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Attached is the

“Summary Report Audit of Calvert Cliffs AEOLUS3 Dispersion Modeling Analysis”

The audit was performed February 11 & 12, 2009

Summary Report – Audit of Calvert Cliffs AEOLUS3 Dispersion Modeling Analysis

Dates:

February 11 & 12, 2009

Location:

EXCEL Services Corporation
11921 Rockville Pike, Suite 100
Rockville, MD 20852

Nuclear Regulatory Commission Audit Team Members:

- Michael D. Mazaika. – Technical, Audit Leader (February 11-12)
- R. Brad Harvey - Technical (Feb. 11; February 12 (AM Only))
- Peter Hearn - Project Management (February 11 (AM Only); Feb. 12)
- John Rycyna - Project Management (February 11 (PM Only))

Applicant Participants:

- Theodore Messier – AREVA NP, Technical (February 11-12)
- John Hamawi – AREVA NP, Technical (February 11-12)
- Darrell Gardner – AREVA NP (February 11-12)
- Wayne Massie – UniStar, Licensing (February 11-12)
- Martin Owens – AREVA NP, Project Management (February 11 – Entrance Briefing; February 12 – Exit Briefing)
- Michael Yox – UniStar (February 12 – Exit Briefing)

Documentation Available for Review – Proprietary (Not Retained by Staff)

- AEOLUS3 dispersion model capabilities, input file structure, output file structure
- John N. Hamawi. *AEOLUS-3 – Technical Description. A Computer Code for the Determination of Atmospheric Dispersion and Deposition of Nuclear Power Plant Effluents During Continuous, Intermittent and Accident Conditions in Open-Terrain Sites, Coastal Sites and Deep-River Valleys*, Entech Engineering, Inc., Report No. P100-R19-A, March 1989, Software Release V00L00 (2/21/1989).
- John N. Hamawi. *AEOLUS-3 – Implementation Test Runs. A Computer Code for the Determination of Atmospheric Dispersion and Deposition of Nuclear Power Plant Effluents During Continuous, Intermittent and Accident Conditions in Open-Terrain Sites, Coastal Sites and Deep-River Valleys*, Entech Engineering, Inc., Report No. P100-R19-C.1, Volume 1 of 3 – Open Terrain, March 1989, Software Release V00L00 (2/21/1989).
- John N. Hamawi. *AEOLUS-3 – Implementation Test Runs. A Computer Code for the Determination of Atmospheric Dispersion and Deposition of Nuclear Power Plant Effluents During Continuous, Intermittent and Accident Conditions in Open-Terrain Sites, Coastal*

Sites and Deep-River Valleys, Entech Engineering, Inc., Report No. P100-R19-C.2, Volume 2 of 3 – Coastal Sites, March 1989, Software Release V00L00 (2/21/1989).

- John N. Hamawi. *AEOLUS-3 – Implementation Test Runs. A Computer Code for the Determination of Atmospheric Dispersion and Deposition of Nuclear Power Plant Effluents During Continuous, Intermittent and Accident Conditions in Open-Terrain Sites, Coastal Sites and Deep-River Valleys*, Entech Engineering, Inc., Report No. P100-R19-C.3, Volume 3 of 3 – Deep River Valleys, March 1989, Software Release V00L00 (2/21/1989).
- John N. Hamawi. *AEOLUS-3 – Code Verification Test Report. A Computer Code for the Determination of Atmospheric Dispersion and Deposition of Nuclear Power Plant Effluents During Continuous, Intermittent and Accident Conditions in Open-Terrain Sites, Coastal Sites and Deep-River Valleys*, Entech Engineering, Inc., Report No. P100-R19-D, March.

Audit Activities - Overview:

February 11, 2009 – AM

- Entrance Briefing
 - Introduction of Audit Participants
 - Purpose and Background
 - Primary Technical Regulatory Bases
- Begin Overview and Presentation of AEOLUS3 Model.
 - Begin Review of Technical Issues and Questions Based on Final Safety Analysis Report (FSAR) §§ 2.3.4 and 2.3.5.

February 11, 2009 – PM

- Begin Review of Requested Hardcopy Documentation.
- Complete Overview and Presentation of AEOLUS3 Model.
 - Continue Review of Technical Issues and Questions Based on FSAR §§ 2.3.4 and 2.3.5.
 - Begin Review of Technical Issues and Questions Based on Hardcopy Documentation.
- Begin Review of Potential Application-Specific Request for Additional Information (RAI;s) Based on FSAR §§ 2.3.4, 2.3.5, 2.3.20.

February 12, 2009 – AM

- Continue Review of Potential Application-Specific RAIs Based on FSAR §§ 2.3.4, 2.3.5, 2.3.2.
- Complete Review of Technical Issues and Questions Based on FSAR §§ 2.3.4 and 2.3.5, and Model Overview and Presentation.
- Continue Review of Technical Issues and Questions Based on Hardcopy Documentation.

February 12, 2009 – PM

- Continue Review of Requested Hardcopy Documentation.
- Complete Review of Potential Application-Specific RAIs Based on FSAR §§ 2.3.4, 2.3.5, 2.3.2.
- Exit Briefing.

Audit Activities - Discussion:

- Audit Participants – See Attachment A
- Purpose - To examine and evaluate non-docketed technical, procedural, and process information related to the AEOLUS3 dispersion modeling analyses. The intent is to gain better understanding of the AEOLUS3 dispersion model and possible reasons for differences between the Staff's initial evaluation of the applicant's modeling results (some of which appear to be less conservative), to verify information, and to identify documentation that will require docketing to support the basis of licensing and regulatory decisions.
- Background - Descriptions of the model, certain model inputs and outputs, and assumptions in combined license (COL) FSAR Sections 2.3.4 and 2.3.5 are, at present, considered by the Staff to be inadequate to support a conclusion in the FSAR that appropriate atmospheric dispersion models have been used:
 - to calculate conservative estimates of atmospheric dispersion conditions during postulated accidental releases of radioactive material to the air, and
 - to calculate atmospheric dispersion and deposition factors from postulated release points during routine airborne releases of radioactive material.

The intent is not to endorse the dispersion model itself; but rather, for the Staff to come to a conclusion that the results the AEOLUS3 model produces are reasonable based on the Staff's better understanding of the code and by comparison to the Staff's own confirmatory modeling runs using the Nuclear Regulatory Commission (NRC)-endorsed PAVAN and XOQDOQ dispersion models.

- Primary Technical Regulatory Bases -
 - NUREG-0800 (Standard Review Plan (SRP) for the Review of Safety Analysis Reports for Nuclear Power Plants), SRP Sections 2.3.4 and 2.3.5 (including Section II, SRP Acceptance Criteria), Revision 3, March 2007.
 - Reg. Guide 1.111, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*, Regulatory Position (1)(c) – Constant Mean Wind Direction Models, Revision 1, July 1977

- Primary Technical Regulatory Bases – (Cont.)
 - NUREG/CR-2919 – *XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Plants*, PNL-4380, September 1982.
 - Reg. Guide 1.145, *Atmospheric Dispersion Models for Potential Accidental Consequence Assessments at Nuclear Power Plants*, Section C (Regulatory Position), Revision 1, November 1982.
 - NUREG/CR-2858 – *PAVAN: An Atmospheric Dispersion Program for Evaluating Design Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations*, PNL-4413, November 1982.
- Overview and Presentation of AEOLUS3 Dispersion Model and Review of Technical Issues and Questions Based on FSAR Sections 2.3.4 and 2.3.5
 - See Attachment B
- Partial Summary of CCNPP3 Application-Specific (Rev. 3) Issues Discussed During Audit
 - Attribution of guidance in Reg. Guide 1.145 to long-term, routine release dispersion modeling analysis not applicable.
 - Discussion of modeling realistic (50%) X/Qs due to short-term accidental releases and identification of corresponding COL Item applicable to ER but not relevant to SAR.
 - COL FSAR Section 2.3.5 silent and/or without cross-references regarding number of routine release points, and, if more than one, the respective release characteristics (location, height, exit diameter, exit velocity, and exit flow rate); whether operational releases will nominally be at ambient temperature and if not, the corresponding heat emission rate(s); whether discharge point(s) are open to the atmosphere and need to confirm that no obstructions to exhaust flow are present; orientation of discharge (e.g., vertical, horizontal, other angle).
 - Reported stack flow rate being referred to as normal but also as conservatively lower than the flow rate during normal operations, and basis for statement that considers reported value to be conservative.
 - Missing and/or incorrect cross-references for physical characteristics of stack (inner stack diameter, and stack height), reactor building height, and stack location.
 - Scant details regarding calculation of minimum building cross-sectional area, rationale for using Reactor Building as opposed to other nearby structures, cross-references to applicable drawings for building dimensions and relative locations of release points, applicability of cross-sectional area (i.e., accounting for building wake effects) to both ground-level releases, and elevated portion of mixed mode releases

- No discussion of presence or absence of any thermal internal boundary layer (TIBL) in site area, its seasonal occurrence, diurnal development, and vertical extent and variation with distance inland from shore of Chesapeake Bay; whether it was accounted for in dispersion analysis and if not why not; TIBL's relationship to fumigation conditions applicable to elevated portion of mixed mode releases.
- No specification of whether recirculation correction factors represent default or site-specific values; no identification of which analysis (i.e., short-term accident or long-term routine release), if any, accounted for plume meander effects; no statement as to whether wet deposition was accounted for in short- and long-term modeling analyses (although implied not to be the case based on tabular results presented in COL FSAR Section 2.3).
- No indication of whether terrain heights can be assigned to special receptors (e.g., nearest residence, garden, meat animal, milk animal) for long-term modeling analysis; no explanation of how terrain elevations are determined (nor corresponding reference citations to source(s) of topographic data) and how elevations are assigned as a function of sector and downwind distance.
- Need for explanation of distinctions, if any, between actual Exclusion Area Boundary (EAB) and actual Low Population Zone (LPZ) boundary and the EAB and LPZ boundary used for dispersion modeling analyses; need for corresponding figures and/or cross-references showing those differences (if any).
- Presentation of extraneous modeling results – accident-related X/Qs at the EAB for post-accident time intervals beyond 0-2 hours; 50th percentile (realistic) X/Qs at EAB and LPZ boundary; gamma X/Qs.
- Need for clarification of how AEOLUS3 generates joint frequency distributions (JFDs) internally from hourly meteorological data (including, but not limited to, identification of wind measurement level used, wind speed groups, determination of wind speed used in X/Q calculations for each wind speed group), and relationship to JFDs presented in COL FSAR Section 2.3 in tabular form.
- Reference in COL FSAR Sections 2.3.4 and 2.3.5 to a licensing action for another facility (Pilgrim Nuclear Power Station, ML051040065) in which the X/Q modeling analyses were performed using the AEOLUS3 model. Because AEOLUS3 is a non-standard dispersion model (i.e., it has not been endorsed by NRC), its use on each licensing action (in this case a COL application) must stand on its own merits and implementation for that action.

Audit Activities – Exit Briefing:

- Nuclear Regulatory Commission Staff:
 - Expressed appreciation for the presentation (model overview, input and output file structure, methodologies), availability of information and documentation, and the cooperative working environment on the part of AREVA NP and UniStar audit participants.

- Mentioned that, given the time available and the proprietary nature of the AEOLUS3 code, the audit approach was chosen in this case over requesting that a topical report be submitted by AREVA NP for review and approval, and possibly leading to NRC endorsement of the AEOLUS3 model.
- Reiterated that the intent of this audit was not to endorse the AEOLUS3 code but to have a better understanding of the dispersion model such that the Staff can come to a conclusion that the results it produces are reasonable when compared to Staff's own confirmatory modeling runs with PAVAN and XOQDOQ.
- Mentioned that, given the two-day audit period, the documentation made available to Staff could not be reviewed in detail.
- Is generally satisfied with AEOLUS3 model capabilities and assumptions that were discussed and with the conservatism/approaches where model features differ from the standard NRC codes (PAVAN and XOQDOQ).
- Mentioned that because other U.S. EPR COL applications docketed to date (i.e., Callaway, Bell Bend, Nine Mile Point) utilize the AEOLUS3 model and that COL FSAR Section 2.3 and ER Section 2.7 appear to have been prepared following a template, RAIs similar to those generated as a result of this audit should be expected for those COL applications as well.
- Took receipt (on February 11, 2009) of sequential hourly onsite meteorological data for calendar year 2006 and meteorological data summaries in the form of JFDs of wind speed, wind direction, and atmospheric stability which were to have been included as part of October 30, 2008 response to RAI No. 02.03.04-3.
- Most Notable Issues:
 - Scant write-up in FSAR Sections 2.3.4 and 2.3.5 as to how model was set up and run for this facility (rather than, in many cases, generic discussions of model capabilities).
 - Uncertainty as to the orientation of discharge from the vent stack for routine releases and whether a rain cap or other flow obstruction is incorporated in design such that it would hinder momentum rise of exhaust gas.
 - JFDs generated internally by AEOLUS3 model from hourly meteorological data are not necessarily the same as the JFDs presented in COL FSAR Section 2.3 introducing some uncertainty in Staff's use of the latter summaries.
- Upcoming AREVA NP / UniStar Action Items:
 - Additional RAIs will be generated based on the CCNPP3 application-specific (Rev. 3) issues discussed during the audit, as well as follow-up RAIs based on Staff's review of the October 30, 2008 responses to earlier RAIs – see earlier partial summary.

- Editorial comments, related to FSAR Section 2.3 and based on the above, will probably be bundled as a letter to UniStar.
- AREVA NP indicated that they would consider providing proprietary copies of AEOLUS3 output files, requested via RAI, that support the dispersion modeling results presented in the current version of the application or as it is to be revised.
- Upcoming Nuclear Regulatory Commission Staff Action Items:
 - Look further into differences between long-term, routine release modeling results estimated by AEOLUS3 and those based on Staff's confirmatory modeling with XOQDOQ. Initial comparisons show marked differences for receptors beyond about 5 miles (Staff values increasingly higher beyond that distance and increasingly lower inside that distance).
 - Re-run PAVAN, XOQDOQ, and ARCON96 dispersion models based on 2000-2006 meteorological data and summaries just received during audit.
- Questions:
 - Michael Yox (UniStar) to Staff – Are these RAIs expected to have an impact on the Draft Environmental Impact Statement review, preparation, and approval? Staff indicated that this will have to be discussed with the Environmental Project Manager and may depend on whether dispersion modeling is affected.

Audit Participants Sign-In Sheet

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Notes from AREVA Responses to Info Needs for Audit of AEOLUS3 Dispersion Model

Introduction

The list of information needs that follows is as provided to AREVA NP and UniStar prior to the audit. Written responses to these information items and technical issues were made available to Staff during the audit to facilitate discussion and issue resolution. Notes, some paraphrased by Staff, based on these responses, appear in italics below the respective information items and technical issues. Where relevant, additional Staff notes based on these discussions and/or review of the available documentation, also appear in italics, underlined and within parentheses.

Documentation

Please make available the following items for reference and demonstration during the audit:

- Hard copies of AEOLUS3 user's manual, verification and validation report (if available), and other related documentation (none of these items will be retained by NRC Staff).

(Provided)

- If possible, at least one laptop PC for demonstrating model set-up, input data entry process, and model output (recommend that examples be specific to CCNPP3)

(PowerPoint presentation was sufficient for demonstration. No need to run on separate laptop PC; FORTRAN-like run structure similar to PAVAN and XOQDOQ.)

Technical Issues Related to Input Data and Assumptions Pertaining to Short-Term and/or Long-Term X/Q Estimates by the AEOLUS3 Model

Please provide a subject matter expert(s) to discuss the following:

- General overview and demonstration of AEOLUS3 dispersion model.

(Ted Messier and John Hamawi (AREVA NP) gave informative PowerPoint presentation.)

- Any modifications to the short-term, accident-related dispersion equations and methodologies in:

- RG 1.145 (Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants); and

Response indicated no modifications or deviations from RG 1.145; but noted that AEOLUS3 has more capabilities. (Statement is generally correct, but appears to be in the context of the modeling analyses performed and the model options used for this COL application.)

- NUREG/CR-2858 (PNL-4413) (PAVAN: An Atmospheric Dispersion Program for Evaluating Design Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations).

- ❖ *Does not incorporate desert sigma curves (OK – desert sigmas do not apply to current COLAs incorporating U.S. EPR design that utilize AEOLUS3 (Calvert Cliffs, Callaway, Bell Bend, Nine Mile Point). Accounts for vertical plume reflection off of mixed layer height (up to 5 times) and for horizontal plume reflection in deep valley locations.*
- ❖ *Distribution of calm wind frequencies is slightly different. PAVAN model distributes into first non-calm wind speed category. AEOLUS3 defines calms as a special group with its own wind speed; set equal to one-half the starting speed of the wind sensors.*
- ❖ *Can account for plume rise as well as mixed mode releases; but, plume rise not applied for estimating accident X/Qs in general or for CCNPP3 analysis in particular.*
- ❖ *Unlike PAVAN, which is limited to 2 receptors, AEOLUS3 can accept an unlimited number of receptors. (AREVA NP clarified “receptors” as meaning, typically, the EAB and LPZ, or special receptors. Staff pointed out that separate receptor distances can be input to PAVAN for each sector for the EAB, LPZ boundary, or other receptor type series.)*
- ❖ *Allows for entry of user-specified wind speed extrapolation coefficients with height based on site-specific measurements; but also includes default coefficients incorporated in PAVAN model. (Staff mentioned the potential for the actual site characteristics (i.e., the change of wind speed with height) to be different from the variation with height based on applying the extrapolation coefficients in the model. This could have either a conservative or non-conservative bias (by stability class) and on the resulting X/Qs estimated by the model. Asked if this was taken into consideration, AREVA NP indicated that it had not, but offered that other conservatisms in the model, and how the code determines and uses a mean wind speed value for a given wind speed group, should minimize such biases. Nevertheless, recommend that Staff should look at this characteristic in its evaluation of onsite meteorological data.)*
- ❖ *Allows for user-specified, post-accident time intervals. Hence, unlike PAVAN, a 6-hour span for the 2- to 8-hour time interval is possible, whereas PAVAN presents results for an 8-hour span (i.e., 0- to 8-hour time interval).*
- ❖ *Has a different, more elaborate approach for computation of the X/Q bounding envelope and computation of the 1-hour accident X/Qs.*

- Any modifications to the long-term, routine release-related dispersion equations and methodologies in:

- RG 1.111 (Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors); and

Response indicated no modifications or deviations from RG 1.111; but noted that AEOLUS3 has more capabilities. (Statement is generally correct, but appears to be

in the context of the modeling analyses performed and the model options used for this COL application.)

- NUREG/CR-2919 (PNL-4380) (XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations).
 - ❖ AEOLUS3 does not use desert sigmas (See Staff note for the comparable entry in the list of responses under NUREG/CR-2858 (PNL-4413) above.)
 - ❖ AEOLUS3 is based on user-selectable wind speed groups.
 - ❖ AEOLUS3 allows for wet deposition.
 - ❖ All X/Q equations include reflection correction (up to 5 reflections).
 - ❖ Allows for user-specified wind speed extrapolation with height coefficients (See Staff note for the comparable entry in the list of responses under NUREG/CR-2858 (PNL-4413) above.)
- AEOLUS3 batch-input mode operation and user-selectable options, including:
 - explanation of batch-mode structure;

Main input file is in FORTRAN card image format similar to PAVAN and XOQDOQ. Input files edited directly by user (no GUI). (Program runs on Unix system. PowerPoint presentation provided sufficient demonstration.)
 - whether “batch-mode” corresponds to separate model runs (e.g., for individual annual cycles of meteorological data);

(No)
 - if other input data are entered as groups of related information;

Input data are categorized – program control options; wind speed group definitions, wind speed extrapolation data; release point data; general site data; Gamma X/Q inputs (energy spectra and relative intensity data, release isotopics); deposition velocity; meteorological data (format, channel sequence, maximum allowable values, units conversion factors); receptor data. (What is basis
 - identification of user-selectable options;
 - identification of default values among options (if any), and, if so, rationale for selecting default/non-default values; and

User may select – continuous (routine), accident, or intermittent release type; printout control (similar to options in PAVAN and XOQDOQ which include or suppress detailed output); plume meander correction; recirculation correction; wind speed extrapolation; option to calculate gamma X/Qs; selection of Entech-developed or XOQDOQ sigma-y and sigma-z determination (Entech determined that the RG 1.111 equations for estimating sigmas did not produce the values shown by the sigma graphs in the RG and developed equations that reproduced the graphical curves.); selection of sea breeze or valley model option; dry deposition options;

option to account for wet deposition; identify number of wind speed groups; identify number of gamma energy groups; specify duration and exceedance probabilities for intermittent releases; specify number of monthly records of meteorological data; select summary file options.

- options selected for CCNPP3 dispersion modeling.

(COL FSAR Sections 2.3.4 and 2.3.5 frequently indicated the capabilities of the AEOLUS3 model but often did not identify the configurations or options selected for the dispersion modeling analyses in the application submittal. This will be the subject follow-up RAs, some of which have been summarized under the heading “Audit Activities – Exit Briefing”. Some of the option selections determined over the course of the audit discussions included: use of plume meander, recirculation correction, and default wind speed extrapolation coefficients; use of momentum rise of routine release plume, but not buoyancy rise; no sea breeze effects considered (applicant acknowledged may be applicable but indicated was unable to identify any available solar radiation data in the site area); wet deposition not accounted for; building wake effects accounted for in short-term, accident-related analysis but not for modeling long-term, routine releases; receptor terrain heights incorporated in long-term modeling; mixing height values entered (associated with plume reflection.)

- If the model is run separately depending on whether short-term, accident-related or long-term routine release-related X/Qs are being estimated.

AEOLUS3 is run separately for short-term (accident) and long-term (routine) releases, although the accident model calculates the annual average values to use with the one-hour values in determining X/Qs for other time periods (e.g., the 2-8 hour).

- If not run separately, explain how the model isolates the appropriate annual average X/Qs (e.g., at EAB and LPZ boundary receptors) depending on whether the X/Qs are associated with short-term accident or long-term routine release conditions since the annual average X/Qs could be fundamentally different if short-term dispersion is evaluated as a ground level release and long-term dispersion is evaluated as mixed mode releases.

(N/A based on preceding response.)

- Whether and, if so, how the short-term accident model generates:
 - the safety-related 0.5 percent, sector-dependent X/Qs pursuant to Regulatory Position 2 in RG 1.145;
 - the safety-related 5 percent overall site X/Qs pursuant to Regulatory Position 3 in RG 1.145; and
 - the environmental impact-related 50 percent, sector-dependent and the 5 percent overall site limit X/Qs;

including an explanation of how the respective upper bound curves of the X/Qs versus probability of being exceeded are constructed and used.

AEOLUS3 generates the sector-dependent and overall-site accident X/Qs pursuant to RG 1.145 Positions 2 & 3. The upper bound curves of the X/Qs vs. probability of being exceeded are based on the methodology in the XOQDOQ code for intermittent releases, with minor modifications for improved accuracy. Specifically, the model is based on least-squares fits applied to the logarithms of the X/Qs vs. probability. Differences from XOQDOQ include the use of a straight-line fit vs. hyperbolic, and selection of a X/Q range and a probability range for optimal results. The final results are increased by 2 standard deviations, as calculated for each fit. Details in AEOLUS3 Technical Manual, Section 8.0.

- Whether the controlling safety-related X/Q value (i.e., the higher of the maximum sector-dependent or the 5 percent overall site limit value, pursuant to Regulatory Position 4 in RG 1.145) is identified internally as part of the model output or must be identified and selected manually from the output. If the latter, provide examples specific to the CCNPP3 COLA.

(The controlling X/Qs are determined internally by the AEOLUS3 code. A summary table, similar to the PAVAN model output, is generated as part of the AEOLUS3 output showing the sector-dependent X/Qs for each of the 16 direction sectors and for the 0-2 hour, 2-8 hour, 8-24 hour, 1-3 day, and 4-30 day post accident time periods, as well as corresponding sector-dependent, annual average X/Q, and the 5 percent overall site X/Q value. The PowerPoint presentation included an example of this part of the output. When asked, the applicant indicated that the output files associated with the CCNPP3 modeling analyses may be provided if requested via RAI, although the Staff and AREVA NP agreed that the information would have to be designated and handled as "Proprietary".)

- Whether and, if so, how the AEOLUS3 model accounts for fumigation conditions, including:

- its applicability to modeling of short-term, accident-related and long-term, routine ground-level releases;

AEOLUS3 follows RG 1.145, Section 1.3.2(b), for fumigation conditions during accident conditions. The fumigation X/Qs are provided for each sector, but they are not used in the least-squares fits. It is the user's obligation to evaluate the applicability of the fumigation X/Qs.

- its applicability to stack releases and the elevated portion of long-term routine releases under mixed-mode scenarios; and

For routine releases, fumigation conditions are calculated only for coastal sites, under sea-breeze conditions, if solar radiation data are provided in the input. The fumigation condition is automatically accounted for by the reflection terms in the X/Q equations, accounting for the reflections between the ground and thermal internal boundary layer (TIBL).

(AREVA NP indicated that no solar radiation measurements were made at the CCNPP3 site and that no other such data were available in the site area, including the nearby Patuxent River NAS. Therefore, fumigation was not accounted for in the AEOLUS3 modeling analyses. AREVA NP explained that input to the AEOLUS3 model includes designation of when fumigation conditions are expected to occur based on an evaluation of daytime hours and relationships between insolation (an

indicator of the onset and cessation of sea-breeze conditions) and wind data (an indicator of the inland sectors affected by the on-shore, sea-breeze flow).

- its interaction with the presence of a thermal internal boundary layer (TIBL) in coastal locations.

There are three different geometries handled by AEOLUS3 for sea-breeze analyses ground-level releases, elevated releases totally beneath TIBL, and elevated releases above the TIBL (followed by plume/TIBL interactions). See AEOLUS3 Technical Manual for details.

- How the AEOLUS3 model differs in its handling of fumigation at coastal locations (would apply to the Calvert Cliffs and Nine Mile Point COL applications) and at inland locations (would apply to the Bell Bend and Callaway COL Applications) in relatively open terrain and in complex terrain (e.g., mountain ridge and valley).

(See response to previous question.)

- How plume recirculation and stagnation effects are accounted for in the short-term, accident-related dispersion model and the long-term, routine release-related dispersion model in terms of required input data and implementation as a function of downwind distance and direction sector.

No recirculation correction factors (RCFs) are applied to the hourly values used in the least-squares fits for the accident X/Qs. The annual average value used in the computation of the accident X/Qs at other time intervals and includes recirculation correction if selected.

For routine releases, the user may choose to input site/receptor specific RCFs if they exist, may assume no RCF, or may use the default RCFs from RG 1.111 (Rev. 0). See Table 4.6 of the AEOLUS3 Technical Manual.

- How plume meander effects are accounted for in the short-term, accident-related dispersion model and the long-term, routine release-related dispersion model.

Plume meander is accounted for in accidental releases as described in RG 1.145. It is not allowed for elevated releases. (As with RG 1.145, AEOLUS3 implements plume meander as a function of wind speed.)

(Re-verify that plume meander is not accounted for in the long-term, routine release-related dispersion modeling, as is the case with XOQDOQ.)

- How the long-term, routine release-related dispersion model accounts for plume depletion by wet deposition, dry deposition, and radioactive decay; and a discussion of gamma X/Qs.

Wet deposition is handled based on NUREG/CR-4158 and makes use of the assumptions that, as precipitation falls through the plume, the rate of material removal from the plume is in proportion to the local concentration of the material and to the rate of precipitation. The required input includes hourly rainfall occurrences and amounts, and the user-specified coefficient for computation of the rainfall scavenging rate. See AEOLUS3 Technical Manual, Section 4.5.3.

Dry deposition is handled in one of two ways: (a) RG 1.111 factors (XOQDOQ equations) or (b) the model from Meteorology and Atomic Energy (based on user-specified deposition velocities for a list of wind speed and stability combinations). See AEOLUS3 Technical Manual, Section 4.5.

Decay in transit is handled in AEOLUS3 through use of:

$$\Gamma^G = \exp [-0.69315X \div (T_{1/2} \times u_g \times 3600 \times 24)]$$

$$\Gamma^e = \exp [-0.69315X \div (T_{1/2} \times u_e \times 3600 \times 24)]$$

where:

Γ^G = the in-transit decay correction factor for the ground level plume,
 Γ^e = the in-transit decay correction factor for the elevated level plume,
 X = the downwind distance from the release point to the receptor,
 u_g = the travel wind speed for the ground level plume,
 u_e = the travel wind speed for the elevated plume, and
 $T_{1/2}$ = is the isotope decay half life.

Two half-lives can be provided by the user, one for noble gases and another for iodines.

AEOLUS3 can compute the Gamma (X/Qs) under all conditions, if so requested. Details on the Gamma (X/Q) concept appear in the AEOLUS3 Technical Manual, Section 4.2. At this point, it suffices to note that the Gamma (X/Q) corresponds to the equivalent concentration in a semi-infinite cloud that will yield the same external-radiation dose as a finite-cloud aloft (or at ground level). It is a function of plume dimensions, height above ground, and emitted radiation spectrum. Different models are available to plume-centerline evaluations and sector-average conditions, with appropriate adjustments for sea-breeze and in-valley flows.

- For mixed-mode scenarios, how the long-term, routine-related dispersion model:
 - determines and apportions the amount of time applicable to each release mode (elevated and ground-level) of a mixed-mode release and how that implementation relates to Regulatory Position 2(b) of RG 1.111; and

AEOLUS3 follows the guidance in RG 1.111, Position 2(b) for defining the time-split of a plume between a ground-level release and an elevated release. Specifically, the split is determined for any given stability-wind speed combination based on the ratio of the vertical exit velocity and the horizontal wind speed at the release height.

- how this determination varies depending on whether JFDs or hourly data are input to the model, and whether wind speed data from the 10-m level only or both the
- 10- and 60-m measurement levels are used. *Even though only hourly meteorological data are input to the code, and only one elevation, the analysis is based on the generated JFDs within the same computer run, and on the applicable wind speed at the release height, which is extrapolated if required.*

(AREVA NP acknowledged that the JFDs generated by AEOLUS3 from the hourly meteorological data may be different from the JFDs presented in the application. AREVA NP will address in response to RAIs resulting from this audit.)

- How receptors are generated by and/or input to the AEOLUS3 model, including:
 - at the EAB and LPZ boundary distances;
 - for fixed radial distances (and the basis for those distances);
 - for distance segments (and the basis for those distance ranges); and

Receptor details are input by the user as part of the main input file. The code can accept an unlimited number of receptor points (with the same format for circular and non-circular boundaries, special locations within a few sectors, etc.). See AEOLUS3 input requirements, Receptor Data, for details.

- at special receptor locations (e.g., nearest residence, garden, meat animal, milk animal).

For CCNPP3, special receptor locations were taken from the annual land use census report.

- How the AEOLUS3 model handles terrain heights as a function of release height and downwind distance from the source to different terrain elevations within the same sector in comparison to how this is handled by the PAVAN and XOQDOQ dispersion models.

AEOLUS3 follows the guidance in RG 1.111 C.2.a:

$$h_e = h_s + h_{pr} - h_t - c$$

where:

h_e = the effective plume height above receptor grade,

h_s = the physical height of the release point (where applicable),

h_t = the maximum terrain height above release point grade elevation between release point and receptor,

The user inputs receptor-specific terrain heights, selecting the maximum value between the release point and the receptor. NRC codes use an input grid of terrain heights and linearly interpolate the terrain height at input receptor locations.

(The terms " h_{pr} " and " c ", the plume rise above the release point and a downwash correction factor to account for low relative exit velocity, respectively, presumably are the same as defined in RG 1.111, Regulatory Position 2(a). Statements regarding implementation of terrain heights by NRC codes not verified.)

- Whether and, if so, how terrain heights can be assigned to special receptors.

Terrain heights are assigned to each receptor, individually.

Technical Issues Related to Meteorological Data as Input to the AEOLUS3 Model for Short-Term and/or Long-Term X/Q Estimates

Please provide a subject matter expert(s) to discuss the following:

Whether joint frequency distributions (JFDs) for each stability class are directly input to the AEOLUS3 model for estimating short-term accident and long-term routine release X/Qs, or if the code operates on one or more sequential hourly data sets.

Hourly average meteorological data are input as one file; JFDs are not input. (AEOLUS3 generates joint frequency distributions of wind speed and wind direction by atmospheric stability class internally based on the hourly meteorological data input to the model run. The JFDs are the basis of the X/Q calculations, which is similar to the approach used by PAVAN and XOQDOQ. However, the internally-generated JFDs are not necessarily the same as the JFDs presented in COL FSAR Section 2.3 introducing some uncertainty in Staff's use of the latter summaries as input to their confirmatory modeling analysis.)

- If the model actually runs on JFDs, how the frequencies of occurrence of wind speed and wind direction by atmospheric stability class, and how the frequencies of calm wind conditions by stability class, are input to the code.

(N/A based on preceding response.)

- If the model actually runs on sequential hourly data, specify or explain:

- what the limit is on the period of record (POR), presumably in years, that can be input to the code;

(20 years)

- if the POR used for an analysis exceeds the maximum length that can be input to the model, how the modeling results are integrated (or post-processed) to develop both short-term X/Q statistics (e.g., probability distributions and upper bound curves) and long-term statistics that represent the composite data set;

(N/A based on preceding response.)

- if the start/end dates for a POR are constrained to a calendar year (i.e., January 1 thru December 31) or if the start/end dates for a POR can cover a different annual cycle (e.g., July 1 thru June 30);

(User may input any set of meteorological data or length of POR. It is not constrained to annual cycles only.)

- how wind speeds and wind directions are sorted internally by the model (e.g., into wind speed class and direction sector groupings equivalent to a JFD);

(Code produces a JFD from input hourly meteorological data using sixteen standard wind direction sectors, user-supplied wind speed groups, and stability classes A through G.)

- whether the actual hourly wind speed value is used in the X/Q calculation or if the average or maximum wind speed for the equivalent JFD wind speed class is used (and the circumstances in which the average or the maximum wind speed value is selected);

Hourly wind speed observations in the entire meteorological data file are analyzed to determine the average wind speed that corresponds to each stability and wind speed group combination. If there are no actual observations, the average wind speed is set equal to the median of the wind speeds that define the lower and upper limits of the group.

- whether and, if so, how the model utilizes hourly sigma-theta wind data if delta-temperature (stability class) data are missing and, if applicable, the basis for the sigma-theta stability typing scheme; and

(N/A – sigma theta data are not read in and used by the AEOLUS3 code for determining stability class if the primary stability class data are not available. If any such alternate stability class typing is used (e.g., to supplement missing delta-T stability class data), that work would have to be done upstream and justified by the person responsible for developing the validated hourly meteorological data set input to the model.)

- whether and, if so, how missing hourly data are handled and how X/Q results are to be interpreted if individual parameter or joint data recovery is less than the 90 percent criterion specified in RG 1.23.

(User inputs maximum allowable values for wind direction, wind speed, delta-temperature, solar radiation, precipitation. Hours with values greater than a maximum allowable limit are not used in the model calculations. AEOLUS3 does not keep track of data recovery rate. AREVA NP indicated that it is up to the model user to determine data recovery and how to interpret the modeling results if there is < 90% data recovery.)

- Whether JFDs or sequential hourly data for only one wind measurement level can be input to the same AEOLUS3 model run.

- If only one measurement level can be input, specify the nominal wind measurement height.

(Only wind data from one measurement level can be input to the model. The default lowest wind measurement level is 10 meters even if the actual measurement height is different.)

- If more than one measurement level can be input, explain how the model selectively uses the wind speed and wind direction data for ground-level releases and the elevated portion of mixed-mode releases.

(N/A based on preceding response. It is not like ARCON96 in that regard.)

- Wind speed scaling factors internal to the AEOLUS3 model that are used to extrapolate wind speeds measured at one level to an elevated release height when applicable to the elevated portion of mixed-mode releases.

(As in XOQDOQ – the default wind scaling factors are 0.25 for stability classes A thru D, and 0.50 for stability classes E thru G. However, AEOLUS3 also allows for entry of user-specified wind speed scaling factors. AREVA NP acknowledged that a site-specific wind speed profile with height may be different than the profile implied by the default scaling factors but did not necessarily consider it essential to verify the reasonability of the default values because of the code's use of a mean wind speed value for a given wind speed group and other model conservatisms.)

- Regarding mixing height:

- whether the AEOLUS3 model is limited to the input of a single annual average value only or if multiple mixing heights (e.g., seasonal average values) can be entered;

(A single annual average mixing height value is typically input; defaults to 100 m if not provided in the input data. However, if a shorter POR is being evaluated by the model (e.g., a season), then the mixing height value could represent that shorter POR.)

- if the value(s) should represent a morning, afternoon, or daily average mixing height and the technical basis for that approach; and

(N/A - See response and note for the item below.)

- how representative a daily or afternoon average value is of the boundary layer conditions that result in the relatively higher X/Qs that occur primarily at nighttime

(Mixing height, for the most part, does not apply at night. EPA dispersion models assume unlimited mixing potential at night (default to 10,000 m) (i.e., effectively, no plume reflection occurs). However, AEOLUS3 accounts for mixing height (and plume reflection, if applicable) for all hours of the day. So, in that regard, the Staff agrees that use of an average value (i.e., the mean of the morning and afternoon mixing heights) is conservative relative to the higher annual average afternoon mixing height, and that accounting for mixing height during nighttime, stable hours is likewise conservative rather than assuming vertical mixing is unlimited.)

- Whether and, if so, how the mixing height affects the diffusion of ground-level releases and the elevated portion of mixed mode releases:

- in terms of any differences between short-term, accident-related and long-term, routine release-related analyses;

(No difference.)

- as a function of downwind distance;

Single, conservative value provided for inversion layer (mixing height); no change with distance, time of day or stability class. See Section 4.1.5 (Vertical Dispersion and Reflection) of Technical Manual.

(In addition, AREVA NP indicated that while ground-level releases are still subject to plume reflection, such as in short-term accident analysis for CCNPP3, the downwind travel distance would likely have to be significant for a reflection to occur and most receptors (e.g., the EAB and LPZ boundary) are relatively close in and not likely to be affected. The Staff agrees.)

- as a function of time of day;

(See preceding response and note.)

- as a function of stability class (especially for stable conditions); and

(See preceding response and note.)

- in terms of plume reflection.

(All X/Q equations include reflection coefficient (correction) with up to five reflections.)