends at most sites,"* although "with sufficient justification [not presented by Entergy here] of its representativeness, the

minimum meteorological data set is one complete year (including all four seasons) of hourly observations."

94. Dr. Edwin Lyman, Declaration of Edwin S. Lyman, PHD, Regarding the Mechanics of Computing Mean Consequences in SAMA Analyses (November 22, 2010, pg., 6) said in his Affidavit that, " It is questionable whether a single year's worth of weather data provides a sufficiently conservative data set for the purposes of SAMA analysis. Some MACCS2 analyses utilize data sets spanning multiple years, which must be averaged in order to be input into the MACCS2 code." (PWA00012)

95. Dr. Egan commented that EPA generally requires 5 years on data even for annual averages. (Egan, PWA00023, pg., 8)

96. Entergy is projecting costs for 2012-2032. Increasingly severe weather has characterized the area, attributed to the effects of global warming that are predicted to continue and increase. This is ignored by reliance on simply 2001 data.
Entergy could have taken data from more locations over a longer period of time. The user has total control over inputs and the " results that will be produced." [1997 MACCS2 User Guide, Section 6.10]. Energy chose not to do so, but there are many other data sources available for coastal Massachusetts and SE Massachusetts. (ENT00004, pgs.,8, 9, 32)

IV. Entergy's SAMA Analyses Not Conservative

97. Entergy has said that its analyses are "conservative." We disagree that Entergy has shown this, for three principal reasons.

- First, although the two reports upon which Energy relies were model-to-model comparisons, the tests that they report were made under conditions so different from those at PNPS that they have no value here. Indeed, the NRC has repeatedly explained that these studies have very limited value and that it would have preferred if they had been conducted at a site more like Pilgrim's.
- Second, the comparisons did not involve any of the variable plume models that are available today.
- Third, Entergy was anything but conservative when it selected the inputs it made into nto the only model, ATMOS, that it used.

98. The fact that a model may seem to be conservative in particular applications or in limited data comparisons does not mean that the model is better or should be recommended. Models can be conservative but have incorrect simulations of the underlying physics. Sensitivity studies do not add useful information if the primary model is flawed. (Egan,PWA0001, § 13)

A. The Reports On Which Entergy Relies

100. Entergy's experts cite two reports (Lewellen and Molenkamp[12]), and say that these reports show that the straight-line Gaussian model was conservative. (ENT0001, Ans., 57-8)

101. The reports themselves show that they do not provide information that can relied on at a site such as PNPS, and do not support Entergy's conclusion. We agree with Dr.Egan:

[12] WSMS refers to the results from a test that released a tracer conducted in 1981 at the Idaho National lab (INL is located in high desert land, eastern Idaho), Lewellen, 1985, NUREG/CR-4159; Mollenkamp et al (2004) compared several codes for recorded data in the Midwest, NUREG/CR-6853]

> The model comparison study (Molenkamp et al, (2004) referenced by Drs. Hanna and O'Kula in their Reponses to questions 57 and 58 shows only model to model comparisons. The model to model setting and meteorological data used was over simple, flat terrain where, as Dr. Hanna discusses, one expects that models with dispersion rates based upon the Prairie Grass experiment data would produce similar results. <u>Therefore a comparison of model predictions made in the relatively flat area of the "Southern Great Plains (SGP) site in Oklahoma and Kansas" cannot be used to state how model comparisons would fare at a coastal area like Plymouth, MA.</u> The Molenkamp study text itself asserts that "the topography of Oklahoma and Kansas is relatively smooth and has minimal effect on the wind field, and the surface is fairly uniform and therefore produces relatively little local thermal forcing." Sea and land breezes are driven by thermal forcing. (Egan, PWA00023, pg., 7)

102. Indeed, the reports themselves, in the section discussing the selection of the study site, states that the investigators were not able to find a site that met one of their criteria: "a site with changes in surface properties that could affect the local flow such as a coastal site with a land-sea breeze." (Ibid)

103. The NRC also agrees that the Mollenkamp study sites agrees that the Mollenkamp study sites in central Oklahoma and Kansas did not have "topography that would interact with the large-scale flow producing local modification of wind speed and direction" and that it did not have "changes in surface properties that could affect local flow, such as a coastal site with a land-sea breeze" (NUREG/CR 6853, 3). The Mollenkamp sites are "relatively smooth and (have) has minimal effect on the wind field and the surface is fairly uniform and therefore produces relatively little thermal forcing." (Ibid)

104. The NUREG goes on to say that it "would have preferred a site with greater topological and diurnal homogeneity" (NUREG/CR-6853, Oct. 2004, at xi and 2); and readily admitted that "it would be best if MACCS2 and RASCAL/RATCHET results could be compared with measurements over the long distances and types of terrain of interest to the NRC." The only reason that "the less desirable comparison with a state-of-the art code was chosen to provide input into the decision on the adequacy of MACCS2 ATD was that such measurements do not exist." (Ibid, pg., 2)

B. Entergy's Sensitivity Studies and Later Analyses

105. Entergy's two previous supplemental sensitivity studies, by Enercon and WSMS, and later work by Dr. Hanna similarly were not conservative. As PW showed, all of the "scenarios" that Enercon, WMSM and Dr. Hanna studied used a "downwind in a straight line" model and assumption. All of these were thus subject to the significant shortcomings we have discussed; none provides a valid comparison to variable trajectory "scenarios" that Entergy never studied. (Egan, PW0001,§ 13, in reference to 2007 studies)

106. PW evidence showed that both the code used by Entergy and their experts and the meteorological and economic information used were inadequate. Dr. Egan summed it up: "sensitivity studies do not add useful information if the primary model is flawed." (Egan, PWA0001, § 13)

107. Dr. Bixler, the NRC Staff's expert, said very plainly that Entergy's claim, that its study was conservative because it used conditions at the beginning of a plume release, was "erroneous."

> (NEB) Material Fact number 16 states that Sensitivity Case 2 estimated the effects of changing wind direction trajectory and was conservative because it used conditions at the beginning of a plume release, when the release has larger dose quantity and less decay has occurred. The MACCS2 value modified in Sensitivity Case 2 appears to have been REFTIM (Representative Time Point for Dispersion and Radioactive Decay). *REFTIM* affects the way in which dispersion, deposition, and radioactive decay are calculated. It *does not affect the manner in which "wind direction trajectory" is calculated.* This statement appears to be *erroneous*…" (Bixler, PWA 00017, § 9 - Nathan Bixler Affidavit Of Joseph A. Jones And Dr. Nathan Bixler Concerning Entergy's Motion For Summary Disposition Of Pilgrim Watch Contention 3, June 25, 2007,

108. Dr. Egan also showed that "[t]he validation history of ATMOS with real observational measurements is very weak" (PWA00023, pg.,7)

C. Pertinent Studies Ignored

109. However, relevant studies have been done that Entergy never points to. (Egan, PWA00001,§ 13) Dr. Egan said that,

> Over the past decades there have been well documented field experiments and data from ambient monitoring networks in a variety of terrain settings that could provide data suitable to be used to produce model performance statistics for ATMOS as used in MACCS2. A validation effort that compared model predictions to observational data for a source at a coastal site and for both short and long distances would be most appropriate for the PNPS. (Ibid)

In addition Dr. Egan showed that,

> The US EPA has used field studies and routine monitoring data to evaluate and improve dispersion models. Numerous studies have shown that flat terrain type models cannot be relied upon to provide competent predictions when applied to complex terrain settings. Not all models are the same in how they handle plume trajectories and atmospheric dispersion rates do vary by terrain setting and surface conditions. (Egan PWA00023, pg., 7)

110. Whether the Gaussian plume model is "conservative" relative to the Pilgrim site cannot be determined without running both ATMOS (the Gaussian plume) and an alternative model (e.g. MM5 and CALPUFF)

111. The NRC Staff's own expert, Dr. Bixler, generally agreed with Dr. Egan and admitted that the Gaussian plume model results are "conservative" is correct only if the word "conservative" is defined narrowly:

> (NEB) Material fact number 12 states that the MACCS2 Gaussian plume model results are in good agreement with, and generally more conservative than those obtained by more sophisticated models. <u>*If* the word conservative implies</u> that calculated plumes with the MACCS2 code are generally more focused and more concentrated than would be the case if the calculations had been performed with more sophisticated models, then the statement is accurate. <u>However, a more focused, more concentrated plume does not always correspond to a smaller number of person-rem*, depending on the trajectory of the plume* compared with population centers. (</u>Emphasis added) (Bixler, PWA00007, §8)

C. Conclusion - Entergy's ATMOS model was non-conservative

112. Dr. Egan's Testimony clearly demonstrated that Entergy's ATMOS model was non-conservative in modeling predictions at long distances and as a result significantly affected the cost-benefit analysis**.** He showed (Egan, PWA00023, pg., 5-6) that:

> Table 3 of Dr. O'Kula's response to question 43 shows that the population dose risk for distances in the range of 30 to 50 miles encompasses 56% of the total risk. Similarly, the offsite economic cost risk in the range of 30 to 50 miles is about 54% of the total. These are in the range greater than 50 km (31 miles) that the US EPA would generally call for the use of a puff model capable of handling temporally and spatially changing meteorological conditions. The results show the importance of impacts in the range beyond 30 miles to the consequences of accidental releases relative to the total impact over the area. This reinforces our argument that model accuracy is important at these large distances. Modeling simulations of radioactive decay and deposition processes act to deplete material from a plume as it travels downwind. Other things being equal, if deposition rates are large in the areas near the source, depletion rates further away will be smaller and vice versa. ATMOS uses rates that do not vary with location. Similarly, the travel time of a plume will determine the fraction of radioactive decay that will occur in the near vs. far field of a release.
>
> One of the computational limits of the ATMOS model is that is can utilize only one value of the surface roughness parameter for the entire modeling domain, in this case the area located within a radius of 50 miles. More advanced models allow roughness length as well as other surface characteristics to vary spatially. CALPUFF, for example can additionally utilize information about surface albedo and the Bowen Ratio , two other parameters that research efforts show are needed to improve the establishment of wind speed, wind speed profiles and dispersion rates for transport and dispersion models.

113. Dr. Egan also showed that Entergy's ATMOS model was non-conservative in modeling predictions at long distances by their use of only the seasonally averaged afternoon mixing depths.

> An example of a systematic bias in the ATMOS application at the PNPS that is especially important at large distances from the PNPS, is the use of only the seasonally averaged afternoon mixing depths. Because the afternoon mixing depths are generally much larger than morning mixing depths, and because at large distances from a source, ground level concentrations will be lower with increased mixing depth, this is not a conservative assumption. (Ibid, pg., 6)

114. Dr. Egan also showed that Entergy's ATMOS model was non-conservative in their modeling assumptions about the role of transport over water that provides support for the likely increased contaminant concentrations occurring during the sea breeze and so-called "hot spot" phenomena – impacting densely populated Metropolitan Boston or to Cape Cod across the Bay with a summer population >600,000 (PW 2007 Br., 5, 17, Representative Matthew Patrick Decl.,2)

> In the discussion about wind over the ocean, (Dr. Egan) found Dr. Hanna's response to Question 85 to be out of context with the potential accidental configurations at the PNPS and therefore leading to an erroneous implication about the role of overwater transport. Dr. Hanna states that "a factor of 2 greater wind speed over the ocean would, by itself, contribute to a reduction of maximum concentrations by approximately a factor of two." This would strictly be true only if the source were also within the airflow over the ocean. As Dr. Hanna correctly states in response to question 28, the dilution effect of wind speed and the inverse wind speed relationship to concentration only applies to the initial dilution of the emission source. <u>What often does happen with an onshore flow, since the air over the water is often more stable than that over land, is that a fumigation type event occurs. This is associated with the fact that the surface roughness change and the warm land surface create</u>

> more turbulence in the surface layer that would mix plume material from an elevated plume down to the surface, resulting in increased ground level concentrations. (Egan, PWA00023, pg., 6) (Emphasis added)

115. The discussions and modeling demonstrations of the impacts of the ATMOS model at large distances from the PNPS underscore the need to have more appropriate models applied to predict atmospheric transport.

116. The model to model comparisons cited do not shed any light on how well the straight-line format of the MAACS2 model will predict concentrations at the very distances where impacts dominate the population dose and economic consequences of accidents of concern.

> One cannot really expect that a single anemometer located at the PNPS site will accurately predict the destination of emissions over such long distances. This is the reason that other regulatory agencies advocate using long range transport models capable of utilizing meteorological measurements that allow a simulation of regional scale differences in air flow patterns for air quality and environmental impact analyses. (Egan, PWA00023, pg.,7-8)

V. NEPA's Rule of Reason

117. In CLI-10-22, pg., 9, the Commission said that NEPA requirements are "tempered by a practical rule of reason" and an environmental impact statement is not intended to be a "research document." If relevant or necessary meteorological data or modeling methodology prove to be unavailable, unreliable, inapplicable, or simply not adaptable for evaluating the SAMA analysis cost-benfit conclusions, there may be no way to assess, through mathmatical or precise model-to

model comparisons, how alternative meteorological models would change the SAMA analysis results."

118. Our opinion and dispute is that it is reasonable for Entergy to conduct analyses using current variable trajectory models; at the very least to have conducted enough comparative analyses to show the correlation, if any, between the results from a good variable trajectory model and the results from its segmented straight-line Gaussian plume model.

A. Research Not Required

119. The plume modeling that PW presented as appropriate for Pilgrim's SAMA analysis, instead of Entergy's decision to use the straight line Gaussian model, are not techniques that require research. They are, in fact, established methods that are publically available, routinely used by other government agencies and independent analysts, and appropriate for quantifying atmospheric dispersion of contaminants. Although an effort may be required to adapt these methods for SAMA analyses, this would be very straightforward and research would not be required. (Egan, PWA00023, pg., 4)

B. Appropriate meteorological data or modeling methodology is available

120. There is no shortage of appropriate meteorological data for a licensing model application. Alternative modeling methods that would use more extensive meteorological data are also available. (Egan, PWA0001, §7,8,11)

Research Efforts on Advanced Models Have Been Completed and Published

121. Dr. Egan explained that,

In response to Questions 59 and 60, Drs. O'Kula and Hanna discuss difficulties associated with trying to improve the MACCS2 code. The comment that eight years were required to develop the AERMOD code needs to be placed in context. The initial multiyear work effort of the AMS/EPA Regulatory Model Improvement Committee (AERMIC) which is responsible for the development of AERMOD, was to sort out, test and determine the best ways to integrate the findings of meteorological research studies and efforts that addressed improving the parameterization of the transport and dispersion characteristics of air flow in the planetary boundary layer. <u>That research effort was time consuming but, it was completed and is well published. It would not need to be done again for purposes of improving ATMOS.</u> Importantly, the results are viewed as representing a major step forward in defining the algorithms for computer simulations ranging from Gaussian dispersion type models to advanced numerical simulation models. The upgrades to the AERMOD code resulting from this research have flowed to improving the CALPUFF model, the Emissions and Dispersion Modeling System (EDMS) used by the FAA for aircraft operations as well as in modeling codes advanced by the National Park Service and other environmental protection agencies in the US and abroad. (PWA00023, pg.,4)

(Dr. Egan has) personal experience as the Project Director responsible for the staffing, budget and performance of contract efforts to develop and validate dispersion atmospheric dispersion models. I agree that an effort would be involved to upgrade ATMOS, but believe that the coding part would not be nearly as difficult as implied by these responses. The code to include radioactive decay used in

ATMOS would need to be integrated into any new code but this could retain the structure presently used in ATMOS. (Egan, PWA00023, pg.4)

Additional Meteorological Data Available

122. The applicant chose to use only one year of onsite data collected at the Pilgrim's site. Meteorological data is also available from nearby airports and, importantly, processed data on a gridded basis can be obtained from NOAA to augment the onsite meteorological data relied upon for the SAMA analyses that have been provided by Entergy. PW demonstrated this by disclosing, for example, the Jennifer Thorpe (PWA00010) site-specific meteorological study and Spengler and Keeler study, PWA00011 (both Dr. Egan and Hanna attended the studies sea breeze workshop, Chapter 8 of Spengler's study) and Dr. Egan's "Development of a Dispersion Modeling Capability for Sea Breeze Circulations and other Air Flow Patterns over Southeastern Massachusetts, Upper Cape Cod Modeling Study," that used available meteorological data from multiple stations. Also Entergy's own experts document multiple sites for data that they,too, relied upon. (ENT00004, examples on pgs., 8,9,15,16)

Site Appropriate Advanced Models Available

123. Also there are several publically available meteorological modeling methods that can simulate variable trajectory transport and dispersion phenomena. MM5 is one which is routinely used nationally and internationally. There are other options as well. The present state of art of an appropriate meteorological model would use multi station meteorological measurement data as input to the meteorological model. The numerical computations, based upon numerical weather prediction techniques, would compute wind fields appropriate for modeling dispersion

over a much larger geographic area than the a single measurement site would be appropriate for. (Egan, PWA00001,§11)

B. Advanced Models Are Reliable

124. The second reasonableness criterion is that the modeling method must be reliable. The outputs from such meteorological models that are used to produce inputs for the dispersion models are well accepted and form the basis for the weather predictions provided by the national weather service as well as analyses of air pollution impacts of concern to regulatory agencies .

125. These techniques have been proven to be reliable and acceptable for air quality permitting and policy applications in complex terrain and over large distances for the US EPA, the US Park Service as well as internationally. PW argued with sufficient particularity that for complex meteorological situations such as for the Pilgrim, these techniques would be *more* reliable than using the straight line Gaussian model.

126. Dr. Egan pointed out that Entergy's experts understand recent advanceds in modeling,

> Dr. Hanna and Mr. Ramsdell seem to acknowledge that recent advances in atmospheric sciences, especially in understanding the complexities of dispersion in the planetary boundary layer have resulted in technical improvements to atmospheric transport simulations. These scientific advances as well as in advances in computational methods have resulted in the remarkable improvements made to the meteorological models that are used operationally to predict future weather. Many of these advances have been incorporated into the coding of the newer transport and diffusion models used for environmental assessments required for permitting and safety of power plants and industrial sources. (Egan PWA00023,pg.,3)

127. Dr. Egan concluded that,

> [I]t would be beneficial to use dispersion models that utilize better science to simulate phenomena and to predict the dispersion consequences of individual events in a highly reliable and competent manner. (Ibid, 6)

128. The validation history of ATMOS with real observational measurements is very weak. (Ibid, pg., 7)

C. Advanced Models Are Applicable To SAMA Analyses

129. The third reasonableness criterion is that the modeling methods be applicable to SAMA analyses. The methods PW recommended are applicable because with straightforward modifications to incorporate nuclear radiation decay rates, they can produce the fields of concentration values and deposition rates needed for dosage calculations.(Ibid.,pg.,5)

130. Advanced Models Equally Applicable SAMA, EPA, Emergency Planning:

Dr. Egan explained that,

> [T]here seems to be a running theme that because the end use of dispersion modeling for SAMA analyses vs. consequence assessments for emergency response planning is different, one can justify using outdated modeling methodologies that ignore technological improvements for SAMAs. [Dr. Egan's] comments will show that [he] disagree[s] with this perspective. <u>Emergency response planning should require</u> the running of accurate and competent models for purposes of identifying evacuation routes, locations of decontamination centers, etc., in order to minimize the potential exposure of residents and workers in the event of an actual accident. Emergency responses in an accident requires a real time alert system showing which evacuation routes, how workers should approach the plant and similar information for use in an actual emergency. <u>SAMA analyses require</u> an assessment of the potential

consequences of various postulated accidents that might happen for anticipated meteorological events. Each of these applications requires that appropriate meteorological data be used. The meteorology at a site does not vary by application and one should apply the best science that is reasonably available for all these applications. There may be tradeoffs if some analysis methods may be substantially more costly than others, but the application of modeling to SAMA analyses does not appear to be one of them. The issue is not cost for the analyses but rather the confidence that one has that the modeling is done reliably with state of the art technologies. (Egan, PWA00023, pgs., 1-2) (Emphaisis added)

Averaging Methods Irrelevant To Choice Model:

139. Dr. Egan explained further that,

> From a computational point of view, the key difference between the modeling needs of SAMA analyses and applications to emergency response is the fact that, as constructed, the SAMA analyses focus on evaluating only long term average consequences. The short term averages are not needed. For emergency response, the short term predictions are essential. However, the difference between these needs from an air quality modeling computational standpoint essentially reduces to the averaging of the results and how the data is manipulated in post processors. The core elements of the RASCAL model described by Mr. Ramsdell are used to calculate 1 hour values that could be averaged to produce the long term averages needed for a SAMA. With today's computers, the computer time in unlikely to be an issue. We think such advances could improve the reliability and credibility of ATMOS because improvements to the model made to the 1-hour predictions would improve the reliability of the annual average values. (Ibid, 3)

140. Dr. Egan:

> An argument is made by Dr O'Kula that improvements to predicting the annual averages are not necessary, because at the PNPS, one would have to show substantial changes to the projected population doses and the economic consequences to have a

another SAMA be cost effective. I note that this is a site specific comment and would not necessarily be applicable to other power plants. At another site, the differences might be much smaller and improvements to the modeling code could change the identification of cost effective SAMAs. The selection of SAMAs should not depend upon the selection of the dispersion model utilized. Improved simulations of transport and dispersion for all time scales would be beneficial to the industry as it would reduce the uncertainty that decision makers have to address. (Ibid)

141. Again, Dr. Egan:

The comments that the US EPA 's requirements to address National Ambient Air Quality Standards (NAAQS) with short term averaging times (one hour, 3 hour, 24 hour averages) is the reason that EPA uses more advanced models are not correct. The averaging times for the National Ambient Air Quality Standards (NAAQS) range for one hour to annual averages. The EPA has guidance for selecting the most appropriate dispersion model for use in different applications (40 CFR Part 51 Appendix W. Guideline ion Air quality models). The criteria are based on a combination of appropriate recent science and model validation. With these criteria, there is no issue of different dispersion modeling techniques for modeling short term averages versus long term averages. Three criteria pollutants have annual average standards: SO2, NO2, and particulate matter. The same models used for estimating short averaging time impacts are used for the annual averages. The modeling requirements for demonstrating compliance with the NAAQS for Nitrogen Dioxide are an example. The initial standard set for NO_2 was for annual average concentrations. On the basis of revised findings of health effects, EPA in 2010, set a new standard with a one hour averaging time. The dispersion modeling methods recommended for compliance demonstrations for both the annual averages and the one hourly values did not change. The choice of model does not depend upon the averaging time over which meteorological variations occur. (Ibid)

142. Further,

> The validation history of ATMOS with real observational measurements is very weak. Over the past decades there have been well documented field experiments and data from ambient monitoring networks in a variety of terrain settings that could provide data suitable to be used to produce model performance statistics for ATMOS as used in MACCS2. A validation effort that compared model predictions to observational data for a source at a coastal site and for both short and long distances would be most appropriate for the PNPS. (Ibid,pg., 7)

C. Advanced Models are Applicable to Cost Benefit Conclusions

143. The next reasonableness criterion is that the modeling methodology be adaptable for evaluating SAMA analysis cost benefit conclusions. There is nothing inherent in variable trajectory models that would prohibit the output concentration and deposition fields from being applied to SAMA analyses.(PWA00023, pgs.,1-2)

D. Any Expense in Time or Money is Justified

144. Entergy has offered the rationale that the use of advanced models would be computationally too expensive and/or burdensome to use are not justified by the actual run time shown in our review of MACCS2 output files. With modern computers, the use in inappropriate models on the basis of differences of computational costs is indefensible.(Ibid)

145. Statements made in Mr. Ramsdell's affidavit also support my earlier assertions that <u>computational time to run more sophisticated models should not be a deterrent to adopting advanced models</u>. He says, "With today's computers, the computer time in unlikely to be an issue. We think such advances could improve the reliability and credibility of ATMOS because

improvements to the model made to the 1-hour predictions would improve the reliability of the annual average values." (Ibid, 3)

146. Further in regard to computational time to run more advanced mdoels not being an issue, Mr. Ramsdell says at A32, referring to his involvement in the NUREG -6853 Study (Molencamp et al, 2004): "Data preparation for MACCS2 was completed in a few hours, and code execution took less than 10 minutes on a PC. Data preparation for RASCAL required somewhat longer, but still only a few days. RASCAL code execution took about an hour on a PC. Finally, weeks were spent getting data ready to run the ADAPT/LODI codes and the execution of these codes took almost a week of calculation on a mainframe computer." (Ibid, pg.,5)

147. Dr. Egan concluded that

> One would think that the licensing of a nuclear power plant would be an important enough application that data preparation time and computer resources would nto be constraining factors. (Ibid., pg., 5)

148. NRC Staff Expert, Dr. Nathan Bixler comment in reqard to Entergy's Motion Summary Disposition:

> Material fact § 10 states that it is impracticable to use computer codes that accommodate multi-station data. The effort needed to perform a multi-weather station consequence analysis is significantly greater than the effort required to perform a similar analysis with MACCS2. But, such multi-station analyses have been and continue to be performed in support of Final Safety Analysis Report (FSAR) documentation for space launches that involve significant quantities of radioactive materials. (Bixler, PWA00007, § 7)

E. Mathematical Or Precise Model To Model Comparisons –no issue

149. There is no basis to the argument that there may be no way to assess through mathematical or precise model to model comparisons, how alternative meteorological models would change the SAMA analysis results. Some assessments may necessarily be qualitative, based simply upon expert opinion. But this argument seems to undercut the very value of mathematical simulation models in general as a method to assess the impacts of nuclear reactor emissions.

Conclusion - NEPA

150. None of the applicable NEPA criteria make it unreasonable to require Entergy to use of alternative models in the Pilgrim's SAMA analyses.

151. Entergy's attempts to invoke the "practical rule of reason" to excuse its failure to use the most appropriate modeling methodology for application to the Pilgrim SAMA analyses is blatantly dismissive of the concept that the present methods are inappropriate and outdated and that there are indeed better alternative models available.

VI. ENTERGY FAILED TO SHOW THAT ITS SAMA ANALYSIS IS ADEQUATE AND REASONABLE

152. Entergy claims that the testimony of Dr. O'Kula and Dr. Hanna (ENT00001) and other supporting exhibits demonstrate that the Pilgrim SAMA analysis is adequate and reasonable. In particular, Entergy says that:

a. The Gaussian Plume Segment model used in the ATMOS module of MACCS2 is adequate and reasonable for performing SAMA analyses. (ENT00001, Entergy Dir., A.33, A. 48-A50)

b. MACCS2 compares favorably with more complex models. (See Entergy Dir., A.51-A.60)

c. The meteorological data inputs used for the Pilgrim SAMA analysis are both temporally and spatially representative. (ENT00001, Entergy Dir., A.61-A.72)

d. Coastal Breezes are appropriately accounted for in the Pilgrim SAMA analysis. (ENT00001, Entergy Dir.,A.73-A.81)

e. "Hot spots" as claimed by Pilgrim Watch are both technically incorrect and immaterial. (ENT00001, Entergy Dir., A.82-A.89)

f. The CALMET Wind Trajectory Analysis shows that any short-term differences in observed winds across the SAMA domain have negligible effect on the annual frequencies of trajectory directions and on the Pilgrim SAMA consequences. (ENT00001, Entergy Dir., A.92-A.105)

g. Terrain is conservatively treated for purposes of the Pilgrim SAMA Analysis. (ENT00001, Entergy Dir., A.106-A,114)

h. Pilgrim Watch's other Contention 3 issues are without merit. (ENT00001, Entergy Dir., A.115-A.118.)

We disagree. As shown by the the following review of these points, the actual facts to not support Entergy's positions.

153. Entergy claims that the testimony of Dr. O'Kula and Dr. Hanna and other supporting exhibits demonstrate that the Pilgrim SAMA analysis is adequate and reasonable. Dr. Egan for example said,

> The claim that MACCS2 is a state-of-the-art computer is not correct. MACCS2 does not rely upon or utilize the most current understandings of boundary layer meteorological parameterizations such as adopted by the current US EPA in the models AERMOD or CALPUFF (EPA, 2005) (PWA00001, §13)

154. Entergy's first contention is that the Gaussian Plume Segment model used in the ATMOS module of MACCS2 is adequate and reasonable for performing SAMA analyses. (ENT00001, Entergy Dir. at A33 and A48-A50)

156. Entergy (ENT00001, A33, A48) says that the Gaussian Plume Segment Model in ATMOS, unlike a standard straight-line Gaussian plume model updates key meteorological variables, <u>other than wind direction,</u> on an hourly basis." [Emphasis added) The key point here is that Entergy admits that Gaussian plume segment model does <u>not vary wind direction</u> so that the plume is assumed to travel in a straight-line. At Pilgrim's coastal location the winds are variable – they change direction – and this is not captured in Entergy's plume segment model. Models that account for variability, such as CALPUFF are readily available.

157. Dr. Egan's concerns about the plume segment model documentation on which Entergy and Drs. Hanna and O'Kula rely were expressed as follows: (PWA00023, pg., 2)

> The responses by Drs Hanna and O'Kula to questions 14 and 33 describe how the ATMOS module within the MACCS2 model simulates transport and dispersion

with a “plume segment” algorithm. Their description states that the plume segment model is more than the straight-line Gaussian plume model in that it is “able to account for hour to hour changes in atmospheric stabilities, wind speed, and precipitation during plume travel. Noticeably absent are hourly changes in wind direction, a key concern for the PNPS site. It is a straight-line Gaussian model. The associated reference to the plume segment model refers to a section of NRC Regulatory Guide 1.111 entitled “Plume Element Models”. The reference to this section is misleading as it has only one equation that is for a “puff” model. No equations are provided for the plume segment model. Reference to the plume segment model is in a following single paragraph that states that the plume segment model uses **spatial and temporal** (emphasis added) variations of wind direction, wind speed and atmospheric stability to define the transport and diffusion of each element. The next and final paragraph in Regulatory Guide 1.111 essentially states what we have being advocating: “The effectiveness of the meteorological input data in defining atmospheric transport and diffusion conditions is dependent on the representativeness of these data and the complexity of the topography in the site region; therefore a detailed discussion of the applicability of the model and input data should be provided.” The plume segment model as has been applied to the PNPS uses temporal but not spatial variations of meteorological conditions. Spatial variations would require the use of simultaneous meteorological data. My understanding is that the application at PNPS did not use multiple station data in this context.

The claim that MACCS2 is a state-of-the-art computer is not correct. MACCS2 does not rely upon or utilize the most current understandings of boundary layer meteorological parameterizations such as adopted by the current US EPA in the models AERMOD or CALPUFF (EPA, 2005) (PWA00001, §13)

158. The description of the ATMOS model equations in Jow et al[13] (1990) reveals that the transport and diffusions algorithms for a plume segment model are much more complicated than those of the steady state, straight line single plume Gaussian model and the Lagrangian puff model. To conserve or account for mass changes, each plume segment would need to have its virtual source emission location and strength, the segment locations, and the segment, lengths, widths, heights, and contaminant concentrations adjusted at each time step in a manner that assures that mass conservation is maintained within each segment and assure that the distortions to the plume dimensions necessary for each time step do not result in any increases of concentration values. With a steady state Gaussian plume model or with the Gaussian puff model these adjustments would not be necessary. It is not clear from Entergy's model descriptions how all these adjustments are made. The lack of documentation therefore calls for a disclosure of computer test results that confirm that the plume segment model conserves mass within each segment and within the plume as whole. A simple set of model runs with a single sequence of time varying meteorological conditions could be used as long as the wind speed, stability, and deposition rates were tested independently for both constant and time varying inputs.

159. Entergy explains that they take a "full year of hourly conditions." (ENT00001, Ans., 39) As we have discussed above PW disputes that one year of data is sufficientfor the following reasons:

- Revised Chapter 4, *Meteorological Monitoring*, of Guide DOE/EH-0173T (PWA00021) says that the joint-frequency distribution and choices of meteorological conditions for the accident analyses should be based on a minimum of 5 years of hourly-averaged data

[13] N Jow, J.L. Sprung, J.A. Rollstin, L.T. Ritchie, D.I. Chanin, "MELCOR Accident Consequence Code System (MACCS), Volume II, Model Description" **...**
http://www.osti.gov/bridge/servlets/purl/10117751-AvVwCk/webviewable/ -

acquired by a meteorological program that meets the objectives and principles of ANSI/ANS-3.11-2000 and EPA-454/R-99-005.

- Spengler and Keeler Report, Page 22, (PWA00011) says that, "Seasonal wind distributions can vary greatly from one year to the next."
- NRC's own document, NRC Regulatory Guide 1.194, 2003, "*The NRC staff considers 5 years of hourly observations to be representative of long-term trends at most sites,"* although "with sufficient justification [not presented by Entergy here] of its representativeness, the minimum meteorological data set is one complete year (including all four seasons) of hourly observations."
- Dr. Edwin Lyman, Declaration of Edwin S. Lyman, Phd, Regarding the Mechanics of Computing Mean Consequences in SAMA Analyses (PWA00012, pg., 6) said in his Affidavit that, " It is questionable whether a single year's worth of weather data provides a sufficiently conservative data set for the purposes of SAMA analysis. Some MACCS2 analyses utilize data sets spanning multiple years, which must be averaged in order to be input into the MACCS2 code."
- Dr. Egan (PWA00023, pg.,8) commented that EPA generally requires 5 years on data even for annual averages.

160. Even if more Entergy's focus on long term averages means, even if more data were used, Entergy's focus on long term averages would cause the relevance of the impact of individual potential accidents would to be entirely lost. (PWA00023, pg.,8)

Entergy concludes that, "the details of a particular plume's trajectory do not have a material impact on the statistical expected value, or mean, of the overall SAMA analysis because the unique behavior in a wind trajectory for a specific plume will tend to be compensated by the trajectories of other plumes." (ENT00001,Entergy Dir. at A17, A52) The tracking of individual plumes is not required for computing a long-term annual consequence summed over a broad area." (ENT0001,Entergy Dir. at A.48)

161. The problem with this approach is that taking a <u>mean average</u> of the weather out over 50 miles, means that the site specific effects are totally masked or washed out. The SAMA analysis is required to be a <u>site specific analysis performed for a major licensing decision</u>. (PWA00023, pg.,8)

162. In Entergy's affidavits, Drs. Hanna and O'Kula repeatedly say that SAMA objectives can be met with a model that only produces long term average concentration and deposition of radionuclides. The technology used to obtain these long term averages requires addressing the impact of every hour in the year, but the only numbers that Entergy, Dr. Hanna, or Dr. O'Kula use are the annual averages of all these computations. Lost is valuable information about the statistical ranges of individual predicted events. For example, the 90th or 95th percentiles of the predictions are not available so help interpret the statistical significance of the annual averages. These numbers can be easily produced by post-processing the dispersion model outputs. By limiting the modeling to only 1 year of meteorological data (note that EPA generally requires 5 years of data even for annual averages.), we also have no measure of year to variability of the key number driving the SAMA alternatives.(PWA00023, pgs.,3,4,8)

163. Because of the focus on long term averages, the relevance of the impact of a potential accident at any particular time or under any particular meteorological conditions is entirely lost. (Ibid)

164. Dr. Egan agrees. He summarized the problem in his concluding statements:

> As is pointed out in many times in these affidavits, the SAMA objectives can be met with a model that only produces long term average concentration and deposition of radio nuclides. Yet the technology used to obtain these long term averages requires addressing the impact of every hour in the year. The only numbers that matter to the results are the annual averages of all these computations. Lost is valuable information about the statistical ranges of individual predicted events. For example, the 90th or 95th percentiles of the predictions are not available to help interpret the statistical significance of the annual averages. Because of the focus on long term averages, the relevance of the impact of individual potential accidents is entirely lost. These numbers can be easily produced by post processing the dispersion model outputs. By limiting the modeling to only 1 year of meteorological data (we note that EPA generally requires 5 years of data even for annual averages.), one does not have any measure of year to variability of the single annual average which determines the SAMA alternatives. (PWA00023, pg.,8)

165. It is not clear why Entergy relies upon the use of a single year of meteorological data when DOE's own guidance Revised Chapter 4, Meteorological Monitoring, of Guide DOE/EH-0173T calls for retaining meteorological data for a five year period and states that assessments of the frequency distributions for routine accidents should be based on 5 or more years of data. (Ibid)

166. Entergy's second contention is that MACCS2 compares favorably with more complex models. (ENT00001, Entergy Dir. at A51-A60. Again, we disagree.

MACCS2 Code does not compare favorably with more complex models – such as SAND 96-0957. (Chanin, PWA00004)

167. Entergy justifies the use of the MACCS2 code based on "tradition" – a tradition, unhampered by progress, of using code going back decades. Entergy claims that "MACCS2 based results have been accepted by NRC" (A.51) The NRC may have accepted them, but David Chanin, who wrote the code's FORTRAN and SAND96-0957, disagrees that MACCS2 is the correct computational tool to use for reactor licensing decisions.

> I have spent much time thinking of a way to ―jigger the inputs so that the cost model of MACCS2 could be used in a sensible way. As the person who coded it into MACCS and then refined it for MACCS2, and also the person who wrote SAND96-0957, I think what you are attempting is impossible. The economic cost model in MACCS2 was included (at request of sponsors) only for historical reasons to allow comparison of its cost estimates to those of previous studies. It is my firm belief that the MACCS2 cost model is so seriously flawed that even with reevaluation and modification of all its input parameters, its cost results should not be used unless for replicating prior studies." When I was involved with the MACCS2 project (from 1991-1996, and also later in 2000-2001) the NRC had no interest in implementing the cost model of SAND96-0957 into MACCS2. I could have done it without a lot of work, but they weren't interested. (PWA00004, August 23, 2006)

168. Mr. Chanin explained also (PWA00004,"The Development of MACCS2: Lessons Learned," [written for:] *EFCOG Safety Analysis Annual Workshop Proceedings*, Santa Fe, NM, April 29–May 5, 2005) that the MACCS2 code was not held to the QA requirements of NQA-a

(American Society of Mechanical Engineering, QA Program Requirements for Nuclear Facilities, 1994). Rather it was developed using following the less rigorous QA guidelines of ANSI/ANS 10.4. [American Nuclear Standards Institute and American Nuclear Society, *Guidelines for the Verification and Validation of Scientific and Engineering Codes for the Nuclear Industry*, ANSI/ANS 10.4, La Grange Park, IL (1987). (Chanin, PWA00004)

169. What this means is that all steps of the code development have **not** been documented and tested, and hand calculations have not verified the code's implementation of major transport and exposure pathways for a subset of the radionuclide library. (Ibid)

170. Mr. Chanin says further that, "If errors are later found in authorization basis calculations, an <u>Unreviewed Safety Question (USQ) could be raised</u>, and continued operation of the facility would then require a demonstration that the facility's safety basis was adequate." (Emphasis added) Further, Mr. Chanin explains the importance of this in his concluding remarks in The Development of MACCS2, Lessons Learned prepared for Energy Facilities Contractor Operating Group Safety Analysis Working Group, Annual Workshop, April 29–May 5, 2005, Santa Fe, NM.

> [T]he QA distinctions between an NQA-1 "licensing code" and a "research code" like MACCS2 have been emphasized in light of the fact that MACCS2 calculations are being used to support the Severe Accident Mitigation Alternatives (SAMA) analyses required for the license renewal of commercial nuclear power plants. It seems to me that the code's QA shortcomings and the lack of input justifications are again being ignored.

171. Mr. Chanin's statements regarding the MACCS2 code make no exception for the ATMOS module that is central to meteorological issues. The Exhibit may be an "Inconvenient Truth" but it is undeniably relevant and within scope.

172. The MACCS2 ATMOS module does not compare favorably with more complex models designed for more complex sites. PNPS is a complex site. There is no basis for Entergy's statement that, at Pilgrim's complex site, the straight-line Gaussian plume model is comparable to variable trajectory models such as AERMOD & CALPUFF. (PWA00001, § 13) Whether the Gaussian plume model is "comparable" relative to the Pilgrim site cannot be determined without running both ATMOS (the Gaussian plume) and an alternative model (e.g. MM5 and CALPUFF) with PNPS site specific data. (Egan, Teleconference Call, May 4, 2010)

173. Entergy's experts incorrectly claim that ATMOS, AERMOD and CALPUFF are likely to produce similar results. As Dr. Egan said,

> The statements by Drs. O'Kula and Hanna in response to Question 60 that the three models (ATMOS, AERMOD and CALPUFF) are likely to produce similar results is because the topography of the region modeled were simple, flat terrain, the only setting that the ATMOS model is designed for. I would expect significant differences would be modeled in other topographic settings such as in complex terrain and in coastal settings where terrain elevations, surface parameters and rainfall precipitation rates vary with location. The differences would be even larger if a risk measure such as the 95 percentile values were examined rather than only annual average calculations. (PWA00021, pg.,5)

174. Comparative Studies: Entergy again puts forward the Molenkamp et al. report[14] comparison of the results from the Gaussian plume model used in ATMOS and results from "more complex" models in an effort to show that the results from the straight-line Gaussian model compare favorably with more complex models. We do not agree. (Ibid, pg., 7)

175. The fundamental flaw in Entergy's contention is that a comparison made in Kansas or Oklahoma tells little or nothing about what a comparison made in Plymouth, Massachusetts would show, and the NRC has agreed that it does not. As shown above, the PNPS site is characterized by its coastal location, varying terrain, "forested hills interspersed with urban areas" (FEIS, pg.,7,9; and Topography Map ENT00004, pg., 19)

176. In contrast, the Molenkamp studies were performed in areas that are not in the least comparable to the PNPS site. As a predictor of what might happen at PNPS, Entergy's reports are not "comparable;" they are simply meaningless.

177. Whether the Gaussian plume model is "conservative" or "comparable" relative to the Pilgrim site cannot be determined without running both ATMOS (the Gaussian plume) and an alternative model (e.g. MM5 and CALPUFF) with PNPS site specific data.

178. The NRC itself said that the Molenkamp study site in central Oklahoma and Kansas did not have "topography that would interact with the large-scale flow producing local modification of wind speed and direction," that it did not have "changes in surface properties that could affect local flow, such as a coastal site with a land-sea breeze" [NUREG/CR 6853, 3], that the

[14] Molenkamp et al (2004) compared several codes for recorded data in the Midwest, NUREG/CR-6853

Molenkamp sites are “relatively smooth and (have) has minimal effect on the wind field and the surface is fairly uniform and therefore produces relatively little thermal forcing,” and that it “would have preferred a site with greater topological and diurnal homogeneity” (NUREG/CR-6853, Oct. 2004, at xi and 2. The NUREG and readily admitted that “it would be best if MACCS2 and RASCAL/RATCHET results could be compared with measurements over the long distances and types of terrain of interest to the NRC;” And that the only reason that “the less desirable comparison with a state-of-the art code was chosen to provide input into the decision on the adequacy of MACCS2 ATD was that such measurements do not exist.” (Ibid, 2)

179. We agree with Dr. Egan’s concern regarding the validation of ATMOS. (Egan , PWA00023, pg., 7).

> The validation history of ATMOS with real observational measurements is very weak. Over the past decades there have been well documented field experiments and data from ambient monitoring networks in a variety of terrain settings that could provide data suitable to be used to produce model performance statistics for ATMOS as used in MACCS2. A validation effort that compared model predictions to observational data for a source at a coastal site and for both short and long distances would be most appropriate for the PNPS.

180. Dr. Egan explained that,

> The US EPA has used field studies and routine monitoring data to evaluate and improve dispersion models. Numerous studies have shown that flat terrain type models cannot be relied upon to provide competent predictions when applied to complex terrain settings. Not all models are the same in how they handle plume trajectories and atmospheric dispersion rates do vary by terrain setting and surface conditions. (PWA000023, pg.,7)

181. Entergy appears not to understand the intended purpose or use of CALPUFF and AERMOD models recommended by PW. Entergy says that these models "were not designed to perform SAMA analysis but to better predict individual plume behavior in order to meet specific regulatory requirements of the Clean Air Act, typically determining maximum allowable concentrations at any location, which differ from the objectives of a SAMA analysis" (Emphasis added) (ENT00001, Ans.52)

182. Earth Tech, the developers of the CALPUFF modeling system do not restrict the use of CALPUFF as Entergy appears to do.[15] For example, the developer says very clearly that the model is appropriate for "long range transport of pollutants… and for certain near-field applications involving complex meteorological conditions." The examples the developer provides of applications for which CALPUFF may be suitable show a fit for Pilgrim's SAMA analysis.

> CALPUFF is an advanced non-steady-state meteorological and air quality modeling system developed by ASG scientists. It is maintained by the model developers and distributed by TRC. The model has been adopted by the U.S. Environmental Protection Agency (U.S. EPA) in its Guideline on Air Quality Models as the preferred model for assessing long range transport of pollutants and their impacts on Federal Class I areas and on a case-by-case basis for certain near-field applications involving complex meteorological conditions. The modeling system consists of three main components and a set of preprocessing and postprocessing programs. The main components of the modeling system are CALMET (a diagnostic 3-dimensional meteorological model), CALPUFF (an air quality dispersion model), and CALPOST (a postprocessing package). Each of these programs has a graphical user interface (GUI). In addition to these components, there are numerous other processors that

[15] http://www.src.com/calpuff/calpuff1.htm; CALPUFF also described ENT00001, Ans. 55

> may be used to prepare geophysical (land use and terrain) data in many standard formats, meteorological data (surface, upper air, precipitation, and buoy data), and interfaces to other models such as the Penn State/NCAR Mesoscale Model (MM5), the National Centers for Environmental Prediction (NCEP) Eta/NAM and RUC models, the Weather Research and Forecasting (WRF) model and the RAMS model.

183 Examples given by the developer of applications for which CALPUFF may be suitable include near-field impacts in complex flow or dispersion situations; complex terrain stagnation, inversion, recirculation, and fumigation conditions; overwater transport and coastal conditions; light wind speed and calm wind conditions; long range transport development; and secondary pollutant formation and particulate matter modeling

184. The Federal Register /Vol. 68, No. 72 /Tuesday, April 15, 2003 /Rules and Regulations 18441, similarly says "*Scientific merits and accuracy*: CALPUFF in its current configuration is suitable for regulatory use for long range transport, and on a case-by-case basis for complex wind situations." The Southeastern Massachusetts Coast is a complex wind situation.

185. Entergy also seems not to take into account model predictions at long distances or the importance of spatially varying parameters. We agree with the statement in Dr Egan's Declaration (PWA0001, pp.5-6)

> The discussions and modeling demonstrations of the impacts of the ATMOS model at large distances from the PNPS underscore the need to have more appropriate models applied to predict atmospheric transport. The model to model comparisons cited do not shed any light on how well the straight-line format of the MAACCS2 model will predict concentrations at the very distances where impacts dominate the

population dose and economic consequences of accidents of concern. One cannot really expect that a single anemometer located at the PNPS site will accurately predict the destination of emissions over such long distances. This is the reason that other regulatory agencies advocate using long range transport model capable of utilizing meteorological measurements that allow a simulation of regional scale differences in air flow patterns for air quality and environmental impact analyses.

Further, the compromises in credibility associated with running the MACCS2 model with a single value of the roughness length to be used year round and a single value of precipitation rate data to be used for all locations within a 50 mile radius (about 7850 square miles) are substantial and unnecessary given today's computer modeling capabilities.

186. We also agree with Dr. Egan's statements (Ibid, pg., 6) that:

One of the computational limits of the ATMOS model is that is can utilize only one value of the surface roughness parameter for the entire modeling domain, in this case the area located within a radius of 50 miles. More advanced models allow roughness length as well as other surface characteristics to vary spatially. CALPUFF, for example can additionally utilize information about surface albedo and the Bowen Ratio, two other parameters that research efforts show are needed to improve the establishment of wind speed, wind speed profiles and dispersion rates for transport and dispersion models.

An example of a systematic bias in the ATMOS application at the PNPS that is especially important at large distances from the PNPS is the use of only the seasonally averaged afternoon mixing depths. Because the afternoon mixing depths are generally much larger than morning mixing depths, and because at large distances from a source, ground level concentrations will be lower with increased mixing depth, this is not a conservative assumption.

187. In response to Entergy's question 59 and 60, Entergy's experts discussed supposed difficulties associated with trying to improve the MACCS2 code. Dr. Egan (Ibid, pg.,4) shows this is not so. He says that,

> In response to Questions 59 and 60, Drs. O'Kula and Hanna discuss difficulties associated with trying to improve the MACCS2 code. The comment that eight years were required to develop the AERMOD code needs to be placed in context. The initial multiyear work effort of the AMS/EPA Regulatory Model Improvement Committee (AERMIC) which is responsible for the development of AERMOD, was to sort out, test and determine the best ways to integrate the findings of meteorological research studies and efforts that addressed improving the parameterization of the transport and dispersion characteristics of air flow in the planetary boundary layer. That research effort was time consuming but, it was completed and is well published. It would not need to be done again for purposes of improving ATMOS. Importantly, the results are viewed as representing a major step forward in defining the algorithms for computer simulations ranging from Gaussian dispersion type models to advanced numerical simulation models. The upgrades to the AERMOD code resulting from this research have flowed to improving the CALPUFF model, the Emissions and Dispersion Modeling System (EDMS) used by the FAA for aircraft operations as well as in modeling codes advanced by the National Park Service and other environmental protection agencies in the US and abroad.
>
> I have personal experience as the Project Director responsible for the staffing, budget and performance of contract efforts to develop and validate dispersion atmospheric dispersion models. I agree that an effort would be involved to upgrade ATMOS, but believe that the coding part would not be nearly as difficult as implied by these responses. The code to include radioactive decay used in ATMOS would need to be integrated into any new code but this could retain the structure presently used in ATMOS.
>
> Statements made in Mr. Ramsdell's affidavit also support my earlier assertions that computational time to run more sophisticated models should not be a deterrent to

adopting advanced models. Mr. Ramsdell says at A32, referring to his involvement in the NUREG-6853 study (Molencamp et al, 2004): "Data preparation for MACCS2 was completed in a few hours, and code execution took less than 10 minutes on a PC. Data preparation for RASCAL required somewhat longer, but still only a few days. RASCAL code execution took about an hour on a PC. Finally, weeks were spent getting data ready to run the ADAPT/LODI codes and the execution of these codes took almost a week of calculation on a mainframe computer."

First, it is clear that running MACCS2 took hardly any time. RASCAL, a model which incorporates some of the advanced atmospheric science features of AERMOD, also takes very little data preparation and execution time. ADAPT /LODI required more time in data gathering and in execution time but still not an unreasonable amount of effort for an important analysis
One would think that the licensing of a nuclear power plant would be an important enough application that data preparation time and computer resources would not be constraining factors.

I note that the draft description of RASCAL Version 4 (Ramsdell et al, 2010) describes the model as using a straight-line Gaussian plume model "near the release point where travel times are short" and a Lagrangian-trajectory Gaussian puff model "at longer distances where temporal or spatial variations in meteorological conditions may be significant". From this perspective, RASCAL appears more advanced than ATMOS.

188. Entergy's next assertion, with which we disagree, is that the meterological inputs for the Pilgrim SAMA analysis are both termporally and spatially representative. (ENT00001, Entergy Dir., A61-A72)

189. Entergy's expert compared the annual wind rose (which shows the frequency that the wind is blowing in each of 16 wind directions) at Pilgrim for 2001 to the annual wind roses at Pilgrim from 1996-2000, apparently to show that the 2001 annual wind rose at the Pilgrim Station is representative of other years; and he then compared the annual wind rose at Pilgrim to the wind roses for 18 other sites in the 50-mile region of interest shows that the Pilgrim site wind direction frequencies are within the range of statistical expectation for 18 other sites and that the Pilgrim data are representative of the 50- mile SAMA region.

190. But these comparisons avoid the real point: measurements from a single tower in time tells what direction the plume will travel when first leaving the site but do nt show <u>not what will happen to the plume once it goes offsite in a complex environment.</u> We do not question Dr. Hanna's research and finding that the initial wind direction from various sites was essentially similar but it does not address the question of what would happen next as the plume was affected by various site specific factors such as the differential between the water and land temperatures, topography, buildings.

191. Dr. Egan explained that,

> The simple fact is that measurements from a single 220' high anemometer will not provide sufficient information to project how an accidental release of a hazardous material would travel. For cases when the sea breeze was just developing and for cases when the onshore component winds do not reach entirely from the ground to the anemometer height, the occurrence of a sea breeze would not be identified. The anemometer would likely indicate an offshore wind indication. (PWA00001, § 13)

192. PW showed that basing wind direction on the single on-site meteorological tower data ignores shifting wind patterns away from the Pilgrim Plant including temporary stagnations, re-circulations, and wind flow reversals that produce a different plume trajectory. [PWA00023,pg.,8; PWA0001 § 13) Since the 1970s, the USNRC has historically documented all the advanced modeling technique concepts and potential need for multiple meteorological towers especially in coastal regions." NRC Regulatory Guide 123 (Safety Guide 23) On Site Meteorological Programs 1972, states that, "at some sites, due to complex flow patterns in non-uniform terrain, additional wind and temperature instrumentation and more comprehensive programs may be necessary; and an EPA 2000 report, Meteorological Monitoring Guidance for Regulatory Model Applications, EPA-454/R-99-005, February 2000, Sec 3.4 points to the *need for multiple inland meteorological monitoring sites.* See also Raynor, G.S.P. Michael, and S. SethuRaman, 1979, Recommendations for Meteorological Measurement Programs and Atmospheric Diffusion Prediction Methods for Use at Coastal Nuclear Reactor Sites. NUREG/CR-0936.

193. The crux of PW's argument is that comparing long-term wind rose data for the same site, or between various sites, is irrelevant unless you simply want to show that the long-term prevailing wind directions are similar in southeastern MA. But, that has nothing to do with evaluating plume trajectory/concentrations/doses at each receptor, which would be more reliably predicted using variable trajectory dispersion modeling coupled with multiple offsite meteorological tower data. EPA would not have gone to the time and expense to develop advanced modeling techniques if the simple straight-line Gaussian models were sufficient.

194. Evaluation of the 2001 Plymouth Municipal Airport annual precipitation data used in the Pilgrim SAMA analysis shows that the data are representative of the precipitation levels from 1995-2009 at Plymouth and at eight other sites in the 50-mile region. What are left out of the analysis are measurements of fog and humidity that would affect contamination. A search of ENT00001 for "fog" turns up nothing; Entergy simply looks at "precipitation" or rain.

195. Entergy's fourth contention is that its SAMA analysis appropriately accounts for coastal breezes. (ENT00001, A73-A81) We do not agree. Entergy's experts say that merely changing meteorological inputs to account for coastal breezes will not make any difference. The only reason that is so is because Entergy has "averaged out" the effects of any differences in meteorology; and because Entergy's chosen inputs into the MACCS2 code and Entergy's use of that code ensure that the effect of Pilgrim's site specific meteorological conditions are effectively ignored.(PWA00023 pg.,8)

196. Entergy (Ibid., A.79) tries to explain that, "SAMA cost benefit analysis sums (takes a mean average of) population dose and economic consequences across a 50 mile radius based on one-year's worth of hourly meteorological data; (and) Coastal sea and land breezes occur only about forty or fifty days per year, very roughly about 10 to 15% of the year, and for a limited duration of about 6 hours on each day." Therefore sea breeze has no impact if a mean average is used; however its significance would be apparent if the 95% percentile were used.

197. However, if Entergy had not "averaged out" the effects of any differences in meteorology and ensured by their chosen inputs into the MACCS2 code, the effect of coastal breezes on increasing consequences would be apparent. For example, "on days with significant sea breezes,

they average about 5 to 10 miles inland penetration, with occasional larger values of up to 30 miles or so" (ENT00001, A.74). Therefore the sea-breeze would contaminate more densely populated areas where long term health effects and requirements for cleanup would significantly affect cost.

198. Entergy (Ibid., A.76) claims that coastal breezes decrease radiological doses because sea and land breezes are not a concentrating phenomenon (increasing the maximum plume centerline concentration). Rather they are a dispersive one. Dr. Egan disagrees, and so do we. As Dr. Egan said (PWA00001, § 13):

> [Mr. O'Kula's] contention that the seabreeze is 'generally beneficial in dispersing the plume and in decreasing doses' is incorrect. In fact, the development of seabreeze flow that would transfer a release inland is the greatest danger. Contrary to the implications of this declaration, the development of a sea breeze flow is the common meteorological condition that must be most closely monitored at the PNPS.
>
> [Mr. O'Kula's] statement reflects a misconception that the sea breeze is "generally a highly beneficial phenomena that disperses and dilutes the plume concentration and thereby lowers the projected doses downwind from the release point." If the same meteorological conditions (strong solar insolation, low synoptic-scale winds) that are conducive to the formation of sea breezes at a coastal site occurred at a non coastal location, the resulting vertical thermals developing over a pollution source would carry contaminants aloft. In contrast, at a coastal site, the sea breeze would draw contaminants across the land and inland subjecting the population to potentially larger doses.

199. Dr. Egan (Ibid) previously disputed other points raised by Entergy's expert Kevin O'Kula, 2007, and his comments remain directly applicable to the same conclusions that Entergy has repeated in its Initial Statement. (ENT00001, A-61-A72)

> [Mr. O'Kula's] statement that the meteorological data collected at the PNPS site would reflect the occurrence of the sea breeze in terms of wind speeds and direction is not necessarily true.
>
> A measurement at a single station tower, 220 feet, will not provide sufficient information to allow one to project how an accidental release of a hazardous material would travel.[16] Measurement data from one station will definitely not suffice to define the sea breeze.

200. Dr. Bixler, NRC Staff expert, <u>agreed with Pilgrim Watch and Dr. Egan</u>, (PWA00001, § 13) and said in his affidavit that "*the effect of sea breeze is not taken into account"* in Entergy's studies.

> 10. (NEB) Material Fact number 19 states that the effect of sea breeze is taken into account in the Pilgrim site meteorological data. *Although the wind speed and direction of a sea breeze may be included in the actual PNPS meteorological data, the effect of sea breeze is not taken into account.* The effect that is not taken into account is that the *complex flow pattern under sea breeze conditions differs substantially from the straight-line pattern used in the MACCS2 analyses*. The sea breeze occurrences are typically diurnal events, occurring during daylight hours and during warmer seasons.[17]

201. When Dr.Bixler was put forth as an expert witness in 2007 and signed an affidavit "declaring under the penalty of perjury that the foregoing was true and correct to the best of [his]

[16] License Application 2.10 Meteorology and Air Quality at 2-31; and at Attachment E, E.1.5.2.6 at E.1-63]

[17] Affidavit of Joseph A. Jones and Dr. Nathan Bixler Concerning Entergy's Motion for Summary Disposition of Pilgrim Watch Contention 3, June 25, 2007 prepared for NRC Staff response to Entergy's Motion for Summary Disposition of Pilgrim Watch Contention 3, June 29, 2007

knowledge, information and belief,." We do not accept the NRC Staff's apparent position that he is not qualified to speak on this issue today.

Entergy's next assertion is that "hot spots" as claimed by PilgrimWatch are both technically incorrect and immaterial. (ENT00001, A82-A89)

202. Entergy's experts say that merely changing meteorological inputs to account for the behavior of plumes over water will not make any difference. But that again is because Entergy has "averaged out" the effects of any differences in any site specific meteorology; and because Entergy's chosen inputs into the MACCS2 code and Entergy's use of that code ensure that the effect of Pilgrim's site specific meteorological conditions are effectively ignored.

203. If Entergy had not "averaged out" the effects of any differences in meteorology and ensured by their chosen inputs into the MACCS2 code, the effect of a concentrated plume over water increasing costs would be seen.

204. Entergy's Gaussian plume model assumed that plumes blowing out to sea would have no impact. PW showed that a plume over water, rather than being rapidly dispersed, will remain tightly concentrated due to the lack of turbulence. The marine atmospheric boundary layer provides for efficient transport. Because of the relatively cold water, offshore transport occurs in stable layers. Wayne Angevine's (NOAA) research of the transport of pollutants on New England's coast concluded that major pollution episodes along the coast are caused by efficient transport of pollutants from distant sources. "The transport is efficient because the stable marine boundary layer allows the polluted air masses or plumes to travel long distances with little

dilution or chemical modification. The sea-breeze or diurnal modulation of the wind, and thermally driven convergence along the coast, modify the transport trajectories." Therefore a plume will remain concentrated until winds blow it onto land. (Zager et al.; Angevine et al. 2006[18]) (PWA00006) If Angevine's research found this to be true for contaminants that result in smog then why would it not hold true for radionuclides? The meteorological phenomena would be the same and the only difference would be factoring in the half-lives of released radionuclides, many of which are long lived.

Dr. Beyea said that this can lead to hot spots of radioactivity in places along the coast, certainly to Boston. [PWA00002, Beyea, pg.,11] The compacted plume also could be blown ashore to Cape Cod, directly across the Bay from Pilgrim and heavily populated in summer. An alternative model that Entergy did not use, CALPUFF, could account for reduced turbulence over water and could be used for sensitivity studies. [Ibid, pgs., 11-12].

205. We agree with Dr. Egan's observation (PWA00023, pg., 6) that:

> In the discussion about wind over the ocean, I found Dr. Hanna's response to Question 85 to be out of context with the potential accidental configurations at the PNPS and therefore leading to an erroneous implication about the role of overwater transport. Dr. Hanna states that "a factor of 2 greater wind speed over the ocean would, by itself, contribute to a reduction of maximum concentrations by approximately a factor of two". This would strictly be true only if the source were also within the airflow over the ocean. As Dr. Hanna correctly states in response to question 28, the dilution effect of wind speed and the inverse wind speed relationship to concentration only applies to the initial dilution of the emission source. What

[18] Angevine, Wayne; Tjernström, Michael; Žagar, Mark, Modeling of the Coastal Boundary Layer and Pollutant Transport in New England, Journal of Applied Meteorology and Climatology 2006; 45: 137-154, Exhibit 6

> often does happen with an onshore flow, since the air over the water is often more stable than that over land, is that a fumigation type event occurs. This is associated with the fact that the surface roughness change and the warm land surface create more turbulence in the surface layer that would mix plume material from an elevated plume down to the surface, resulting in increased ground level concentrations.

206. Entergy also says that the CALMET Wind Trajectory Analysis shows that any short-term differences in observed winds across the SAMA domain have negligible affect on the annual frequencies of trajectory directions and on the Pilgrim SAMA consequences. (ENT00001, Entergy Dir., A92-A105)

207. Entergy's expert, Dr. Hanna, says that any short-term differences in observed winds across the SAMA domain have negligible effect on the annual frequencies of trajectory directions and on the Pilgrim SAMA consequences; but he admits that the only reason that is so is because Entergy has "averaged out" the effects of any differences in meteorology. He also says that Entergy's chosen inputs into the MACCS2 code and Entergy's use of that code ensure that the effect of Pilgrim's site specific meteorological conditions are effectively ignored in the SAMA analysis.

208. Dr. Hanna's analysis did not address the real dispute: the difference between a Gaussian plume model and a variable trajectory model on the area impacted and deposition within that area cannot be determined without running both ATMOS (the Gaussian plume) and an alternative model (e.g. MM5 and CALPUFF) with PNPS site specific data. Dr. Hanna did not do this so that we have not answered the question.

209. With respect to "terrain," Entergy says that it is conservatively treated for purposes of the Pilgrim SAMA Analysis. (Ibid, A106-A114)

210. However, if Entergy had not "averaged out" the effects of terrain on dispersion, the real and important effect of terrain on increasing consequences would have been clear. (PWA00023, pg.,3,4,8)

211. Entergy says that terrain is conservatively treated, but we disagree. NRC Staff's expert, Dr. Bixler is in full accordance with PW's argument that whether a Gaussian model is conservative depends entirely on "*the trajectory of the plume compared with population centers*[19]*;"* and PW submitted significant evidence that the straight-line Gaussian plume could not, and did not, predict site-specific atmospheric dispersion for Pilgrim's coastal region, or accurately predict what population centers the likely variable plume would affect. (PWA00023, pgs., 5,7)

212. Finally, Entergy contends that Pilgrim Watch's other Contention 3 issues are without merit. (ENT00001, Entergy Dir., A.115-A.118.).

213. To the extent that this may be so, it is only the result of the many ways that "real" consequences are minimized and masked by Entergy's methodology. In the "real world," real issues are raised and are important in analyzing costs.

[19] Affidavit of Joseph A. Jones and Dr. Nathan Bixler Concerning Entergy's Motion for Summary Disposition of Pilgrim Watch Contention 3, June 25, 2007 prepared for NRC Staff response to Entergy's Motion for Summary Disposition of Pilgrim Watch Contention 3, June 29, 2007, Bixler paragraph 8

214. Taking resuspension as an example, Pilgrim Watch MACCS2 Guidance Report, June 2004,[20] is clear that Entergy's inputs to the code do not account for variations resulting from *site-specific* conditions such as those present at PNPS. The "code does not model dispersion close to the source (less than 100 meters from the source)," thereby ignoring resuspension of contamination blowing offsite.

215. Entergy seeks to render this meaningless by averaging one-year of meteorological data over the 50-mile radius area. For example, the consequences of resuspension of contaminants blowing off Pilgrim's site is obvious if there are strong winds or on days with significant sea breezes. Dr. Hanna estimated that the inland penetration of sea breezes average about 5 to 10 miles inland penetration, with occasional larger values of up to 30 miles or so. (ENT00001, A.74) Densely populated areas such as Metropolitan Boston, Cape Cod and smaller cities such as Brockton and Quincy are within 30 miles.

216. Entergy concluded that, "The meteorological modeling in the Pilgrim SAMA analysis is adequate and reasonable to satisfy NEPA. Furthermore, as demonstrated by the CALMET trajectory wind analysis, accounting for the meteorological patterns and issues of concern to Pilgrim Watch cannot credibly alter the Pilgrim SAMA analysis conclusions on which SAMAs are cost-beneficial to implement." Entergy's conclusions are simply wrong.

217. Pilgrim Watch has shown that the meteorological modeling in Pilgrim's SAMA analysis is inadequate and not reasonable to satisfy NEPA; and instead that PW's recommended alternate

[20] MACCS2 Guidance Report June 2004 Final Report page 3-8:3.2 Phenomenological Regimes of Applicability

meteorological modeling does not pose any conflict with NEPA's Rule of Reason. Entergy's arguments (Entergy's Initial Statement of Position, January 3, 2011, pgs.2-5) are without merit.

218. Dr. Egan (PWA00023, pg.,5) discussed that numerous studies have shown that flat terrain type models, such as was used in ATMOS, cannot be relied upon to provide competent predictions when applied to complex terrain settings, such as Pilgrim's. He showed that not all models are the same in how they handle plume trajectories and atmospheric dispersion rates do vary by terrain setting and surface conditions.

> The discussions and demonstrations of the impacts of the ATMOS model at large distances from the PNPS underscore the need to have more appropriate models applied to predict atmospheric transport. The model to model comparisons do not shed any light on how well the straight-line format of the MACCS2 model will predict concentrations at the very distances where impacts dominate the population dose and economic consequences of accidents of concern. One cannot really expect that a single anemometer located at the PNPS site will accurately predict the destination of emissions over such long distances. This is the reason that other regulatory agencies advocate using long range transport model capable of utilizing meteorological measurements that allow a simulation of regional scale differences in air flow patterns for air quality and environmental impact analyses.
>
> Further, the compromises in credibility associated with running the MACCS2 model with a single value of the roughness length to be used year round and single values of precipitation rate data to be used for all locations within a 50 mile radius (about 7850 square miles) are substantial and unnecessary given today's computer modeling capabilities.
>
> As is pointed out in many times in these affidavits, the SAMA objectives can be met with a model that only produces long term average concentration and deposition of radio nuclides. Yet the technology used to obtain these long term averages requires

addressing the impact of every hour in the year. The only numbers that matter to the results are the annual averages of all these computations. Lost is valuable information about the statistical ranges of individual predicted events. For example, the 90th or 95th percentiles of the predictions are not available to help interpret the statistical significance of the annual averages. These numbers can be easily produced by post processing the dispersion model outputs. By limiting the modeling to only 1 year of meteorological data (we note that EPA generally requires 5 years of data even for annual averages.), one does not have any measure of year to variability of the single annual average which determines the SAMA alternatives.

Because of the focus on long term averages, the relevance of the impact of individual potential accidents is entirely lost. It is not clear why Entergy relies upon the use of a single year of meteorological data when (for example) DOE's guidance Revised Chapter 4, *Meteorological Monitoring*, of Guide DOE/EH-0173T (PW Exhibit 13) says that the joint-frequency distribution and choices of meteorological conditions for the accident analyses should be based on a minimum of 5 years of hourly-averaged data acquired by a meteorological program that meets the objectives and principles of ANSI/ANS-3.11-2000 and EPA-454/R-99-005.

219. In addition, and as we next discuss, Pilgrim Watch has shown not only that the meteorological modeling in Pilgrim's SAMA analysis is inadequate and not reasonable to satisfy NEPA, but also that PW's recommended alternate meteorological modeling does not pose any conflict with NEPA's Rule of Reason. Entergy's arguments (Entergy's Initial Statement of Position, January 3, 2011, pgs.2-5) are without merit.

<u>NEPA's Rule of Reason</u>

220. PW presented evidence that statements made in the O'Kula declarations that were relied on by Entergy to support its contention that the inputs into the MACCS2 code were sufficient are

incorrect or misleading. MACCS2 is not a state-of-the-art computer model. It does not rely upon or utilize current understandings of boundary layer meteorological parameterizations such as those adopted by the EPA in the models AERMOD OR CALPUFF (EPA, 2001). (PWA00001Egan, § 13)

221. The Gaussian plume model employed in the PNPS MACCS2 model may be the standard for NRC but it is not the basis for advanced modeling used by other US regulatory agencies. (PWA00001, § 13)

222. Computational time should not be a major factor in the choice of a dispersion model used for non-real time applications. Contrary to Entergy, these applications are not "simply impracticable" (PWA00023, pg., 5)

223. Dr. Hanna and Mr. Ramsdell seem to acknowledge that recent advances in atmospheric sciences, especially in understanding the complexities of dispersion in the planetary boundary layer have resulted in technical improvements to atmospheric transport simulations. These scientific advances as well as in advances in computational methods have resulted in the remarkable improvements made to the meteorological models that are used operationally to predict future weather. Many of these advances have been incorporated into the coding of the newer transport and diffusion models used for environmental assessments required for permitting and safety of power plants and industrial sources. We are sure that these experts would also agree that for emergency planning or for use during actual emergencies, it would be beneficial to use dispersion models that utilize better science to simulate phenomena and to predict the

dispersion consequences of individual events in a highly reliable and competent manner. (PWA00023, pg.,6)

224. From a computational point of view, the <u>key difference between the modeling needs of SAMA analyses and applications to emergency response</u> is the fact that, as constructed, the SAMA analyses focus on evaluating only long term average consequences. The short term averages are not needed. For emergency response, the short term predictions are essential. However, the difference between these needs from an air quality modeling computational standpoint essentially reduces to the averaging of the results and how the data is manipulated in post processors. The core elements of the RASCAL model described by Mr. Ramsdell are used to calculate 1 hour values that could be averaged to produce the long term averages needed for a SAMA. With <u>today's computers, the computer time in unlikely to be an issue</u>. We think such advances could improve the reliability and credibility of ATMOS because improvements to the model made to the 1-hour predictions would improve the reliability of the annual average values. (Ibid)

225. Entergy's expert's comments that the US EPA 's requirements to address National Ambient Air Quality Standards (NAAQS) with short term averaging times (one hour, 3 hour, 24 hour averages) is the reason that EPA uses more advanced models are not correct. The averaging times for the National Ambient Air Quality Standards (NAAQS) range for one hour to annual averages. The EPA has guidance for selecting the most appropriate dispersion model for use in different applications (40 CFR Part 51 Appendix W. Guideline ion Air quality models). The criteria are based on a combination of appropriate recent science and model validation. With

these criteria, there is no issue of different dispersion modeling techniques for modeling short term averages versus long term averages. Three criteria pollutants have annual average standards: SO2, NO2, and particulate matter. The same models used for estimating short averaging time impacts are used for the annual averages. The modeling requirements for demonstrating compliance with the NAAQS for Nitrogen Dioxide are an example. The initial standard set for NO_2 was for annual average concentrations. On the basis of revised findings of health effects, EPA in 2010, set a new standard with a one hour averaging time. The dispersion modeling methods recommended for compliance demonstrations for both the annual averages and the one hourly values did not change. The choice of model does not depend upon the averaging time over which meteorological variations occur. (PWA00023, Egan, pg.8)

226. In response to Questions 59 and 60, Drs. O'Kula and Hanna discuss difficulties associated with trying to improve the MACCS2 code. The comment that eight years were required to develop the AERMOD code needs to be placed in context. The initial multiyear work effort of the AMS/EPA Regulatory Model Improvement Committee (AERMIC) which is responsible for the development of AERMOD, was to sort out, test and determine the best ways to integrate the findings of meteorological research studies and efforts that addressed improving the parameterization of the transport and dispersion characteristics of air flow in the planetary boundary layer. That research effort was time consuming but, it was completed and is well published. It would not need to be done again for purposes of improving ATMOS. Importantly, the results are viewed as representing a major step forward in defining the algorithms for computer simulations ranging from Gaussian dispersion type models to advanced numerical simulation models. The upgrades to the AERMOD code resulting from this research have flowed

to improving the CALPUFF model, the Emissions and Dispersion Modeling System (EDMS) used by the FAA for aircraft operations as well as in modeling codes advanced by the National Park Service and other environmental protection agencies in the US and abroad. (Ibid., pg.9)

227. I have personal experience as the Project Director responsible for the staffing, budget and performance of contract efforts to develop and validate dispersion atmospheric dispersion models. I agree that <u>an effort would be involved to upgrade ATMOS, but believe that the coding part would not be nearly as difficult as implied by these responses. The code to include radioactive decay used in ATMOS would need to be integrated into any new code but this could retain the structure presently used in ATMOS</u>. (Ibid., pg.4)

228. Statements made in Mr. Ramsdell's affidavit also support my earlier assertions that <u>computational time to run more sophisticated models should not be a deterrent to adopting advanced models</u>. Mr. Ramsdell says at A32, referring to his involvement in the NUREG -6853 Study (Molencamp et al, 2004): "Data preparation for MACCS2 was completed in a few hours, and code execution took less than 10 minutes on a PC. Data preparation for RASCAL required somewhat longer, but still only a few days. RASCAL code execution took about an hour on a PC. Finally, weeks were spent getting data ready to run the ADAPT/LODI codes and the execution of these codes took almost a week of calculation on a mainframe computer." (PWA00023, Egan, pg.,5)

229. First, it is clear that running MACCS2 took hardly any time. RASCAL, a model which incorporates some of the advanced atmospheric science features of AERMOD, also takes very

little data preparation and execution time. ADAPT /LODI required more time in data gathering and in execution time but still not an unreasonable amount of effort for an important analysis. (Ibid)

230. We agree that the licensing of a nuclear power plant is an important enough application such that data preparation time and computer resources would not be constraining factors. PWA00023, pg.,5)

231. The draft description of RASCAL Version 4 (Ramsdell et al, 2010) describes the model as using a straight-line Gaussian plume model "near the release point where travel times are short" and a Lagrangian-trajectory Gaussian puff model "at longer distances where temporal or spatial variations in meteorological conditions may be significant". From this perspective, RASCAL appears more advanced than ATMOS. (Ibid., pg.,5)

232. The idea that randomly chosen meteorological conditions would give the same results as inputting meteorological conditions as a function of time is erroneous. To accommodate the real role of persistence in dispersion modeling EPA requires sequential modeling for all averaging times from 3 hour averages to annual averages. (PWA00001, § 13)

233. CLI-10-22, pg., 9 emphasized, as they had done earlier, that NEPA requirements are "tempered by a practical rule of reason" and an environmental impact statement is not intended to be a "research document." If relevant or necessary meteorological data or modeling methodology prove to be unavailable, unreliable, inapplicable, or simply not adaptable for

evaluating the SAMA analysis cost-benfit conclusions, there may be no way to assess, through mathmatical or precise model-to model comparisons, how alternative meteorological models would change the SAMA analysis results."

234. The plume modeling that PW presented as appropriate for Pilgrim's SAMA analysis, instead of Entergy's decision to use the straight line Gaussian model, are not techniques that require research. They are, in fact, established methods that are publically available, routinely used, and appropriate for quantifying atmospheric dispersion of contaminants. (Appendix 2 lists examples from government and independent sources) Although an effort may be required to adapt these methods for SAMA analyses, this would be very straightforward and research would not be required. (PWA00023, pg., 4)

235. Appropriate meteorological data or modeling methodology is available. There is no shortage of appropriate meteorological data for a licensing model application. Alternative modeling methods that would use more extensive meteorological data are also available. (PWA00001, § 7,8,11)

236. The applicant chose to use only one year of onsite data collected at the Pilgrim's site. Meteorological data is also available from nearby airports and, importantly, processed data on a gridded basis can be obtained from NOAA to augment the onsite meteorological data relied upon for the SAMA analyses that have been provided by Entergy. PW demonstrated this by disclosing, for example, the Thorpe site-specific meteorological study (PWA00010) and Spengler and Keeler study (PWA00011), both Dr. Egan and Hanna attended the studies sea

breeze workshop, Chapter 8 of Spengler's study) and Dr. Egan's "Development of a Dispersion Modeling Capability for Sea Breeze Circulations and other Air Flow Patterns over Southeastern Massachusetts, Upper Cape Cod Modeling Study," (Referenced PWA00001 & PWA00023) that used available meteorological data. Also there are several publically available meteorological modeling methods that can simulate variable trajectory transport and dispersion phenomena. MM5 is one which is routinely used nationally and internationally.

237. There are other options as well. The present state of art of an appropriate meteorological model would use multi station meteorological measurement data as input to the meteorological model. The numerical computations, based upon numerical weather prediction techniques, would compute wind fields appropriate for modeling dispersion over a much larger geographic area than a single measurement site would be appropriate for.

238. A second reasonableness criterion is that the modeling method must be reliable. The outputs from such meteorological models that are used to produce inputs for the dispersion models are well accepted and form the basis for the weather predictions provided by the national weather service as well as analyses of air pollution impacts of concern to regulatory agencies . These techniques have been proven to be reliable and acceptable for air quality permitting and policy applications in complex terrain and over large distances for the US EPA , the US Park Service as well as internationally. PW argued with sufficient particularity that for complex meteorological situations such as for the Pilgrim, these techniques would be *more* reliable than using the straight line Gaussian model.(PWA00023, pgs., 3,6)

239. The third reasonableness criterion is that the modeling methods be applicable to SAMA analyses. The methods PW recommended are applicable because with straightforward modifications to incorporate nuclear radiation decay rates, they can produce the fields of concentration values and deposition rates needed for dosage calculations. (PWA00023, pgs.,1,2,5)

240. The fourth reasonableness criterion is that the modeling methodology be adaptable for evaluating SAMA analysis cost benefit conclusions. There is nothing inherent in variable trajectory models that would prohibit the output concentration and deposition fields from being applied to SAMA analyses.

241. None of the criteria cited would make the use of alternative models unreasonable to apply to the Pilgrim's SAMA analyses.

242. Further there is no basis to the argument that there may be no way to assess through mathematical or precise model to model comparisons, how alternative meteorological models would change the SAMA analysis results. Some assessments may necessarily be qualitative, based simply upon expert opinion. But this argument seems to undercut the very value of mathematical simulation models in general as a method to assess the impacts of nuclear reactor emissions.

243. The rationale offered by Entergy that the use of advanced models would be computationally too expensive and/or burdensome to use are not justified by the actual run time

shown in our review of MACCS2 output files. With modern computers, the use in inappropriate models on the basis of differences of computational costs is indefensible.

244. Invoking the "practical rule of reason" to the present disagreement about the most appropriate modeling methodology for application to the Pilgrim SAMA analyses is blatantly dismissive of the concept that the present methods are inappropriate and outdated and that there are indeed alternative modeling available.

245. Entergy's SAMA analysis uses MELCOR Accident Consequence Code System (MACCS2) computer program. No NRC regulation *requires* the use of that code, or any other particular code. It was Entergy's choice. There are other consequence computer codes in use for nuclear accidents around the world. Research is not necessary. Alternatively modifying the code with updated assumptions and inputs is clearly reasonable for a site-specific, Category 2 analysis.

<u>VII. CONCLUSIONS OF LAW</u>

246. This Board has previously decided that

a. SAMA analyses are within scope under 10 CFR §51(c)(ii)(L);

b. SAMA analyses are a site specific Category 2 issue within in Subpart B to Appendix A of section 51; and

c. The Issue Raised in Contention is Material. (10 CFR 2.309(f)(iv)). *In the Matter of Dominion Nuclear Connecticut, Inc.* (Millstone Nuclear Power Station, Units 2 and 3) Docket Nos. 50-336-LR, 50-423-LR ASLBP No. 04-824-01-LR July 28, 2004, p. 7. See

Private Fuel Storage, L.L.C. (Independent Spent Fuel Storage Installation), LBP- 98-7, 47 NRC 142, 179-80 (1998), aff'd in part, CLI-98-13, 48 NRC 26 (1998)

247. As amended and admitted in this Board's In its October 16, 2006 Memorandum And Order, Contention 2 is:

> Applicant's SAMA analysis for the Pilgrim plant is deficient in that the input data concerning (1) evacuation times, (2) economic consequences, and (3) meteorological patterns are incorrect, resulting in incorrect conclusions about the costs versus benefits of possible mitigation alternatives, such that further analysis is called for.

248. As admitted by this Board, Contention 3 asks only whether "further analysis is required." It does not require Pilgrim Watch to conduct that analysis or to show what the results of any such further analysis might be. As Judge Young said in her dissent to the Board's Order granting Entergy's Motion for Summary Disposition, requiring PW to "provide calculations proving the negative of Entergy's sensitivity analysis …. is unreasonable…." [LBP-07-13, 66 NRC, Dissent, 39]

249. In its Order of September 23, 2010, the Board identified the issues it would consider in the remand hearing and the manner in which the remand hearing would be conducted:

> Contention 3 will be bifurcated, to the following extent:
> If the Board decides in favor of Intervenors on the primary and threshold issue of *whether the meteorological modeling in the Pilgrim SAMA analysis is adequate and reasonable to satisfy NEPA, and whether accounting for the meteorological patterns/issues of concern to Pilgrim Watch could, on its own, credibly alter the Pilgrim SAMA analysis conclusions on which SAMAs are cost-beneficial to implement* (hereinafter referred to as "the meteorological

modeling issues"), the hearing will proceed to consideration of whether, and the extent to which, additional issues as set forth below will be heard

A. Entergy's Burden of Proof.

250. Consistent with the admitted contention and the Board's September 23, 2010 Order, it is Entergy's burden to prove that its meteorological modeling adequately and reasonably satisfies NEPA, that "the meteorological patterns/concerns of concern to Pilgrim Watch, on its own, could [not] credibly alter the Pilgrim SAMA analysis," and, that "further analysis is [not] required. NRC Regulations are quite clear that it is the applicant's burden to perform a site-specific appropriate SAMA analysis. 10 C.F.R § 2.325. We find that the analysis Entergy has so far performed is not sufficient, that Entergy has not met its burden, and that Entergy's license cannot properly be renewed on the basis of the record before us.

251. Entergy bears the ultimate burden of proving, by a preponderance of the evidence, that it is entitled to an extension of its operating license. Metropolitan Edison Co. (Three Mile Island Nuclear Station, Unit 1), ALAB-697, 16 NRC 1265, 1271 (1982), citing, 10 C.F.R. § 2.325 (formerly § 2.732). This is also true for a Part 2, Subpart K proceeding. Carolina Power & Light Co. (Shearon Harris Nuclear Power Plant), LBP-00-12, 51 NRC 247, 254-55 (2000). An intervener such as Pilgrim Watch must give some basis for requiring further inquiry, and PW has done so here. Three Mile Island, supra, 16 NRC at 1271.

252. The issues raised under Contention 3 are safety issues on which an applicant carries the burden of proof. Duke Power Co. (Catawba Nuclear station, Units 1 and 2), CLI-83-19, 17

NRC 1041, 1048 (1983), citing, Consumers Power Co. (Midland Plant, Units 1 and 2), ALAB-283, 2 NRC 11, 17 (1975).

253. Pilgrim Watch has shown that there are significant deficiencies in the meteorological model used by Entergy, and thus in Entergy's sensitivity analyses. Pilgrim Watch having done so, it is Entergy's burden to provide a sufficient rebuttal to satisfy the Board that it should reject Pilgrim Watch's contention. (Waterford steam Electric station, Unit 3), ALAB-732, 17 NRC 1076, 1093 (1983), citing, Consumers Power Co. (Midland Plant, Units 1 and 2), ALAB-123, 6 AEC 331, 345 (1973); Louisiana Power and Light Co. (Waterford steam Electric station, Unit 3), ALAB-812, 22 NRC 5, 56 (1985). See Consumers Power Co. (Midland Plant, Units 1 and 2), ALAB-315, 3 NRC 101, 103 (1976); General Public Utilities Nuclear Corp. (Three Mile Island Nuclear station, Unit 2), ALAB-926, 31 NRC 1, 15-16 (1990).

254. Although "[a]n intervenor must come forward with sufficient evidence to require reasonable minds to inquire further. (Seabrook, supra, 17 NRC at 589.) (NRC Rules and Practices, pg., 69); under Commission practice, the applicant for a construction permit or operating license always has the ultimate burden of proof. 10 C.F.R. § 2.325 (formerly § 2.732).

255. Entergy has not shown that its meteorological modeling adequately and reasonably satisfies NEPA, or that "the meteorological patterns/concerns of concern to Pilgrim Watch, on its own, could [not] credibly alter the Pilgrim SAMA analysis," The fact that Entergy has not performed a sufficient analysis, and "further analysis is required," could result in "a difference in outcome of the licensing proceeding" (See *In the Matter of Dominion Nuclear Connecticut,*

Inc. (Millstone Nuclear Power Station, Units 2 and 3) Docket Nos. 50-336-LR, 50-423-LR ASLBP No. 04-824-01-LR July 28, 2004, p. 7). Difference in outcome is the standard of "material." *Duke Energy Corp.,*(McGuire Nuclear Station, Units 1 and 2; Catawba Nuclear Station, Units 1 and 2), CLI-02-17, 56 NRC(2002).

256. In *Duke Entergy,* the Board said "if 'further analysis' is called for, that in itself is a valid and meaningful remedy under NEPA." (cited in PW Motion to Intervene, p. 48-49, emphasis added).

257. The Board in *Duke Energy* also said that "While NEPA does not require agencies to select particular options, it is intended to 'foster both informed decision making and informed public participation, and thus to ensure the agency does not act upon incomplete information, only to regret its decision after it is too late to correct" *(citing Louisiana Energy Services* (Claiborne Enrichment Center), CLI-98-3, 47 NRC 77,88 (1998) emphasis added. Entergy's current analysis is "incomplete information," and the Board will require further analysis to insure that it will not "regret its decision after it is too late to correct.")

B. Pilgrim Watch's Burden

258. It is not PW's burden to redo the SAMA analysis using variable trajectory models that Entergy should have used, or to run the number of "scenarios" comparing different models that would be required to provide precise costs.

259. "A petitioner is not required to redo a SAMA analyses in order to raise a material issue" [In re Entergy Nuclear Operations, ASLBP No. 07-858-03-LR, BD01, Order of July 31, 2008, at 79].

260. Where a petitioner alleges that, although a SAMA was done ,the Applicant's analysis was significantly flawed due to the use of inaccurate factual assumptions, that is enough to support a contention that "further analysis is required." Entergy Nuclear Operations, Inc. (Indian Point, Units 2 and 3), LBP-08-13, 68 NRC 43, 102 (2008). (NRC Practices, General Matter, pg., 581)

C. NEPA's "Rule of Reason"

261. The admitted contention obliged PW only to show that "further analysis is required" and the under NEPA's rule of reason it would be reasonable to require Entergy to conduct that further analysis using an appropriate variable plume model. Pilgrim Watch has done so.

262. [C]computational time should not be a major factor in the choice of dispersion model for use in non- real-time applications." [PWA00001, Egan, 13 in response O'Kula Item 15].

263. Numerous variable plume models currently exist and reasonably could have been used by Entergy. NRC Staff expert, Dr. Bixler, [PWA00017, Affidavit Of Joseph A. Jones And Dr. Nathan Bixler Concerning Entergy's Motion For Summary Disposition Of Pilgrim Watch Contention 3, June 25, 2007 Prepared For The NRC Staff, (NEB, 7)] agrees that although "the effort to perform a multi-weather station consequences analysis is significantly greater than the

efforts to perform a similar analysis with MACCS2… such multi-state analyses have been and continue to be performed…"

264. Because Entergy failed to run a variable model to compare against its straight-line model, it has failed to prevail on the threshold issue dispute, the modeling issue. **"**For an applicant to prevail on each factual issue, its position must be supported by a preponderance of the evidence. Pacific Gas and Electric Co. (Diablo Canyon Nuclear Power Plant, Units 1 and 2), ALAB-763, 19 NRC 571, 577 (1984), review declined, CLI-84-14, 20 NRC 285 (1984); Philadelphia Electric Co. (Limerick Generating Station, Units 1 and 2), ALAB-819, 22 NRC 681, 720 (1985). See Tennessee Valley Authority (Hartsville Nuclear Plant, Units 1A, 2A, 1B, and 2B), ALAB-463, 7 NRC 341, 360 (1978), reconsideration denied, ALAB-467, 7 NRC 459 (1978); Duke Power Co. (Catawba Nuclear Station, Units 1 and 2), ALAB-355, 4 NRC 397, 405 n.19 (1976)." (NRC Rules and Practices, pg., Page 373)

265. Pilgrim Watch's expert testimony that Entergy's analysis was deficient, that "'further analysis is required," and that requiring further analysis using a variable plume model meets NEPA's Rule of reason, was fully admissible. "In order for (Pilgrim Watch's) expert testimony to be admissible, it need only (1) assist the trier of fact, and (2) be rendered by a properly qualified witness. Louisiana Power and Light Co. (Waterford Steam Electric Station, Unit 3), ALAB-732, 17 NRC 1076, 1091 (1983). See Fed. R. Evid. 702; Duke Power Co. (William B. McGuire Nuclear Station, Units 1 and 2), ALAB-669, 15 NRC 453, 475 (1982); Philadelphia Electric Co. (Limerick Generating Station, Units 1 and 2), ALAB-808, 21 NRC 1595, 1602 (1985). Page 378

266. In addition Pilgrim Watch's expert relied upon scientific treatises and periodicals. "An expert may rely on scientific treatises and articles despite the fact that they are, by their very nature, hearsay. Illinois Power Co. (Clinton Power Station, Units 1 & 2), ALAB-340, 4 NRC 27 (1976). (NRC Practices, pg., 380)

267. Pilgrim Watch's evidence is also supported by government documents. "NRC adjudicatory boards may follow Rule 902 of the Federal Rules of Evidence, waiving the need for extrinsic evidence of authenticity as a precondition to admitting official government documents to allow into evidence government documents. Public Service Company of New Hampshire (Seabrook Station, Units 1 and 2), ALAB-520, 9 NRC 48, 49 (1979). NRC Rules and Practices, pg., 381)

D. Summary and Conclusion

268. Entergy has failed to satisfy its burden of proving that (a) "further analysis is [not] required," and (b) that "the meteorological patterns/concerns of concern to Pilgrim Watch, on its own, could [not] credibly alter the Pilgrim SAMA analysis."

269. The deficiencies in Entergy's model and sensitivity analyses show that many SAMAs could be cost effective if the defects in the analyses were addressed. In *Duke Energy Corp.*, at 13, the board said that ― [w]hile NEPA does not require agencies to select particular options, it is intended to foster both informed decision-making and informed public participation, and thus to ensure the agency does not act upon incomplete information, only to regret its decision after it is too late to correct' (*citing Louisiana Energy Services* (Claiborne Enrichment Center), CLI-98-

3, 47 NRC 77, 88 (1998)). It then said ―if further analysis‘ is called for, that in itself is a valid and meaningful remedy under NEPA.

270**.** As the Board suggested in *Vermont Yankee,* Entergy should conduct further analyses consistent with this decision, and provide the results of that further analysis to the Board and Pilgrim Watch. We will then entertain further briefing, and perhaps oral argument, to determine whether the results of the further investigation and analyses satisfy Entergy's burden.

Respectfully Submitted,

Signed Electronically

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