IPRenewal NPEmails

From:	Jones, Joe A [jojones@sandia.gov]
Sent:	Monday, February 08, 2010 4:14 PM
To:	Stuyvenberg, Andrew
Cc:	Palla, Robert; Grenier, Bernard; Ghosh, Tina
Subject:	Indian Point Task I Report - Deliverable
Attachments:	IP Task 1 Report 1 8 10.doc

Drew,
Sandia has completed the Indian Point Technical Report - Task I deliverable and submitted the final draft to Bob Palla on January 8, 2010. Sections of the report were developed and discussed with NRC prior to the submittal, and the final draft was submitted in January, after we had received the updated MACCS2 calculations which had been recomputed to address the meteorological data changes.

We submitted the deliverable in January directly to Bob Palla; however, I had not formally distributed this to the project team. Please accept this as the formal distribution.

Thank you,
Joe

Hearing Identifier: IndianPointUnits2and3NonPublic_EX
Email Number: 1982

Mail Envelope Properties (6CB822B6A99D04468CFA4F3B294B373B841204E33B)

Subject: Indian Point Task I Report - Deliverable
Sent Date: 2/8/2010 4:14:15 PM
Received Date: 2/8/2010 4:14:31 PM
From: Jones, Joe A

Created By: jojones@sandia.gov

Recipients:
"Palla, Robert" <Robert.Palla@nrc.gov>
Tracking Status: None
"Grenier, Bernard" <Bernard.Grenier@nrc.gov>
Tracking Status: None
"Ghosh, Tina" <Tina.Ghosh@nrc.gov>
Tracking Status: None
"Stuyvenberg, Andrew" <Andrew.Stuyvenberg@nrc.gov>
Tracking Status: None

Post Office: ES03SNLNT.srn.sandia.gov

Files	Size	Date & Time
MESSAGE	615	2/8/2010 4:14:31 PM
IP Task 1 Report 1 8 10.doc	172096	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

PREDECISIONAL DRAFT
January 8, 2010

Technical Assistance in Support of the Indian Point Units 2 and 3 License Renewal

Initial Assessment - Technical Review

PREDECISIONAL DRAFT

1.0 Introduction

On July 31, 2008, the Atomic Safety and Licensing Board ("Board") admitted two contentions by New York State (NYS) regarding the Severe Accident Mitigation Alternative (SAMA) analysis required by 10CFR 51.53(c)(3)(ii)(L) as part of the Environmental Report for license renewal. Sandia National Laboratories has performed an initial assessment to understand the potential impacts of the issues raised and whether these could alter conclusions of the SAMA analysis.

Sandia reviewed the related documentation and the MACCS2 input files to understand the issues raised in the contentions and their potential impact on the conclusions of the SAMA analysis. The scope included review of MACCS2 code input in the following areas:

- projected population distribution,
- decontamination/cleanup costs,
- economic impacts,
- meteorology, and
- plume behavior.

An assessment of the separate effects and integral effect of the issues identified in each contention is provided.

2.0 Contentions 12/12A and 16/16A

The Board admitted contentions 12 and 16 by NYS regarding the SAMA analysis. The contentions state:

> **(NYS-12)** - Entergy's SAMAs for IP2 and IP3 do not accurately reflect decontamination and clean up costs associated with a severe accident because specific inputs and assumptions made in the MACCS2 code regarding decontamination and clean up costs may not be correct.
>
> **(NYS-16)** - The population projections used by Entergy are underestimated, the ATMOS module in MACCS2 is being used beyond its range of validity (beyond thirty-one miles), and use of MACCS2 with the ATMOS module leads to non-conservative geographical distribution of radioactive dose within a fifty-mile radius of Indian Point.

The decontamination/cleanup costs and economic impacts are discussed below with Contention 12/12A. The population, evacuation/relocation criteria, and plume behavior are discussed in the assessment of Contention 16/16A.

2.1 Contention 12/12A: Decontamination and Clean-up Costs

Contention 12/12A states that the SAMA analysis does not accurately reflect decontamination and clean up costs associated with a severe accident because specific inputs and assumptions made in the MACCS2 code regarding decontamination and clean up costs may not be correct. The contention argues that the particle sizes used in MACCS2 are too large and result in an underestimate of the decontamination costs.

The size of the particles released to the environment affect both the transport/deposition of particles and the cost-effectiveness of decontamination measures. The impact of particle size on transport/deposition is reflected in the MACCS2 code through a user input value for dry deposition velocity. The impact of particle size on decontamination costs is reflected through the user input value for decontamination costs.

The code does not perform any internal computations to relate or adjust the decontamination cost value based on deposition velocity values, but does apply decontamination costs to areas that are contaminated. Therefore, if smaller particles travel to farther distances, the decontamination cost would be applied to these farther distances. To address the issue of whether the MACCS2 calculations performed by Entergy adequately captured these costs, the inputs and assumptions regarding particle size distribution and decontamination costs used in the SAMA analysis were reviewed.

The contention states that the MACCS2 cost calculation subroutine relies on an assumption that the dispersion will consist of large-sized radionuclide particles [12]. NYS defines large-sized particles in Contention 12A as ranging in size from "tens to hundreds of microns" [7, 12], and defines small particles as ranging in size from "a fraction of a micron to a few microns" referencing the study "Site Restoration: Estimation of Attributable Costs from Plutonium-Dispersal Accidents," [7]. NYS contends that the size of the particles dispersed from a severe accident at Indian Point would be smaller than considered in MACCS2, and that the MACCS2 cost calculations subroutine does not take into account additional costs that would be incurred in decontaminating a suburban/urban area such as the one that exists within the 50-mile EPZ around Indian Point because it will be more expensive to decontaminate and clean up a suburban/urban area in which small-sized radionuclide particles have been dispersed [12]. NYS contends that large-sized radionuclide particles are easier and less expensive to remove and clean up than small-sized radionuclide particles, and conversely, it will be more expensive to decontaminate and clean up a suburban/urban area in which small-sized radionuclide particles have been dispersed [12].

MACCS2 represents particle size by allowing a distribution of dry deposition velocities. The deposition velocity is a function of particle size and affects the dispersion of contaminants. Sandia first evaluated the aerosol deposition values used in the Entergy MACCS2 input files (atmbi2NS.inp and atmbi3NS.inp). A single value of 0.01 m/s was used for the dry deposition velocity of all aerosol particles. An analysis of the particle size associated with a 0.01 m/s deposition velocity can be performed applying Stokes' Law to estimate the gravitational settling velocity of small spheres in dilute laminar flow fluids.

$$w = \frac{2(\rho_p - \rho_f)gr^2}{9\mu}$$

w= settling velocity (m/s)
ρ_p = particle density (2 g/cm^3)[1]
ρ_f = fluid density (1.2×10^{-3} g/cm^3 for air at 25°C)[1]
g= gravitational acceleration = 9.80665 m/s^2
μ= dynamic fluid viscosity = 1.85×10^{-2} g/m s
r=particle radius

[1] page F-230 of the CRC Handbook of Chemistry and Physics, 53rd ed., (1972), "Characteristics of Particles and Particle Dispersoids" provides a scale for calculating terminal gravitational settling velocity for spheres having a specific gravity of 2 g/cm^3 in air at 1 atmosphere and 25C.

For r in meters, settling velocity in meters/second is given by:
$w = 1.17x10^{+8} r^2$, or for r in units of microns, $w = 1.17x10^{-4} r^2$ m/s

Solving for r (particle radius) gives

$$r = \sqrt{\frac{w}{1.17x10^{-4}}} = 92.45\sqrt{w}$$

A 1 m/s settling velocity corresponds to a particle of radius approximately 100 microns, and a 0.01 m/s velocity corresponds to a particle radius of 10 microns. At 10 microns, gravitational settling is the dominant mechanism for deposition, so this is a reasonable estimate for the particle size corresponding to a 0.01 m/s deposition velocity.

The above calculation demonstrates that a 0.01 m/s settling velocity corresponds to approximately a 10 micron radius particle. The deposition velocity more likely corresponds to about a 5 micron radius particle because of particle density, which may be higher than the 2 g/cm^3 assumed in the above derivation; therefore, it may be concluded that the particle size used in the SAMA analyses is a 5 to 10 micron radius.

Particle sizes of 10 microns do not meet the definition of large-size particles which NYS describes as "tens to hundreds of microns." The above calculation demonstrates:

- The MACCS2 dispersion does not include an assumption that the dispersion will consist of large-sized radionuclide particles as NYS contends.
- The MACCS2 input parameter for dry deposition velocity is consistent with small-sized particles. Therefore, contamination dispersed by the MACCS2 model does include small particles which, as NYS asserts, are more likely to have traveled into the populous areas farther away from the plant.

Next, Sandia reviewed the decontamination cost parameters used in the SAMA analysis. A comparison of the Indian Point Units 2 and 3 values and those in the MACCS2 Sample Problem A are shown below. Sample Problem A is provided to users of the MACCS2 model with populated parameters primarily developed for the Surry plant analysis in NUREG 1150 [15] and represent best estimate information for that site and time.

Parameter	Entergy	Sample Problem A
Decontamination worker labor cost ($/man-yr)	60,480	35,000
Emergency phase cost of evacuation/relocation ($/person-day)	46.7	27.0
Per capita cost of long-term relocation ($/person)	8,640	5,000
Relocation cost per person-day ($/person-day)	46.7	27.0
Value of farm wealth ($/hectare)	50,071	2,613
Value of non-farm wealth ($/person)	208,838	84,000
Farmland decontamination cost ($/hectare)	972	562.5
[2 decontamination levels]	2,160	1,250.
Non-farmland decontamination cost ($/person)	5,184	3,000
[2 decontamination levels]	13,824	8,000

With the exception of farm and non-farm wealth, Entergy values are higher than Sample Problem A values typically by a factor of 1.7. Farm and non-farm values for Indian Point 2/3 were based on site specific data and not extrapolated from Sample Problem A. As described in the Environmental Report, the values were obtained by adjusting the generic Sample Problem A economic data with the consumer price index of 195.3 [14, page E.3-83], which was the average inflation between 1986 and 2005[5].

The Volume I, "Site Specific MACCS2 Input Data for Indian Point Energy Center," [4] Table 6.2, "Percent Farmland Devoted to Crop Categories," identifies that most counties within the SAMA area consist of less than one percent farmland. Therefore, the more important parameter of interest in the decontamination cost for this area is non-farm land. If the cost of decontamination exceeds the value of non-farm wealth, then land is assumed condemned and the value of the property is the maximum cost applied. As indicated above, the value used for non-farm wealth was $208,838 per person and includes the value of lost business and tourism [5]. The total population value used by Entergy in the SAMA analysis was 19,228,712 [4]. The non-farm wealth is expressed on a per capita basis, thus the high population within the Indian Point area would result in a very high cost of decontamination when expressed on a cost per square kilometer basis.

Clean Up Costs

NYS suggests that in place of the 'outdated' decontamination cost figure used by Indian Point as input to the MACCS2 code, three reports should be used to determine the present and future value of decontamination for the area within 50-miles of the plant [12]:

1) Site Restoration: Estimation of Attributable Costs from Plutonium-Dispersal Accidents [7];

2) "Damages from a Major Release of Cs137 into the Atmosphere of the United States." Science and global Security, 12:125-136, [9]; and

3) "Chernobyl on the Hudson? The Health and Economic Impacts of a Terrorist Attack at the Indian Point Nuclear Power Plant" [10].

In review of Beyae, et al [9], it is clearly stated that "decontamination cost estimates are based primarily on the results of the Site Restoration study." A review of Lyman [10] also shows that the cost model in the analysis utilized the results of the Site Restoration [7] study. The suggestion by NYS that these 3 studies be used in the cost analysis can be viewed simply as a suggestion that the methodology in the Site Restoration study be used in establishing decontamination values for input to MACCS2.

To understand whether use of the Site Restoration study methodology to estimate decontamination costs would impact the results of the SAMA analysis, a review of the study was completed. The study [7] does present a detailed evaluation of the cost of cleanup of a nuclear weapons facility accident and describes the methodology applied in the estimation, but as indicated within the study, it is not representative of sites similar to Indian Point.

As stated in the study, the methodology was applied to a 1) mixed-use urban areas at average population density; 2) Midwest farmland; 3) western rangeland; and 4) forested land (pg. 6-1). For the mixed-use urban areas, Section 6.1 "Simplifying Assumptions in Cost Estimates" [7, pg. 6-2], provides a key assumption stating "The cost estimates for mixed-use urban land do not include downtown business and commercial districts, heavy industrial areas, or high-rise apartment buildings." New York City, in the outer areas of the SAMA analysis consists of downtown business, commercial districts, heavy industrial areas, and high-rise apartment buildings. Thus, the methodology used in the Site Restoration study does not directly address the urban areas of interest to this SAMA analysis.

The conclusions state on page 7-2 that "an important consideration for accidents postulated to occur in urban areas is the influence of local meteorology. In the presence of large buildings and trees, deposition can become localized, decreasing the size of the affected area." However, the study does not address urban areas and presents no methodology to do so. The study also concludes that the results show there are two major components of attributable costs: (1) compensation for acquired property and (2) decontamination and waste disposal. It states that both of these components of cost are uncertain to possibly a large degree and as a result of these uncertainties, "it is not possible to identify the major cost component with any confidence" (page 7-2). Study conclusions also state (page 7-3) there were many types of costs that were difficult to quantify and thus omitted from the analysis. In summary, the study only applied the methodology to urban areas that are not similar to the SAMA analysis area; identified that major cost components are not possible to identify with any confidence; and omitted costs that were difficult to quantify. As such, using the Site Restoration study as a basis for estimating decontamination costs resulting from a nuclear power plant accident at Indian Point would therefore not provide defensible or necessarily credible results.

Nonetheless, NYS has suggested that the cost estimating methodology of the Site Restoration Study be used for determining decontamination costs of a potential NPP accident. Although the methodology for clean up of a nuclear weapons accident is not relevant to clean up following a NPP accident, Sandia performed a comparison of the estimated cost using the Site Restoration Study. The approach to developing the cost comparison included identifying basic considerations of each type of accident (e.g., contaminants, half life of contaminants, health and safety, etc.), the decontamination methods required, and then comparing the Site Restoration Study cost values as applied for the urban area of New York City to those in Entergy's analysis. Each of the decontamination estimates is described below including characteristics of each type of accident.

- Site Restoration Study (Plutonium Dispersal Accident): The primary constituent in weapons grade plutonium is Pu239, which is an alpha emitter with a low gamma that can be difficult to characterize in the field. Field instruments are available for detection of the contaminant, but characterization and verification efforts can take longer and can be more expensive than for gamma emitters like Cs137. Pu239 is primarily an inhalation hazard with a half life of 24,000 years. As an inhalation hazard, many elements of response and decontamination are more difficult. The importance of evacuating the public is much greater with plutonium because if inhaled, the health consequences can be severe.

- NPP accident: The primary contaminant from an NPP accident would be cesium (Cs137), which is a gamma emitter. As a gamma emitter, characterization and verification efforts are more easily performed using hand-held field instrumentation. Cs137 is primarily an external health hazard but is also an internal hazard and has a half life of about 30 years. Evacuees should leave the area near the plant promptly, but shielding and distance from the source reduce the health and safety concerns.

Each study uses decontamination factors (DF) in the determination of decontamination cost. The Site Restoration study provides cost estimates for remediation of light contamination (DF=2 to 5), moderate contamination (DF=5-10), and heavy contamination (DF>10) [page 6-5]. MACCS2 allows for the use of 3 DFs. For the Indian Point analysis, 2 DFs were used: a DF of 3 and a DF of 15.

Appendix F of the Site Restoration study describes the decontamination methods for light, moderate, and heavy contamination as follows:

> Decontamination of lightly contaminated areas would include primarily non-destructive methods such as vacuuming, pressure washing, and scrubbing of contaminated surfaces. Areas of unoccupied land would have the vegetation removed and soil removed to an average of 10 cm. Clean soil would be used to replace the excavated areas.
>
> Decontamination of moderately contaminated areas would include removal of some roadway sections, planing and scraping of the remaining roadway sections and sealing or asphalt overlay of all roadways. Page F-17 identifies that it is conservatively assumed that 100 percent of streets would require planing and all streets would be resurfaced.
>
> For heavy contamination, [page F-18] the report states that streets would be torn up and above ground utilities removed. All land surfaces would be scraped to an average depth of 10 centimeters. Such demolition would be necessary because an area heavily contaminated with plutonium, which is an inhalation hazard with a long half life, cannot be left in place due to potential resuspension if the surfaces are disrupted.

For decontamination of Cs137, less costly options available rather than complete destruction and removal of infrastructure. Road surfaces contaminated with cesium could be planed or scraped just a few millimeters, using commercial equipment, to significantly reduce the radiation dose and could then be seal coated with asphalt. If needed a pavement overlay could be added, which is considerably cheaper than complete destruction. Such actions would reduce the dose to a low enough level to assure protection of public health and safety. Cs137 does present some risk from resuspension and inhalation, but because it is primarily a dose hazard, reducing the dose through scraping and placing a cover over the remaining contamination may be expected to be sufficient. The life expectancy of an asphalt roadway is more than 30 years, providing time for the remaining Cs137 to decay.

A pavement overlay could also be used to encapsulate the Pu239 to prevent disturbance or migration. However, anytime long-lived contamination is left in place, even if encapsulated, loss of control, which would result in a health hazard to the public, must be considered. It is reasonable to consider that control may be maintained for the life of a pavement surface (i.e., 30 years); however, it is not practical to assume that control could be maintained for the thousands of years the Pu239 would be present. Given the long term health hazard present from the Pu239, it is expected that decontamination efforts would be focused on complete removal, which is consistent with the Site Restoration study decontamination description for heavy contamination.

Considering the decontamination activities described above, the activities required to support decontamination of moderate plutonium contamination align more closely with decontamination activities for heavy decontamination of cesium.

Cost Comparison with the Site Restoration Study

A comparison of decontamination cost values used in Entergy's MACCS2 analysis and those in the Site Restoration study has been performed. The approach to developing the cost estimate is limited to urban areas because urban areas are more costly to decontaminate, and Table 6.2, Volume I [4] shows that farmland makes up a very small percentage of land area within the

SAMA area, with most counties identified as having less than 1 percent farmland. The small amount of farmland simplifies the cost comparison allowing the focus of the comparison to be on urban areas.

To further simplify the cost analysis and provide a comparison of the highest cost areas, the cost comparison was performed only for New York City, which includes five counties (the Bronx, Kings, New York, Queens, and Richmond). The total land area of New York City is 790 km^2, and the population is 9,511,380. In these areas, the total farm area identified for all counties except Richmond was zero percent. The total farm land for Richmond was identified as 0.01 percent in Table 6.2, Volume I [4]. Therefore all land is assumed to be urban.

The cost estimate was developed considering the decontamination factors described above. The Site Restoration study provides the following in Table 6-2 "Cleanup Costs for Expedited Decontamination of Urban Areas."

Light Contamination (DF=2-5): \$127.8 million/km^2.
Moderate Contamination (DF=5-10): \$178.4 million/km^2
Heavy Contamination (DF>10): \$398.4 million/km^2

As described above, the more appropriate comparison is the Moderate Contamination values. Because MACCS2 expresses decontamination costs for an urban area on a per capita basis, the Site Restoration study value of \$178.4 million/km^2 is converted into dollars per person.

First, establish the population density: 9,511,380 / 790 km^2 = 12,000 people/km^2

Next, divide the Site Restoration value of \$178.4 million/km^2 by the average population density to produce \$/person.

(\$178.4 million/km^2) / 12,000 people/km^2 = \$14,900 per person.

The MACCS2 input values used in Entergy's analysis are:

Decontamination costs for DF of 3 = \$5,184 per person.
Decontamination costs for DF of 15 = \$13,824 per person.

The comparison in common units of dollars per person shows that the Site Restoration cost of \$14,900 per person is very close to the value of \$13,824 per person used in the SAMA analysis. If the Site Restoration study values were escalated to 2005 dollars, as are the MACCS2 values used in the SAMA analysis, the difference would be greater, but would still be expected to be within a factor of about 2.

Other Cost Considerations
Advancements in technologies, economies of scale, and lessons learned have occurred in the last 15 or so years through large scale decontamination and demolition of many Department of Energy (DOE) sites. Section 7.0 of the study (page 7-1) acknowledges that technological advances in detection, decontamination, and treatment of waste to minimize volume could decrease costs in comparison to the provided estimates. However, the study does not include any potential savings from technological advances. As an example, in 2008, the Interstate Technology & Regulatory Council published the "Decontamination and Decommissioning of Radiologically Contaminated Facilities," [11] which is designed to help regulators and others develop a consistent approach to their evaluation, regulatory approval, and deployment of

specific technologies at specific sites. This document identifies cost savings through the use of decontamination technologies. The IRTC is a state-led, national coalition of personnel from the environmental regulatory agencies of all 50 states and the District of Columbia, three federal agencies, tribes, and public and industry stakeholders and is devoted to reducing barriers to, and speeding interstate deployment of better, more cost-effective, innovative environmental techniques [11]. Improved technologies and efficiencies such as these were not factored into the Site Restoration study which was published 10 years prior to the closure of the Fernald, Mound, and Rocky Flats.

In the 1990's, the Department of Energy (DOE) began many large-scale decontamination and closure projects that resulted in release of land for public use. The DOE Office of Environmental Management (EM) was responsible for D&D of a wide variety of facilities including cleanup and closure of Rocky Flats in Colorado, Mound and Fernald in Ohio, and many radiological facilities at Oak Ridge National Laboratories, Hanford, Sandia National Laboratories, Argonne National Laboratory, and other DOE sites comprising thousands of acres of decontaminated land. There continue to be a number of national technology development programs funded by agencies to provide effective, alternative decontamination methodologies [8]. The Defense Threat Reduction Agency (DTRA), the Defense Advanced Research Projects Agency (DARPA), Department of Homeland Security (DHS), and the Technology Support Working Group (TSWG), are just a few sponsors with multiple development programs in this area. DOE laboratories participate in these decontamination research programs and have amassed a vast amount of decontamination experience during decades of nuclear facility decontamination [8].

Contention 12/12A Summary

Contention 12/12A states that the SAMA analysis does not accurately reflect decontamination and clean up costs associated with a severe accident because specific inputs and assumptions made in the MACCS2 code regarding decontamination and clean up costs may not be correct. Sandia reviewed both the particle size and the decontamination cost values and made the following determinations:

- The particle size used in the SAMA analysis is consistent with the definition of small particle size as provided by NYS.
- The decontamination values used in the SAMA analysis were based on Sample Problem A values and were adjusted for inflation.
- The Site Restoration study recommended by NYS for use in determining decontamination costs is not applicable to a nuclear power plant accident.
- When comparing costs resulting from use of the Site Restoration study values, the SAMA results are within about a factor of 2.
- Cost saving factors and efficiencies in decontamination gained through technology advancements and lessons learned have not been factored into either the Site Restoration study or the SAMA analysis.

2.2 Contention 16/16 A: Population Distribution and Use of ATMOS

The Board limited the NYS Contention 16/16A to the following issues:

1. Whether the population projections used by Entergy are underestimated;
2. Whether the ATMOS module in MACCS2 is being used beyond its range of validity; and
3. Whether use of MACCS2 with the ATMOS module leads to non-conservative geographical distribution of radioactive dose within a fifty-mile radius.

2.2.1 Population Projections

In the "State of New York Contentions Concerning NRC Staff's Draft Supplemental Environmental Impact Statement," [12] footnote 4 on page 10 states that Entergy's projections of the 2035 population living within the 50 mile radius of Indian Point are suspect and underestimate the potential exposed population. NYS identifies that the Entergy 2035 projected population of 1,570,657 for Manhattan is less than the 2007 US Census estimate of 1,620,867 for Manhattan. Based on this difference in population for Manhattan, NYS asserts that the 2035 population within 50 miles used by Entergy is suspect [12].

To address whether population projections were underestimated, Sandia reviewed the county population values and total population values used by Entergy. Entergy obtained population estimates directly from State agency reports for periods ranging from 2000 to 2020 and 2000 to 2030, depending on the State data available [4]. Entergy projected total permanent populations to the year 2035 for 25 of the 28 counties that are within or encroach upon the limit of 50 miles from Indian Point using linear extrapolation. Entergy used areal weighting, which assumes a constant population distribution over the area assessed (i.e., in each of the 160 cells within the 16 sectors and radial rings representing the 50 mile radius surrounding the IP site), to establish fractional population within 50 miles of Indian Point. Entergy then adjusted this permanent population projection upward to account for the presence of the transient (tourist) population as estimated from available tourist information [4]. The results of the Entergy approach are summarized in Section 2.6.1 of Entergy LRA Appendix E, [14] with details on the approach provided in Volume 1, "Site Specific MACCS2 Input Data for Indian Point Energy Center" [4]. The response to SAMA RAI 4g states that SECPOP 2000 was not used in the analysis [5].

Entergy used polynomial regression for projecting the population for the remaining 3 counties including New York (Manhattan), Rockland, and Westchester counties. A polynomial regression appears to have been used for these counties because State data shows a decrease in the population of these counties as indicated in Volume 1, "Site Specific MACCS2 Input Data for Indian Point Energy Center," Table 2.1 "Population Projections (2035 Calculated from Table)" [4]. The population was projected by the State to increase for New York County from 2000 to 2020 and then decrease from 2020 to 2030 resulting in a peak in population at 2020. Because there is a peak within the projection period, Sandia agrees that use of a polynomial projection to the year 2035 is a more appropriate approach than a linear projection for these counties.

Sandia performed an independent assessment of the population data within a 50-mile radius of Indian Point. First, SECPOP2000 was used to estimate the population based on 2000 US Census Bureau data. The population for the year 2000 estimated by SECPOP2000 is 16,800,272; this compares very closely with Entergy's year 2000 estimate of the permanent population within the 50-mile radius, which is 16,914,178. Entergy projected the permanent population out to 2035 to be 18,879,657, an increase of 12.43%. The population Entergy used in their SAMA analysis was 19,228,714, which accounts for the transient (tourist) population, as described above.

Sandia performed two separate evaluations of population growth to project from the 2000 data to the year 2035. The first was based on the US Census Bureau's projected growth from 2000 to 2008 for the Northeast region of the US. During these 8 years, the projected growth is 2.344%; based on this number, the annualized growth rate for the Northeast region of the country is 0.2900%. Assuming a constant growth rate between the years 2000 and 2035 results in an estimated growth for the Northeastern region of the US of 10.67%. This estimate is lower than the Entergy value of 12.43%.

The second evaluation used the same data for the 28 counties surrounding Indian Point as used by Entergy, but used a simpler method than Entergy for extrapolating out to 2035. The annualized growth rate was calculated starting from the 2000 census values to the final year projected by each of the states. Then assuming this growth rate to continue through 2035, the estimated growth for the 29 counties is 15.98%. This value is slightly larger than Entergy's projected growth of 12.43%, but the difference is small. Thus, the two evaluations performed by Sandia bound the Entergy projection for population growth. The conclusion is that Entergy's projection is very reasonable.

Sandia performed a separate evaluation of the population data for New York City. Sandia used the same method of extrapolation described above to project populations to the year 2035. Sandia's and Entergy' 2035 projected values (provided in Table 2.3 [4]) for the five counties that comprise New York City are shown below.

5 Counties Comprising New York City	**Sandia 2035 Projected Values**	**Entergy 2035 Projected Values**
Bronx	1,579,474	1,634,750
Kings	2,600,686	2,618,418
New York	1,605,258	1,570,657
Queens	3,040,556	3,024,717
Richmond	668,744	662,838
Totals	9,548,718	9,511,380

For New York, Queens, and Richmond Counties, Sandia projected slightly higher populations than Entergy. For Bronx and Kings Counties, Entergy projected higher populations. The difference between the Sandia's and Entergy's population projections for all 5 counties is only 0.39%.

Population Summary
The population projections used by Entergy for the 5 counties comprising New York City are virtually equal to Sandia's projection. The Entergy approach to using State information to project population growth provides conservative population values for the SAMA analysis because:

- The total (permanent + transient) population is larger, and therefore more conservative, than a projection based solely on US Census data; and
- The population projections used by Entergy for the 5 counties comprising New York City are virtually the same as Sandia's projection of US Census, which are based on US Census Bureau data for the year 2000 and population projections published by NYS.

2.2.2 ATMOS is being used beyond its Range of Validity

The Board states that the answer could materially affect the costs because the potentially exposed population rapidly increases with distance between thirty-one miles and fifty miles from the plant [3].

The MACCS2 code was developed to evaluate the potential impacts of severe accidents at nuclear power plants on the surrounding public. MACCS2 calculations are used by the NRC for planning purposes, for cost-benefit analyses, and in level-3 probabilistic risk analyses (PRAs). The MACCS2 model generates average or expected values of metrics of interest considering all of the relevant dose pathways, including the food and water pathway, and covering essentially a lifetime of exposure to a contaminated environment [6].

The MACCS2 code considers, among other things, phenomena related to atmospheric transport and deposition under time-variant meteorology, short- and long-term mitigative actions, potential exposure pathways, deterministic and stochastic health effects, and economic costs as described in NUREG/CR 6613, "Volume I, Code Manual for MACCS2: User's Guide" [2]. The MACCS2 code samples the meteorological data from an entire year and uses wind rose data to account for the plume traveling through all 16 compass sectors to ensure that all the potential plume paths are accounted for in the calculations. This ensures that likely impacts for the entire area within a 50-mile radius have an accurate statistical model for likelihood of a plume reaching that area and its expected concentration.

ATMOS is a Gaussian plume model within MACCS2 that treats plume segments under different weather conditions based on hourly changes from the site met data. The met data considered for each segment include wind speed, direction, stability class, and precipitation. Once a plume is formed, the direction does not change; however, the wind speed, stability class, and precipitation rate can change hour-by-hour based on the met data.

Questions regarding the adequacy of averaging metrics of interest over numerous weather sequences have been studied in detail. The study "Comparison of Average Transport and Dispersion Among a Gaussian, a Two-Dimensional, and a Three-Dimensional Model," [6] was completed with the objective of determining if the average atmospheric transport dispersion results from these codes are sufficiently close that more complex models are not required for the NRC purposes of planning, cost-benefit analysis, and probabilistic risk assessment or different enough that one or both of the NRC codes should be modified to provide more rigorous estimates of atmospheric transport and dispersion [6]. The study assessed results out to a distance of 100 miles, which is well beyond the 50 mile (80 Km) SAMA boundary.

The use of the Gaussian plume model was evaluated against state-of-the-art dispersion models in the study. This study was based on data from the highly instrumented Atmospheric Radiation Measurement (ARM) site in Oklahoma where topography in the area ranges from 153 to 760 meters above sea level [6]. In the study, MACCS2 was directly compared to LODI (Lagrangian Operational Dispersion Integrator) and RASCAL 3.0 (Radiological Assessment System for Consequence Analysis, Version 3.0).

LODI is a state-of-the-art, three-dimensional advection dispersion code that uses a Lagrangian stochastic Monte Carlo method. LODI is coupled to ADAPT (Atmospheric Data Assimilation and Parameterization Technique), which provides time-varying, three dimensional fields of mean winds, turbulence, pressure, temperature, and precipitation based on, in this case, observed meteorology. LODI is an element of the National Atmospheric Release Advisory Center (NARAC) emergency response modeling system at Lawrence Livermore National Laboratory (LLNL) which is a national support and resource center for planning, real-time assessment, emergency response, and detailed studies of incidents involving the spread of hazardous material accidentally or intentionally released into the atmosphere.

RASCAL 3.0 is used by the NRC for emergency response applications where a rapid response id required. The NRC evaluates accident conditions using RASCAL and compares results to those produced by NARAC during an accident. RASCAL 3.0 contains atmospheric transport and dispersion components that are intermediate in complexity between MACCS2 and ADAPT/ LODI. RASCAL employs time-varying, two-dimensional meteorological fields of wind, stability, and precipitation based on surface-level meteorological observations as input to a Lagrangian trajectory transport model and a Gaussian puff dispersion model. While the dispersion portions of RASCAL 3.0 are similar to those of MACCS2, the transport portions are significantly different [6]. The capabilities of RASCAL 3.0 are similar to those of the dispersion models CALPUFF and AERMOD, which were recommended by NYS.

In the analysis, the same set of 610 release times, derived from the MACCS2 weather binning process, was used for all models. Each code used hourly meteorological data and ran each case until all the released material exited the 160.9-km (100-mile) radius domain. An 80.5-km (50-mile) radius domain was used for RASCAL/ RATCHET because that is the limit allowed in those codes. The characteristics of the release including location, start time, duration, amount of depositing and non-depositing species, height, and heat energy of release were identical for all models.

In this highly controlled study, the results of the analysis show that MACCS2 with ATMOS was demonstrated to perform consistently with these more complex plume models at distances up to 100 miles, which is greater than the 80 km (50 miles) distance required for SAMA analyses. Tables 15 and 16 from that study are reproduced below. Table 15 shows the average, time-integrated, air concentrations (exposures) at distances of 10, 20, 50, and 100 miles from the source. These exposures are directly related to inhalation and cloudshine doses. Parenthetical quantities are values normalized by the values predicted by LODI, which was considered to be the standard for comparison. Table 16 is similar, but shows the average deposition at the same distances. The deposition predictions are directly related to groundshine and ingestion pathway doses.

As shown in Tables 15 and 16, the MACCS2 predictions for ground-level exposure and deposition were very comparable to the state-of-the-art NARAC codes, ADAPT/LODI, at all distances. The direct comparison to state-of-the-art codes demonstrates that MACCS2 is well within its range of validity when used to perform SAMA analyses.

Table 15. Depositing Species Arc Average Exposure (Bq-s/m^3) and Ratio to LODI

Model	16.1 km (10 mi)	32.2 km (20 mi)	80.5 km (50 mi)	161 km (100 mi)
MACCS2	5.18E+07 (1.41)	1.40E+07 (1.05)	2.49E+06 (0.81)	7.86E+05 (0.89)
RASCAL	5.91E+07 (1.61)	2.01E+07 (1.50)	3.94E+06 (1.28)	
RATCHET	2.89E+07 (0.79)	1.09E+07 (0.81)	2.69E+06 (0.88)	
LODI	3.68E+07 (1.00)	1.34E+07 (1.00)	3.07E+06 (1.00)	8.86E+05 (1.00)

Table 16. Arc Average Deposition (Bq/m^2) and Ratio to LODI

Model	16.1 km (10 mi)	32.2 km (20 mi)	80.5 km (50 mi)	161 km (100 mi)
MACCS2	5.57E+05 (1.21)	1.53E+05 (0.96)	2.87E+04 (0.78)	8.96E+03 (0.83)
RASCAL	7.20E+05 (1.56)	2.34E+05 (1.46)	4.71E+04 (1.29)	

RATCHET	3.10E+05 (0.67)	1.06E+05 (0.66)	2.63E+04 (0.71)	
LODI	4.62E+05 (1.00)	1.60E+05 (1.00)	3.67E+04 (1.00)	1.08E+04 (1.00)

2.2.3 Use of MACCS2 with the ATMOS module leads to non-conservative geographical distribution of radioactive dose within a fifty-mile radius of Indian Point

The Board states the answer could substantially change costs because of very large geographic variations of population density within 50 miles [3].

To understand whether the ATMOS module leads to non-conservative geographical distribution of radioactive dose within a fifty-mile radius of Indian Point, the characteristics of a Gaussian plume model must be understood, and it is critical to properly represent the population distribution and meteorology. The review of population distribution performed in Section 2.1 confirms that the highest population area is New York City. Review of the meteorology, as discussed later, confirms that wind directions are more dominant toward New York City than any other direction.

The ATMOS Gaussian model assesses contamination travel in a straight line, and for the Indian Point SAMA analysis, this corresponds to the shortest distance to the high populated areas. The shorter path of travel and dominant wind toward New York City ensures that a conservatively large amount of contaminant reaches the areas with higher population density. Furthermore, under variable terrain conditions the Gaussian plume provides an inherent conservatism [1]. When variable terrain features, such as river embankments, intervene between a source and an observation point, one of the effects is that the plume becomes more disperse (dilute) than it would have been otherwise. In situations where the plume is forced to move around obstacles, the Gaussian model conservatively estimates the plume path as the shorter distance over the obstacle. This corresponds to a larger accumulated radiological dose and higher estimates of economic consequences in areas farther from the plant.

This means that although there are large geographic variations of population density within 50 miles, these variations show larger populations at farther distances and the use of a Gaussian plume model predicts larger doses at these farther distances, which would correspondingly predict higher potential costs. Therefore, use of the ATMOS module leads to a conservative geographical distribution of radioactive dose within a fifty-mile radius of Indian Point.

Sandia reviewed the MACCS2 input files used in the Entergy baseline analysis to determine whether parameter selection might contribute to non-conservative geographical distribution of radioactive dose within a fifty-mile radius of Indian Point. Most of the input parameters used by Entergy in the MACCS2 analyses were standard choices consistent with Sample Problem A that is distributed with the MACCS2 code. The following input choices were specifically reviewed by Sandia:

- Meteorology – In the initial submittal, Entergy used an average of 5 years of weather data. This approach is different from previous SAMA analyses

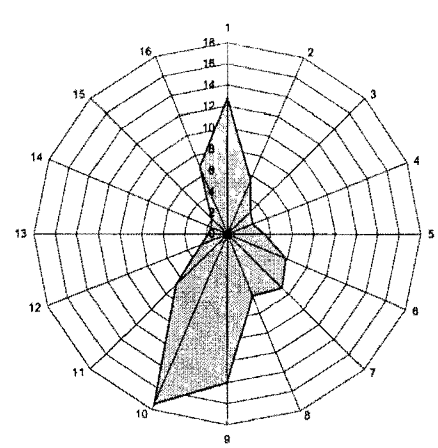

Figure 1. Plot of a single weather year from the IP site 10 meter tower showing direction wind is blowing toward. (percent by direction)

which typically use a single weather year. After major inconsistencies with regard to wind direction were identified, Entergy submitted an updated MACCS2 input file which uses a single weather year. A windrose of the MACCS2 weather input file is provided in Figure 1. As shown in the figure, the wind direction is dominant to the south toward New York City.

- Population values in the MACCS2 input files were consistent with the values reported in the Environmental Report. The population values were also found to be consistent with the US Census data as discussed in Section 2.2.1. The 2035 projected population value of 19,228,712 used by Entergy was reviewed and appears to be very reasonable. Sandia confirmed that the Entergy population projections for Manhattan are reasonable for all 5 counties that make up New York City, which are in the dominant downwind plume direction. The use of populations accounting for tourists by Entergy is reasonable and provides a slightly higher estimated cost.
- Dry Deposition Velocity. The dry deposition velocity of 0.01 m/sec corresponds to relatively small particle size. Within the plume model, small particle sizes will travel greater distances than large particle sizes and therefore would favor deposition at the higher population locations farther from the site. This would likely result in greater population dose. It will also tend to show greater decontamination costs because the areas farther away from the plant are more densely populated urban areas which have higher decontamination costs.
- Plume representation - A single Gaussian plume was used in the analysis. MACCS2 has the ability to model up to 4 plume segments. Use of additional plume segments likely would reflect some variation in wind direction and result in lower peak doses to the public.
- Spatial grid extends to 50 miles which is standard for regulatory analysis as provided in NUREG/BR-0184.
- Decontamination costs were based on Sample Problem A and adjusted for inflation using the consumer price index factor. Comparing the Site Restoration study decontamination cost values to the decontamination cost values used in the SAMA analysis shows the values are within reasonable range of each other.
- Emergency phase evacuation was not modeled in the Entergy analysis, which is described as more conservative than use of the radial evacuation approach applied in Sample Problem A.

Review of the selected input parameters showed that the parameters used were consistent with SAMA analyses.

Summary

The Board stated that questions raised in contention 12/12A relating to cleanup and decontamination costs based on the validity of assumptions used with the code should be appropriately resolved at the hearing. The Board limited the NYS Contention 16/16A to whether the population projections used by Entergy are underestimated; whether the ATMOS module in MACCS2 is being used beyond its range of validity; and whether use of MACCS2 with the ATMOS module leads to non-conservative geographical distribution of radioactive dose within a fifty-mile radius. Having reviewed the supporting documentation and MACCS2 input files, it is apparent that the parameters modeled are reasonable, appropriate, and consistent with regulatory guidance and current best practice.

Contention 12/12A states that the SAMA analysis does not accurately reflect decontamination and clean up costs associated with a severe accident because specific inputs and assumptions made in the MACCS2 code regarding decontamination and clean up costs may not be correct. The Sandia review demonstrated that both the particle size and the decontamination cost values are reasonable and appropriate. More specifically,

- The particle size used in the SAMA analysis is consistent with the definition of small particle size as provided by NYS.
- The decontamination cost values used in the SAMA analysis were based on Sample Problem A values and were escalated to account for inflation.
- The Site Restoration study recommended by NYS for use in determining decontamination costs is not applicable to a nuclear power plant accident.
- Comparing decontamination cost estimates using the Site Restoration study values and the Entergy values in the MACCS2 input shows reasonable agreement.

For Contention 16/16A, Sandia confirmed that the population values used by Entergy are appropriate. The review confirms that NYS is incorrect in asserting ATMOS was used beyond its range of validity. ATMOS has been demonstrated to perform consistently with more advanced codes at distances up to 100 miles. The review regarding whether ATMOS leads to a non-conservative geographical distribution of radioactive dose within a fifty-mile radius also shows this assertion by NYS to be incorrect. Because ATMOS is a Gaussian plume model, it provides greater transport of contaminants to the more populous areas farther away from the plant. Use of other models may more accurately predict dispersion around topographical features near the plant for a single weather condition, but these models would then show less deposition in the more populous areas farther away from the plant. Therefore, ATMOS was used within its range of validity and provides the more conservative analysis.

Follow On Approach:
It is recommended that additional activities be performed in preparation for potential hearings. These additional activities include:

Redacted

[redacted]

[redacted]

References

[1] Department of Energy. "MACCS2 Computer Code Application Guidance for Documented Safety Analysis". United States Department of Energy, Washington D.C., 2004. DOE, 2004.

[2] Nuclear Regulatory Commission (U.S.) (NRC). NUREG/CR-6613, "Code Manual for MACCS2: Volume 1, User's Guide". NRC: Washington, D.C. May, 1998.

[3] Nuclear Regulatory Commission (U.S.) (NRC) Atomic Safety and Licensing Board LBP-08-13. ASLB No. 07-858-03-LR-BD01. July 31, 2008.

[4] Volume 1, Site Specific MACCS2 Input Data for Indian Point Energy Center, (4/7/2006).

[5] Entergy. "Reply to Request for Additional Information Regarding License Renewal Application – Severe Accident Mitigation Alternatives Analysis. Indian Point Units 2&3 Docket Nos. 50-247 and 50-286. February 5, 2008.

[6] Nuclear Regulatory Commission (U.S.) (NRC). NUREG/CR-6853, "Comparison of Average Transport and Dispersion Among a Gaussian, a Two-Dimensional and a Three-Dimensional Model". NRC: Washington, D.C. October, 2004. NRC, 2004.

[7] Chanin, David and Walter Murfin. Site Restoration: Estimation of Attributable Costs from Plutonium-Dispersal Accidents. Technadyne Engineering Consultants. SAND96-0957. May, 1996.

[8] Demmer, Rick. "Large-Scale Urban Decontamination; Developments, Historical Examples, and Lessons Learned." Idaho National Laboratory. INL/CON-06-11659. February, 2007.

[9] Beyea, Lyman, and von Hippel. "Damages from a Major Release off Cs137 into the Atmosphere of the United States." Science and global Security, 12:125-136, 2004.

[10] Lyman, Edwin. "Chernobyl on the Hudson? The Health and Economic Impacts of a Terrorist Attack at the Indian Point Nuclear Power Plant." Union of Concerned Scientists. 2004.

[11] Technical/Regulatory Guidance: Decontamination and Decommissioning of Radiologically Contaminated Facilities. The Interstate Technology & Regulatory Council Radionuclides Team, January, 2008. (ITRC, 2008).

[12] State of New York Contentions Concerning NRC Staff's Draft Supplemental Environmental Impact Statement. ASLBP No. 07-858-03-LR-BD01. February, 27, 2008.

[13] U.S. Census http://www.census.gov/popest/counties/CO-EST2008-01.html, assessed 9/1/2009.

[14] Entergy LRA Appendix E, Applicant's Environmental Report Operating License Renewal Stage Indian Point Energy Center.

[15] Nuclear Regulatory Commission (U.S.) (NRC). NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, Final Summary Report." Washington DC.: NRC. 1990.

[16] MACCS2 Meteorological Input File Generation Report (IPEC00103877 thru IPEC00103889).

[17] Indian Point Annual Effluent Reports for 1999 though 2002. (ML031220099, ML021260723, ML011240172, ML003714664).

[18] Environmental Protection Agency (EPA). EPA-400-R-92-001. "Manual of Protective Action Guides and Protection Actions for Nuclear Incidents." 1992.