UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 19, 2015

Mr. Bill Kappel
President, Chief Meteorologist
Applied Weather Associates, LLC
P.O. Box 175
Monument, CO 80132

SUBJECT: PLAN FOR THE AUDIT OF APPLIED WEATHER ASSOCIATES, LLC, REGARDING SITE SPECIFIC PROBABLE MAXIMUM PRECIPITATION DEVELOPMENT IN SUPPORT OF NEAR-TERM TASK FORCE RECOMMENDATION 2.1 FLOOD HAZARD REEVALUATIONS (TAC NO. MF5609)

Dear Mr. Kappel:

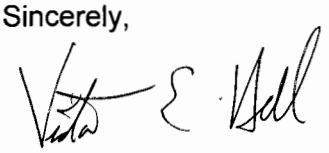
This letter documents the U.S. Nuclear Regulatory Commission (NRC) staff's plan to perform a regulatory audit of Applied Weather Associates, LLC (AWA), from February 23, to February 25, 2015, at NRC Headquarters, in Rockville, MD. This technical audit will be performed consistent with NRC Office of Nuclear Reactor Regulation Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008, (Agencywide Documents Access and Management System (ADAMS) Accession No. ML082900195). The NRC staff will develop an audit summary report to document its observations and conclusions within 90 days of the completion of the audit.

The audit will provide the NRC staff with a better understanding of site-specific probable maximum precipitation (SSPMP) estimates that AWA has done in support of licensee flood hazard reevaluation reports (FHRRs). The audit is intended to support staff reviews of FHRRs that include SSPMP estimates.

The enclosed audit plan outlines the process that will allow the NRC staff to identify additional information potentially necessary for licensees to supplement their FHRRs, and identify any potential technical concerns.

If you have any questions, please contact me at (301) 415-2915 or by e-mail at Victor.Hall@nrc.gov.

Sincerely,



Victor Hall, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Enclosure:
Audit Plan

PLAN FOR THE AUDIT OF APPLIED WEATHER ASSOCIATES, LLC
REGARDING SITE SPECIFIC PROBABLE MAXIMUM PRECIPITATION DEVELOPMENT
IN SUPPORT OF NEAR-TERM TASK FORCE
RECOMMENDATION 2.1 FLOOD HAZARD REEVALUATIONS

## BACKGROUND AND AUDIT BASIS:

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f) "Conditions of license" (referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant as documented in The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident. Recommendation 2.1 in that document recommended that the staff issue orders to all licensees to reevaluate seismic and flooding for their sites against current NRC requirements and guidance. Subsequent Staff Requirements Memoranda associated with Commission Papers SECY 11-0124 and SECY-11-0137, instructed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

The NRC staff is reviewing reevaluated flooding effects for operating reactor sites, using present-day information. A number of NRC licensees have submitted, or are planning to submit, Flood Hazard Reevaluation Reports (FHRRs) that contain site-specific probable maximum precipitation (SSPMP) estimates. The SSPMPs can be used as input for estimating site flooding due to short-duration, local intense precipitation (LIP) storm events and/or longer-duration watershed scale (WS) storm events. The NRC is developing a SSPMP Project Plan intended to provide guidance for evaluating and assessing the technical adequacy of the SSPMP estimates contained in FHRR submittals.

Applied Weather Associated, LLC (AWA) has performed the analyses for the sites that have chosen to apply SSPMPs. The NRC staff plans to conduct a regulatory audit of AWA to inform its development of SSPMP Project Plan and aid in its review of licensees' FHRRs. AWA specializes in meteorological analyses and Geographic Information Systems (GIS) applications with emphasis on Probable Maximum precipitation (PMP) and rainfall analysis.

## AUDIT SCOPE:

This technical audit will be performed consistent with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008. The NRC staff will develop an audit summary report to document its observations and conclusions. The audit is intended to support staff reviews of FHRRs that include SSPMP estimates. The audit process will focus on generic issues that are common to FHRRs. It will allow the staff to identify additional information that may be necessary to supplement FHRRs, and will reduce the need for licensee audits. The results of the audit will also support staff development of internal guidance and acceptance criteria applicable to 10 CFR Part 50.54(f) reviews that include SSPMP estimates.

Enclosure

NRC AUDIT TEAM

| Title | Team Member |
|---|---|
| Team Leader, NRR/JLD | Victor Hall |
| Branch Chief, NRR/JLD | Sheena Whaley |
| Technical Lead | Barbara Hayes |
| Technical Support | Carla Roque-Cruz |
| Technical Support | Scott DeNeale |
| Technical Support | Joe Kanney |
| Technical Support | Shih-Chieh Kao |
| Technical Support | Kevin Quinlan |

The following observers have been invited to attend on behalf of AWA:

- Joe Bellini, Exelon Corporation
- Dean Hubbard, Duke Energy
- Greg Halnon, FirstEnergy Nuclear Operating Company (FENOC)
- Kyle Kaminski, Enercon Services, Inc.
- Colin Keller, FENOC
- Jim Riley, Nuclear Energy Institute (NEI)
- Tom Spink, Tennessee Valley Authority (TVA)
- Representative from Dominion

LOGISTICS:

The audit will be conducted at NRC Headquarters in Rockville, MD on February 23–25, 2015.

Time Charge Information: The auditors will charge their time in HRMS to TAC No. MF5609. This is not a fee billable TAC.

DELIVERABLES:

Audit team members are requested to provide a written outline of recommendations and observations for input to the lead auditor for exit meeting development.

The NRC team will develop an audit summary report to convey the audit results. The report will be placed in ADAMS within 90 days of the completion of the audit (May 26, 2015), and will be publicly available. The audit team members are requested to provide their input to the audit team leader within 14 days following completing of the audit (March 11, 2015).

TEAM ASSIGNMENTS:

The audit will focus on evaluating AWA's general methods, software, and evaluation of key storms that drive SSPMP estimates over specific regions. The technical objectives of the audit include evaluating and assessing AWA methods for:

1. Validation/verification of software used by AWA to analyze storm data;
2. Identifying and quantifying actual and potential storm moisture sources;
3. Determining storm transposition limits;
4. Adjusting available moisture during storms transposition; and
5. Application of professional judgment.

The audit will frame the discussion relative to four identified storm types (General Warm Season, General Cold Season, Hurricanes, and Mesoscale Convective Clusters (MCC)). Questions are organized by the 5 areas of inquiry. The AWA is asked to reference storms that have been selected for discussion or other storms suggested by AWA, as appropriate.

TECHNICAL APPROACH:

The NRC staff developed the following audit questions for AWA:

**Validation/Verification of Software Used by AWA to Analyze Storm Data**

1. Software Quality Management and Verification of the Storm Precipitation Analysis System (SPAS) system
    a. Describe what internal controls were and are included in the development, maintenance and addition of new functionality for SPAS
    b. Describe any quality management system standards such as ISO 9000 or American Society of Mechanical Engineers NQA-1 that AWA adheres to either for development and maintenance of the SPAS system or for SSPMP estimation projects it is used for.
    c. Describe how to verify SPAS storm depth-area-duration (DAD) curves for:
        i. Pre-radar period
        ii. Post-radar period
    d. Has an independent verification of SPAS been performed and are the results available?
    e. Has AWA done internal verifications of SPAS using NOAA Hydro meteorological Report (HMR) or other reports to demonstrate consistency of results with similar established SSPMP or other projects?
    f. Has SPAS and/or SPAS results been presented in peer reviewed journals?
    g. Be prepared to discuss reviews of SSPMP products done by states, or other federal entities.

**Identifying and Quantifying Actual and Potential Storm Moisture Sources**

2. Identification of Moisture Sources
    a. Demonstrate the usage of National Oceanic and Atmospheric Administration (NOAA) Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model (http://ready.arl.noaa.gov/HYSPLIT.php) using selected storms
    b. Describe the subjective judgments of storm representative dew points selection along HYSPLIT tracks. In particular, when multiple gauges are co-located in the region of moisture sources, what are the criteria to follow?
    c. Describe the current collection of historic dew point data (for both gauges and sea surface temperatures). In particular, describe the sufficiency of this data to support dew point selection.
    d. Describe the rationale to examine 6-, 12-, and 24-hour average dew points rather than 12-hour persistent dew point used in NOAA's HMRs. Also explain the reason for selecting 6-, 12-, and 24-hour rather than some other durations. Has a comprehensive analysis been conducted and peer-reviewed to support the conversion from 12-hour persistent dew point to average dew point? In at least one submission (Quad Cities local intense precipitation), 7-degree °F was added onto the U.S. Army Corps of Engineers (USACE) Black Book storms which may result in an over 30 percent reduction of PMP depth. Explain the rationale for this addition, whether it follows standard practice within AWA's approach, and whether it applies to other sites or studies.
    e. Describe further related data requirements for site-specific PMP reviews, e.g.
        i. HYSPLIT map of each short list storm
        ii. The original data of storm representative dew point

3. Maximum Dew Point Climatology
    a. Describe the most current methodology in SPAS. So far, the most detailed description was only provided in the NE/AZ PMP reports. Were these maximum dew point climatology maps peer-reviewed?
    b. Describe the procedures to select annual maximum dew point series at each gage. How many years of records in general do these stations have and what is the minimum length of record.
    c. Explain the purpose of "15th of the Month Adjustment" referenced in the NE PMP report. Was this done on the sample level, or conducted after fitting of a generalized extreme value (GEV) distribution?
    d. Describe the procedures of GEV fitting. Has any goodness-of-fit tests been conducted to verify the results?
    e. Describe the applicability and necessity of PRISM-based spatial interpolation. If a gage station with estimated maximum dew point is available in the region of moisture sources, how would PRISM values compare? Also, discuss whether the current approach could result in excessive smoothing the maximum dew point climatology maps.

f. Describe further related data requirements for site-specific PMP reviews, e.g.
    i. Work sheet at gauge level (before spatial interpolation).
        1. Annual maximum dew point
        2. GEV fitting
        3. Goodness-of-fit test
        4. For each short list storm, this information should be provided for gauges nearest to the locations where the dew climate climatology is looked up for moisture maximization.
    ii. Interpolated maps and analysis of bias at gauge locations

**Determining Storm Transposition Limits**

4. Storm Selection and Transposition
    a. Describe the storm screening methodology
    b. Describe explicit vs. implicit transposition
    c. Discuss how features of the large-scale atmospheric circulation (e.g. semi-permanent high-pressure systems, oscillations such as ENSO & NAO) inform assignment of transposition limits.
    d. Describe further related data requirements for site-specific PMP reviews, e.g.
        i. Long list (including all applicable HMR and Black Book storms)
        ii. Justification if not included in the short list
    e. Describe the procedures for storm selection. Ultimately we would like to establish a workflow to check if all storms have been considered in a particular SSPMP study. Discuss:
        i. Considerations for storm selection for watershed-scale PMP
        ii. Considerations for storm selection for local intense precipitation
    f. Discuss storm transposition limits
    g. Discuss further documentation of storms that are omitted from short lists.

**Adjusting Available Moisture during Storm Transposition**

5. Storm Envelopment
    a. Discuss if undercutting can be allowed with regards to
        i. Envelopment across duration and area at individual points of analysis in the basin.
        ii. Envelopment across a region
        iii. Describe further related data requirements for site-specific PMP reviews, e.g.
    b. Summary table stating when undercutting occurred and the corresponding meteorological justification
    c. Explain DAD envelopment as it was applied in the Nebraska statewide PMP study

6. Topographic Effects
    a. Demonstrate AWA method for moisture adjustment for orographic regions inlcuding:
        i. Development and application of orographic transposition factor (OTF)
        ii. Use of precipitation frequency and climatology data including data sources, data properties (e.g., resolution, accuracy)
        iii. Use of topographic data including data sources, data properties (e.g., resolution, accuracy)
        iv. Detailed walk through for 2-3 case studies
        v. Description of scenarios under which the OTF would be implemented and why.
    b. Demonstrate AWA method for moisture inflow barrier analysis including:
        i. Terrain elevation data set properties (e.g., resolution, accuracy)
        ii. GIS method for terrain analysis
        iii. Subjective aspects of determining "effective barrier height"
        iv. Provide quantitative examples of how implementing the effective barrier height influences the precipitation amounts.

**Application of Professional Judgment**

7. Sensitivity Analysis to Specific Storms

    For the SSPMP estimates (LIP and WS) for Indian Point Energy Center (IPEC) and the suite of Exelon sites in Illinois, the Smethport storm is a key driver in HMR values that is not included in the storm catalogues. Please provide a sensitivity analysis to these results relative to the inclusion of the Smethport storm with variation related to amounts of undercutting. Identify transposition limits for this storm and how they were developed.

    For the storms of interest, describe the regions in which they are likely to influence SSPMP estimates as well as explicit and implicit transposition limits for each. Define the appropriate scales of application: generalized estimates, watershed-based estimates, and local intense precipitation estimates.

8. Uncertainty in SSPMP Estimates

    It is well known that there is considerable uncertainty in PMP estimates. Until recently, there have been no systematic attempts to quantify this uncertainty. A very recent paper (Micovic, et al. 2015) [1] identifies key variables which influence PMP estimates, discusses uncertainties in these variables and proposes a method for assessing overall PMP uncertainties. In light of the discussion and results presented in Micovic et al. (2015), please address the following topics:
    a. How uncertainties in the key variables identified by Micovic et al. (2015) are addressed and accounted for in AWA SSPMP studies

[1] Micovic, Z., Schaefer, M. and Taylor, G. (2015), Uncertainty analysis for Probable Maximum Precipitation estimates, Journal of Hydrology, Vol 521, pp. 360-373, http://dx.doi.org/10.1016/j.jhydrol.2014.12.033

b. Describe the level of uncertainty associated with AWA's SSPMP estimates and how they may vary by region or storm type.

9. Climate Change and SPAS estimates of SSPMP

Climate change has been associated with increases in extreme precipitation events. A recent report on climate change[2] relayed findings that significant increases in heavy precipitation events have been observed in the Northeast, Midwest and Great Plains and average U.S. temperatures are projected to increase from 2 to 4 degrees F in most areas in the next few decades. Some approaches to extreme weather estimation, e.g. physically based regional atmospheric modelling as used in a recent paper[3] are readily adaptable to nonstationary atmospheric processes that affect upper bounds to maximum precipitation.

a. How are trends related to climate change addressed and accounted for in AWA's approach to estimating SSPMPs?
b. Describe how this approach affects AWA's SSPMP estimates and the associated effects on the level of conservativeness. How might this vary by region or storm type?
c. Describe how a warmer and more humid climate affects moisture maximization methods for PMP type storms.
d. How may postulated changes of the climate affect the historical transposition limits of controlling storms?

**Selected Storms for Discussion**

To support the discussion, several storms have been selected as general test cases for this audit. These storms covered various storm types, in which some have been included in the current FHRR submittals while others were only documented in NOAA HMR, the USACE Black Book, and the 2011 USBR report, "Review of Probable Maximum Precipitation Procedures and Databases Used to Develop Hydrometeorological Reports[4]".

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[2] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2 (http://nca2014.globalchange.gov/downloads).

[3] Ishida, K., Kavvas, M., Jang, S., Chen, Z., Ohara, N., and Anderson, M. (2015). "Physically Based Estimation of Maximum Precipitation over Three Watersheds in Northern California: Relative Humidity Maximization Method." *J. Hydrol. Eng.* , 10.1061/(ASCE)HE.1943-5584.0001175 , 04015014.

[4] Review of Probable Maximum Precipitation Procedures and Databases Used to Develop Hydrometeorological Reports, USBR report for the Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, John F. England, Jr., Victoria L. Sankovich, R. Jason Caldwell, 2011, ftp://s5ftp.usbr.gov/jengland/NRC/reports/Review_PMP_Procedures_SE_US.pdf

| Storm Name or Location | Storm Date | Storm Type | Note |
|---|---|---|---|
| Slide Mountain, NY | 3/20/1980 – 3/24/1980 | General (Cool Season) | IPEC WS cool season storm. (SPAS 1259) |
| Alley Spring, MO | 3/17/2008 – 3/20/2008 | General (Cool Season) | Quad Cities Nuclear Power Station (QCNPS) WS cool season storm. Specific questions related to the selection of storm representative dew point and dew point climatology. |
| Warner, OK | 5/6/1943 – 5/10/1943 | General (Warm Season) | QCNPS WS warm season storm. Specific questions related to the selection of storm representative dew point and dew point climatology. |
| Gorham, ME | 10/19/1996 – 10/22/1996 | General (Warm Season) | IPEC WS warm season storm. (SPAS 1025) |
| Edgerton, MO | 7/18/1965 – 7/20/1965 | General (Warm Season) / MCC | QCNPS WS warm season storm. Specific questions related to the selection of storm representative dew point and dew point climatology. |
| Mounds, OK | 5/15/1943 – 5/20/1943 | MCC | Both QCNPS WS and LIP storms. |
| Tyro, VA | 8/19/1969 | MCC | USACE Black Book Storm (NA 2–23), not included in the current analysis for IPEC. |
| Port Allegheny, PA (Smethport) | 7/17/1942 – 7/18/1942 | MCC | World record rainfall event. Questions about transposition limits. |
| Yankeetown, FL (Hurricane Easy) | 9/3/1950 – 9/7/1950 | Hurricane | USACE Black Book Storm (SA 5-8), not included in current analysis for IPEC. Questions about transposition limits. |
| Zerbe, PA (Hurricane Agnes) | 6/19/1972 – 6/23/1972 | Hurricane | IPEC WS warm season storm. |
| Hurricane Irene | 8/27/2011 – 8/29/2011 | Hurricane | IPEC WS warm season storm (SPAS 1224) |
| Hurricane Floyd, areas of NC and VA | 9/16/1999 | Hurricane | |

Using these storms as examples, this audit will focus on the following general aspects of AWA SSPMP analysis. It is expected that AWA shall bring detailed information of these storms to facilitate efficient discussion.

PROPOSED SCHEDULE

Location:
U.S. Nuclear Regulatory Commission
One White Flint North, O-16B4 Conference Room
11555 Rockville Pike
Rockville, Maryland 20852

**Day 1: Monday, February 23, 2015**

| Time | Topic | Led by |
|---|---|---|
| 10:00am - 10:30am | Entrance Meeting | NRC |
| 10:30am - 11:00am | AWA Opening Presentation | AWA |
| 11:00am - 12:00pm | Audit Team Activities | NRC/AWA |
| 12:00pm - 1:00pm | LUNCH | |
| 1:00pm - 2:30pm | Audit Team Activities | NRC/AWA |
| 2:30pm - 2:45pm | BREAK | |
| 2:45pm - 4:00pm | Audit Team Activities | NRC/AWA |
| 4:00pm - 4:15pm | Audit Team Meeting | NRC |
| 4:15pm - 4:30pm | Audit Team Daily Debrief with Vendor | NRC |
| 4:30pm | Adjourn Day 1 of Meeting | |

**Day 2: Tuesday, February 24, 2015**

| Time | Topic | Led by |
|---|---|---|
| 8:30am - 10:00am | Audit Team Activities | NRC/AWA |
| 10:00am - 10:15am | BREAK | |
| 10:15am - 12:00pm | Audit Team Activities | NRC/AWA |
| 12:00pm - 1:00pm | LUNCH | |
| 1:00pm - 2:30pm | Audit Team Activities | NRC/AWA |
| 2:30pm - 2:45pm | BREAK | |
| 2:45pm - 4:00pm | Audit Team Activities | NRC/AWA |
| 4:00pm - 4:15pm | Audit Team Meeting | NRC |
| 4:15pm - 4:30pm | Audit Team Daily Debrief with Vendor | NRC |
| 4:30pm | Adjourn Day 1 of Meeting | |

**Day 3: Wednesday, February 25, 2015**

| Time | Topic | Led by |
|---|---|---|
| 8:30am - 10:00am | Audit Team Activities | NRC/AWA |
| 10:00am - 10:15am | BREAK | |
| 10:15am - 12:00pm | Audit Team Activities | NRC/AWA |
| 12:00pm - 1:00pm | LUNCH | |
| 1:00pm - 1:45pm | Audit Team Activities | NRC/AWA |
| 1:45pm - 2:00pm | Audit Team Meeting | NRC |
| 2:00pm - 2:30pm | Exit Meeting | NRC |
| 2:30pm | End of Audit | |

If you have any questions, please contact me at (301) 415-2915 or by e-mail at Victor.Hall@nrc.gov.

Sincerely,

***/RA/***

Victor Hall, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Enclosure:
Audit Plan

DISTRIBUTION:
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| | | | |
|---|---|---|---|
| VHall, NRR | RKuntz, NRR | SWhaley, NRR | LQuinn-Willingham, NRO |
| CCook, NRO | ARivera, NRO | KErwin, NRO | MFranovich, NRR |
| BHayes, NRO | JBowen, NRR | KQuinlan, NRO | JKanney, RES |

**ADAMS Accession No.: ML15041A080**

| OFFICE | NRR/JLD/JHMB/PM | NRR/JLD/JHMB/LA | NRR/JLD/JHMB/PM | NRR/JLD/JHMB/BC | NRR/JLD/JHMB/PM |
|---|---|---|---|---|---|
| NAME | VHall | SLent | RKuntz | SWhaley | VHall |
| DATE | 02/11/15 | 02/13/15 | 02/19/15 | 02/18/15 | 02/19/15 |

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