July 31, 2012

PILGRIM WATCH COMMENT REGARDING SECY-12-0110, CONSIDERATION OF ECONOMIC CONSEQUENCES WITHIN THE NRC'S REGULATORY FRAMEWORK

Pilgrim Watch (hereinafter "PW") provides comment regarding meteorology discussed at the July 29, 2013 public meeting to assist in the staff's development of recommendations for the NRC Commission.

METEOROLOGY- PLUME MODELS

A. COMPARISON TRANSPORT MODELS- CONSERVATISM GAUSSIAN PLUME MODEL

The only fair comparison of transport models is to compare a straight line Gaussian model with an advanced variable model in complex terrains. This was not done in Pilgrim's LRA referred to in SECY-12-0110, Enclosure 9. PW did not have the funds to conduct the study and Entergy chose not to make that comparison.

Secy-12-0110, Enclosure 9, discusses MELCOR Accident Consequence Code System, Version 2 (MACCS2. It says at pages 2 referencing C.R. Molenkamp, N.E. Bixler, C.W. Morrow, J,V. Ransdell, Jr., J.A. Mitchell, "Comparison of Average Transport Model NUREG/CR-6853, October 2004.

> Previous Commission papers have indicated limitations associated with MACCS capability to evaluate land contamination and economic consequences. In SECY 00-0077, "Modifications to the Reactor Safety Goal Policy Statement," the staff considered whether a land contamination goal should be added to the safety goal policy but recommended against it. Part of the justification was that the current analytical tools have weaknesses in predicting land contamination and collective dose at significant distances. NRC staff continues to acknowledge that uncertainties increase for consequence projections at significant distances, but a 2004 benchmarking study provides increased confidence in the ATD model results from MACCS2 for distances out to 100 miles. The MACCS2 ATD model was compared against two Gaussian puff codes (Radiological Assessment System for Consequence AnaLysis (RASCAL) and Regional Atmospheric Transport Code for Hanford Emission Tracking (RATCHET)) and a Lagrangian particle tracking code (Lagrangian Operational Dispersion Integrator (LODI) from the National Atmospheric Release Advisory Center (NARAC)) [5]. The study showed that the MACCS2 mean results (over weather) were within a factor of 2 for arc-averages and a factor of 3 at a specific grid location out to 100 miles from the point of release.

And further (pages 2-3) say that:

> [economic consequence] cost are interrelated and depend on models for rehabilitation and clean up. There is some evidence that the models may be excessively conservative." It is not obvious to current MACCS2 experts at both the NRC and Sandia National Laboratories (SNL) that rehabilitation and clean up, land contamination area, or economic models and results are excessively conservative. Economic results and some land contamination area results are controlled by user inputs and could be biased to be either conservative or nonconservative, depending on the input values selected by the user. A MACCS2 user's guide and code manual is available for reference when deciding various parameter inputs [1]. Other land contamination areas produced by MACCS2 are influenced chiefly by the Gaussian plume and deposition modeling. Based on the 2004 benchmarking study, these values do not appear to have either a conservative or nonconservative bias. Current MACCS2 experts do note that a conservative result produced by the code is likely to be the peak centerline dose, due to the use of the Gaussian plume ATD model. This particular result is not used in current MACCS2 applications (such as cost-benefit analyses and SAMA analyses), which rely on the mean results out to 50 miles.
>
> Most recently, the Pilgrim nuclear power plant license renewal proceeding included a contention related to the SAMA analyses and the use of the MACCS2 code. The issue was whether the ATD model was adequate for the Pilgrim site, and whether a potential existed for underestimating offsite property damage. After the hearing in March 2011, the Atomic Safety and Licensing Board (ASLB) ruled that SAMA analyses and use of MACCS2 were adequate (NRC testimony available at [6] and [7]; final ASLB ruling available at [8]).

Reference 6 is to N.E. Bixler and S.T. Ghosh and later references likewise refer to the Pilgrim NPD License Renewal Application proceeding.

Pilgrim Watch was the petitioner in those proceedings; and we direct the staff to Pilgrim Watch Findings Fact and Conclusions of Law – SAMA Remand (ML110630442).

Conservatism

Pilgrim Watch Findings Fact and Conclusions of Law – SAMA Remand Section IV discusses the reasons why Entergy's SAMA Analyses is not conservative, and applies to other sites using ATMOS. Section IV pertains directly to the staff's interest in model-to-model comparisons and conservatism.

It reads:

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 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- Lewellen and Molenkamp

100. Entergy's experts cite two reports (Lewellen and Molenkamp[1]), 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:

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[1] 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. 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. 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. *If* the word conservative implies 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. 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. (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 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</u>. (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)

B. PILGRIM WATCH FINDINGS FACT CONCLUSIONS LAW – SAMA REMAND PILGRIM LRA- METEOROLOGY

Pertinent portions from Pilgrim's License Renewal Adjudication regarding meteorology have broad application to Option 2. They include the following:

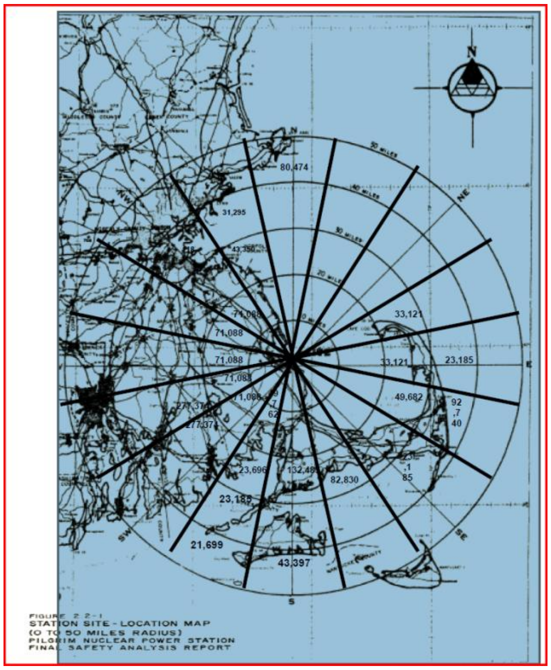
II. Meteorological Modeling Overview

13. What meteorological 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)

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 grid (FEIS 1972) ENT00004)

LRA, E-161 showing 1990 population per

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 Massachusetts 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.

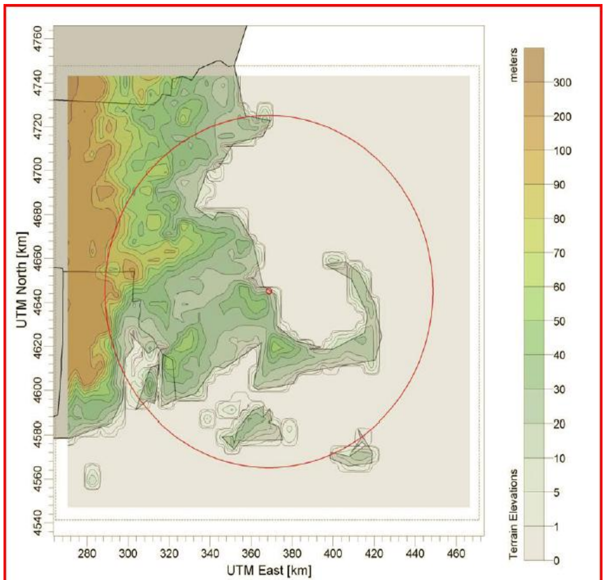


Figure 5. Terrain elevations in the CALMET modeling domain. The Pilgrim Station and the 50 mi radius circle around the Pilgrim Station are shown in red.

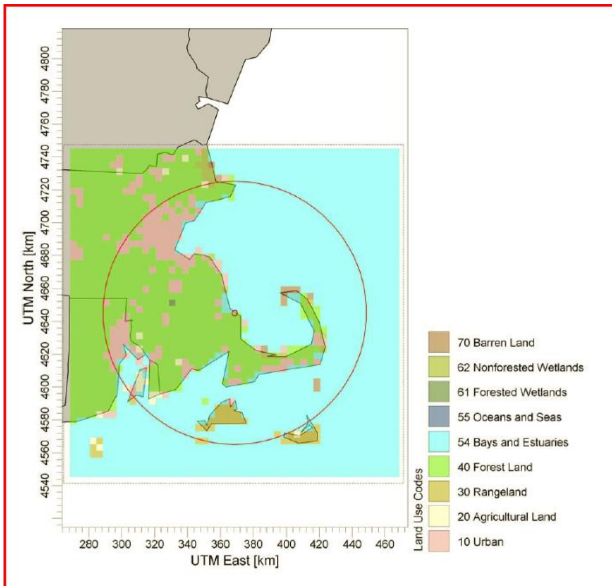


Figure 6. Land use categories in the CALMET modeling domain. The Pilgrim Station and the 50 mi radius circle around the Pilgrim Station are shown in red.

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 characteristics 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. It does not allow consideration for the fact that the winds for a given time period may be spatially varying. 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 constant 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 cannot "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 characterized by flat terrain.

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

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

> 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 community 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 year's 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 makes 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 variable 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, 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).

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

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, meteorological 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 single, on-site 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).

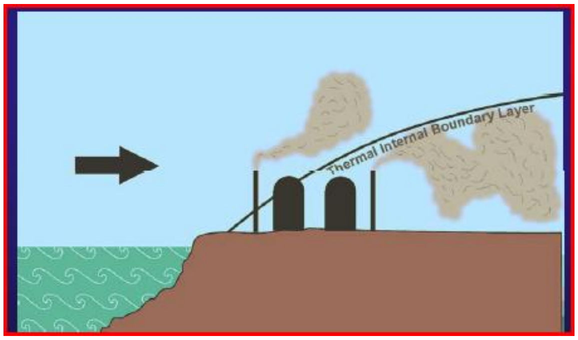
53. Climate change during license renewal is likely to increase the number of days sea breezes occur due to Global warming predictions.

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 is

known as the thermal internal boundary layer (TIBL). Because the air below the TIBL is unstable, there is turbulence 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.

Entergy'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, referring 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

[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]

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. (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])

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[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.

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

67. If <u>Angevine's research found this to be true for contaminants that result in smog then why would it not hold true for radionuclides</u>? 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

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[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

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 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

<u>Storms:</u>

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,

> [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

[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

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

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]

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

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

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.

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)

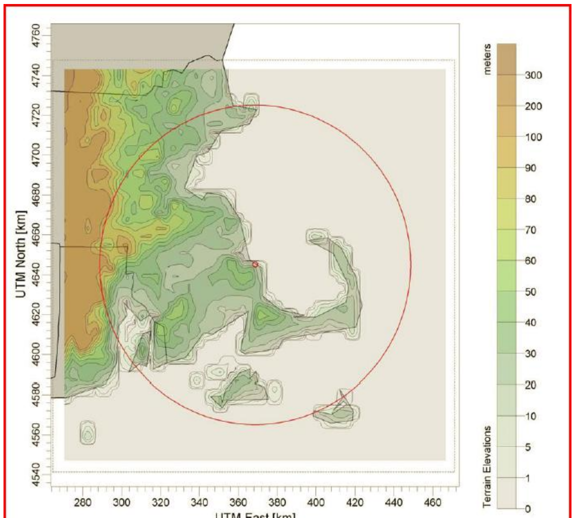

Figure 5. Terrain elevations in the CALMET modeling domain. The Pilgrim Station and the 50 mi radius circle around the Pilgrim Station are shown in red.

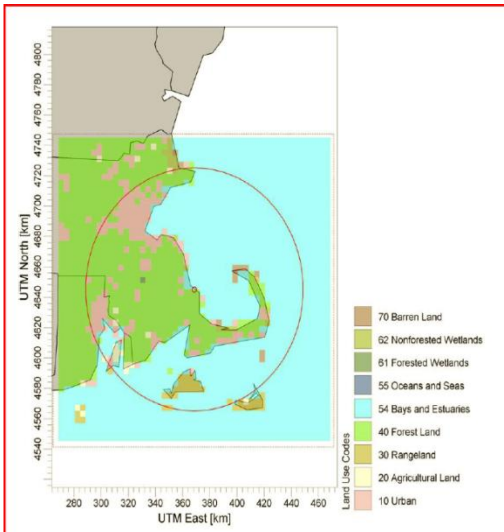

Figure 6. Land use categories in the CALMET modeling domain. The Pilgrim Station and the 50 mi radius circle around the Pilgrim Station are shown in red.

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,

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[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 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 meteorological 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

[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]

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)

C. HOW OTHER FEDERAL GOVERNMENT AGENCIES ASSESS ECONOMIC CONSEQUENCES- PLUME MODELS

Advanced variable plume models are preferred.

Staff was directed to determine how other federal agencies and governments assess economic consequences; part of the assessment would include plume models.

Meteorological Modeling: Government and Independent Studies

EPA has been a leader in advanced meteorological studies. Also other government and independent studies support that a straight line Gaussian plume model cannot account for the effects of complex terrain on the dispersion of pollutants from a source. Therefore the final Staff recommendation should make this clear to the Commission.

EPA

EPA recognized the need for complex models. For example: EPA's 2005 Guideline on Air Quality Models says in Section 7.2.8 *Inhomogenous Local Winds* that,

> In very rugged hilly or mountainous terrain, along coastlines, or near large land use variations, the characterization of the winds is a balance of various forces, such that the assumptions of steady-state straight line transport both in time and space are inappropriate. (Fed. Reg., 11/09/05).

EPA goes on to say that, "In special cases described, refined trajectory air quality models can be applied in a case-by-case basis for air quality estimates for such complex non-steady-state meteorological conditions." This EPA Guideline also references an EPA 2000 report, *Meteorological Monitoring Guidance for Regulatory Model Applications*, EPA-454/R-99-005, February 2000. Section 3.4 of this Guidance for coastal locations, discusses the need for

multiple inland meteorological monitoring sites, with the monitored parameters dictated by the data input needs of particular air quality models.

Most important, EPA's November 2005 Modeling Guideline (Appendix A to Appendix W) lists EPA's "preferred models" and the use of straight line Gaussian plume model, called ATMOS, is not listed. Sections 6.1 and 6.2.3 discuss that the Gaussian model is not capable of modeling beyond 50 km (32 miles) and the basis for EPA to recommend CALPUFF, a non - straight line model.[12]

NRC

Since the 1970s, the USNRC too has historically documented advanced modeling technique concepts and potential need for multiple meteorological towers appropriately located in offsite communities, especially in coastal site regions. But ignored implementing its' own advice.

In 2009, the NRC made a presentation to the National Radiological Emergency Planning Conference;[13] and although it was focused on emergency planning, the content is equally relevant to meteorological modeling for consequence analysis. The presentation concluded that the straight-line Gaussian plume models cannot accurately predict dispersion in a complex terrain and are therefore scientifically defective for that purpose [full presentation is available at ML091050226, ML091050257, and ML091050269 (page references used here refer to the portion attached, Part 2, ML091050257). Exhibit 19

Most reactors, if not all, are located in complex terrains, including Pilgrim. In the presentation, NRC said that the "most limiting aspect" of the basic Gaussian Model, is its "inability to evaluate spatial and temporal differences in model inputs" [Slide 28]. Spatial refers to the ability to represent impacts on the plume after releases from the site e.g., plume bending to follow a river valley or sea breeze circulation. Temporal refers to the ability of the model to reflect data changes over time, e.g., change in release rate and meteorology [Slide 4].

[12] http://www.epa.gov/scram001/guidance/guide/appw_05.pdf

[13] What's in the Black Box Known as Emergency Dose Assessment (ML091050226), 2. Dispersion (ML091050257), 3. Dose Calculation (ML091050269), 2009 National Radiological Emergency Planning Conference, Stephen F. LaVie

Because the basic Gaussian model is non-spatial, it cannot account for the effect of terrain on the trajectory of the plume – that is, the plume is assumed to travel in a straight line regardless of the surrounding terrain. Therefore, it cannot, for example, "'curve' a plume around mountains or follow a river valley." NRC 2009 Presentation, Slide 33. Entergy acknowledges that within 50-miles from Pilgrim there are hills and river valleys. Further it cannot account for transport and diffusion in coastal sites subject to the sea breeze. Sea breeze also applies to any other large bodies of water. The sea breeze causes the plume to change direction caused by differences in temperature of the air above the water versus that above the land after sunrise. If the regional wind flow is light, a circulation will be established between the two air masses. At night, the land cools faster, and a reverse circulation (weak) may occur [Slide 43]. Turbulence causes the plume to be drawn to ground level [Slide 44].

The presentation goes on to say that, "Additional meteorological towers may be necessary to adequately model sea breeze sites" [Slide 40].

Significantly, the NRC 2009 Presentation then discussed the methods of more advanced models that *can* address terrain impact on plume transport, including models in which emissions from a source are released as a series of puffs, each of which can be carried separately by the wind, (NRC 2009 Presentation Slides 35, 36). This modeling method is similar to CALPUFF. Licensees are not required, however, to use these models in order to more accurately predict where the plume will travel to base either consequence analyses or protective action recommendations.

The NRC recognized as early as 1977 that complex terrain presented special problems that a model must address if the air dispersion analysis is to be accurate.[14] For example: NRC, Regulatory Guide 1.111, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors* (July 1977) (Draft for Comment) says that, "Geographic features such as hills, valleys, and large bodies of water *greatly* influence dispersion and airflow patterns. Surface roughness, including vegetative cover, affects the degree of turbulent mixing." (Emphasis added).

[14] Ibid

This is not new information; knowledge of the inappropriateness of straight-line Gaussian plume in at complex sites goes back a long way within NRC. For example:

1972: 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."

1977: NRC began to question the feasibility of using straight line Gaussian plume models for complex terrain. *See* U.S.NRC, 1977, Draft for Comment Reg. Guide 1.111 at 1c (pages 1.111-9 to 1.111-10)

1983: In January 1983, NRC Guidance [**NUREG-0737, Supplement 1 "Clarification of TMI Action Plan Requirements," January 1983 Regulatory Guide 1.97- Application to Emergency Response Facilities; 6.1 Requirements],** suggested that changes in on-site meteorological monitoring systems would be warranted if they have not provided a reliable indication of monitoring conditions that are representative within the 10-mile plume exposure EPZ.

1996: The NRC acknowledged the inadequacy of simple straight-line Gaussian plume models to predict air transport and dispersion of a pollutant released from a source in a complex terrain when it issued RTM-96, *Response Technical Manual,* which contains simple methods for estimating possible consequences of various radiological accidents. In the glossary of that document, the NRC's definition of "Gaussian plume dispersion model" states that such models have important limitations, including the inability to "deal well with complex terrain." NUREG/BR-0150, Vol.1 Rev.4, Section Q; ADAMS Accession Number ML062560259,

2004: A NRC research paper, *Comparison of Average Transport and Dispersion Among a Gaussian, A Two- Dimensional and a Three-Dimensional Model*, Lawrence Livermore National Laboratory, October, 2004 at 2. ("Livermore Report") had an important caveat added to the Report's summary about the scientific reliability of the use of a straight-line Gaussian model in complex terrains:

> . . . [T]his study was performed in an area with smooth or favorable terrain and persistent winds although with structure in the form of low-level nocturnal jets and severe storms. In regions with *complex terrain*, particularly if the surface wind

direction changes with height, *caution should be used.* Livermore Report at 72 (Emphasis added)

2005: In December, 2005, as part of a cooperative program between the governments of the United States and Russia to improve the safety of nuclear power plants designed and built by the former Soviet Union, the NRC issued a Procedures Guide for a Probabilistic Risk, related to a Russian Nuclear Power Station. The Guide, prepared by the Brookhaven National Laboratory and NRC staff, explained that atmospheric transport of released material is carried out assuming Gaussian plume dispersion, which is "generally valid for flat terrain." However, the Guide the caveat that in "specific cases of plant location, such as, for example, a mountainous area or a valley, more detailed dispersion models may have to be considered." *Kalinin VVER-1000 Nuclear power Station Unit 1 PRA, Procedures Guide for a Probabilistic Risk Assessment*, NUREG/CR- 6572, Rev. 1 at 3-114; excerpt attached as Exhibit 8, full report available at http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6572. Exhibit 20

2007: NRC revised their Regulatory Guide 1.23, Meteorological Monitoring Programs for Nuclear Power Plants. On page 11, the section entitled *Special Considerations for Complex Terrain Sites* says that, "At some sites, because of complex flow patterns in nonuniform terrain, additional wind and temperature instrumentation and more comprehensive programs may be necessary. For example, the representation of circulation for a hill-valley complex or a site near a large body of water may need additional measuring points to determine airflow patterns and spatial variations of atmospheric stability. Occasionally, the unique diffusion characteristics of a particular site may also warrant the use of special meteorological instrumentation and/or studies. The plant's operational meteorological monitoring program should provide an adequate basis for atmospheric transport and diffusion estimates within the plume exposure emergency planning zone [i.e., within approximately 16 kilometers" (10 miles)].[15]

These excerpts from Regulatory Guide 1.23 demonstrate that the NRC recognizes there are certain sites, such as those located in coastal areas, like Pilgrim, that multiple meteorological data input sources are needed for appropriate air dispersion modeling. Not simply one or two meteorological towers onsite. Since the straight-line Gaussian plume model is incapable of

[15] For example, if the comparison of the primary and supplemental meteorological systems indicates convergence in a lake breeze setting, then a "keyhole" protective action recommendation (e.g., evacuating a 2-mile radius)

handling complex flow patterns and meteorological data input from multiple locations, Regulatory Guide 1.23 demonstrates NRC's recognition that it should not be used at any site with complex terrain.

DOE

DOE, too, recognizes the limitations of the straight-line Gaussian plume model. They say for example that Gaussian models are inherently flat-earth models, and perform best over regions of transport where there is minimal variation in terrain. Because of this, there is inherent conservatism (and simplicity) if the environs have a significant nearby buildings, tall vegetation, or grade variations not taken into account in the dispersion parameterization.[16]

National Research Council

Tracking and Predicting The Atmospheric Dispersion of Hazardous Material Releases Implications for Homeland Security, Committee on the Atmospheric Dispersion of Hazardous Material Releases Board on Atmospheric Sciences and Climate Division on Earth and Life Studies, National Research Council of the National Academies, 2003. The report discusses how the analytical Gaussian models were used in the 1960s and tested against limited field experiments in flat terrain areas performed in earlier decades.

In the 1970s the US passed the Clean Air Act which required the use of dispersion models to estimate the air quality impacts of emissions sources for comparison to regulatory limits. This resulted in the development and testing of advanced models for applications in complex terrain settings such as in mountainous or coastal areas. In the 1980s, further advances were made with Lagrangian puff models and with Eulerian grid models. Gaussian models moved beyond the simple use of sets of dispersion coefficients to incorporate Monin-Obukhov and other boundary layer similarity measures which are the basis of contemporary EPA models used for both short range and long range transport applications. Helped enormously by advances in computer technologies, in the 1990s, significant advances were made in numerical weather prediction models and also further improve dispersion models through the incorporation of field experiment results and improved boundary layer parameterization. The decade starting with the

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

year 2000 has seen improved resolution of meteorological models such as MM5 and the routine linkage of meteorological models with transport and dispersion models as exemplified by the real time forecasts of detailed fine grid weather conditions available to the public at Olympic events. Computational Fluid Dynamics (CFD) models which involve very fine grid numerical simulations of turbulence and fluid flow began to see applications in atmospheric dispersion studies. The next decade will see routine application of CFD techniques to complex flows associated with emergency response needs.

The nuclear industry does not show evidence of keeping up with these technological advances. For use in modeling air quality concentrations, the NRC uses straight-line Gaussian dispersion algorithms that date back to the 1960s. EPA should, but does not, advocate in the draft keeping up with these technological advances. Complex flow situations such as those associated with flow around high terrain features or that would incorporate sea breeze circulations are not simulated. For emergency response applications, the EPA, unlike NRC, should be advocate of advanced modeling to be installed at nuclear power plants.

Atmospheric Scientists & Meteorologists

For over three decades atmospheric scientists and meteorologists have been identifying problems in the use of models similar to ATMOS for such settings. Example: Steven R. Hanna, Gary A. Briggs, Rayford P. Hosker, Jr., National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Laboratory, *Handbook on Atmospheric Diffusion* (1982)).

The inability of a simple Gaussian plume model to accurately predict air transport and dispersion in complex terrains is such a basic flaw that it is discussed in a textbook for a college-level introductory course in environmental science and engineering (Steven R. Hanna, Gary A. Briggs, Rayford P. Hosker, Jr., National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Laboratory, *Handbook on Atmospheric Diffusion* (1982)). (Chapter 13 authored by William J. Moroz). In listing the assumptions that are made to develop a simple straight line Gaussian plume model, the textbook warns that:

The equation is to be used over relatively flat, homogeneous terrain. It should not be used routinely in coastal or mountainous areas, in any area where building profiles are highly

irregular, or where the plume travels over warm bare soil and then over colder snow or ice covered surfaces

We also direct you to the State of New York Indian Point LRA, Declaration Dr. Bruce Egan and attachments: NRC Electronic Library, Accession numbers: ML092610910, Ml 092940754, Ml 100150122, ML 100150111 EIS IP, Ml092610910, Ml092610912, Ml 092640223, Ml092640221, Ml091050257, Ml092640169, Ml092640173, Ml062640170, Ml092640171, Ml092640172, Ml092640174, Ml092640175, Ml092640177, and Ml092640178

Thank you for your consideration,

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