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U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Braidwood Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Subject: License Amendment Request to Utilize the TORMIS Computer Code Methodology

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit or early site permit," and 10 CFR 50.59, "Changes, tests, and experiments," paragraph (c)(2)(viii), Exelon Generation Company, LLC, (EGC) requests amendments to Renewed Facility Operating License Nos. NPF-72 and NPF-77 for Braidwood Station, Units 1 and 2. This amendment request proposes to revise the Braidwood Station licensing basis for protection from tornado-generated missiles. Specifically, the Updated Final Safety Analysis Report (UFSAR) will be revised to identify the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of unprotected plant structures, systems and components (SSCs) and to describe the results of the Braidwood Station site-specific tornado hazard analysis. The results from the Braidwood Station TORMIS analysis will be used to credit unprotected equipment for post-tornado safe shutdown. Note that there are no Technical Specifications changes associated with this request.

The Braidwood Station TORMIS analysis utilizes a probabilistic approach performed in accordance with the guidance described in the NRC TORMIS Safety Evaluation Report dated October 26, 1983, as clarified by Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008.

Attachment 1 to this letter provides an evaluation of the proposed changes and a summary of the supporting analysis.

The proposed amendment has been reviewed by the Braidwood Station Plant Operations Review Committee in accordance with the requirements of the EGC Quality Assurance Program.

In accordance with 10 CFR 50.91, "Notice for public comment; State consultation," paragraph (b), EGC is notifying the State of Illinois of this application for license amendment by transmitting a copy of this letter and its attachments to the designated State of Illinois official.

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It should be noted that Braidwood Station issued Event Notification Report No. 51959, dated May 25, 2016, "Discovery of Non-Conforming Conditions During Tornado Hazards Analysis." This Notification Report documents non-conforming conditions in the plant design such that specific Technical Specifications equipment on both units is considered to be inadequately protected from tornado missiles. These conditions are being addressed in accordance with Enforcement Guidance Memorandum 15-002, "Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance," Revision 1, dated February 7, 2017 and DSS-ISG-2016-01, "Clarification of Licensee Actions in Receipt of Enforcement Discretion per Enforcement Guidance Memorandum EGM 15-002, 'Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance,'" Draft Revision 1, dated February 2017.

EGC requests approval of the proposed license amendment request within one year of this submittal date; i.e., by February 1, 2019; which meets the timeframe specified in the EGM for addressing tornado missile non-compliances. Once approved, the amendment shall be implemented within 90 days.

A summary of regulatory commitments is contained in Attachment 1A of this letter. Should you have any questions concerning this letter, please contact Joseph A. Bauer at (630) 657-2804.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 1st day of February 2018.

Respectfully,

David M. Gullott
Manager – Licensing
Exelon Generation Company, LLC

Attachments:		
	Attachment 1	Evaluation of Proposed Changes
	Attachment 1A	Summary of Regulatory Commitments
	Attachment 1-1	TORMIS Results Tables 1-4
	Attachment 1-2	TORMIS Results Figures 1-8
	Attachment 1-3	Draft Markup of Updated Final Safety Analysis Report Pages

cc: NRC Regional Administrator, Region III
NRC Senior Resident Inspector, Braidwood Station
Illinois Emergency Management Agency – Division of Nuclear Safety

ATTACHMENT 1
Evaluation of Proposed Changes

Subject: License Amendment Request to Utilize the TORMIS Computer Code Methodology

1.0 SUMMARY DESCRIPTION

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit or early site permit," and 10 CFR 50.59, "Changes, tests, and experiments," paragraph (c)(2)(viii), Exelon Generation Company, LLC, (EGC) requests amendments to Renewed Facility Operating License Nos. NPF-72 and NPF-77 for Braidwood Station, Units 1 and 2. This amendment request proposes to revise the Braidwood Station licensing basis for protection from tornado-generated missiles. Specifically, the Updated Final Safety Analysis Report (UFSAR) will be revised to identify the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of unprotected plant structures, systems and components (SSCs); and to describe the results of the Braidwood Station site-specific tornado hazard analysis. The results from the Braidwood Station TORMIS analysis will be used to credit unprotected equipment for post-tornado safe shutdown. Revisions to the affected UFSAR sections will be performed in accordance with 10 CFR 50.59, "Changes, tests and experiments," after approval of the proposed amendment. Note that there are no Technical Specifications changes associated with this request.

The Braidwood Station TORMIS analysis utilizes a probabilistic approach performed in accordance with the guidance described in the NRC TORMIS Safety Evaluation Report (SER) dated October 26, 1983 (Reference 1), as clarified by Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008 (Reference 2). The Braidwood Station TORMIS analysis was performed by Applied Research Associates, Inc. (ARA) using TORMIS_14, an updated version of the original EPRI NP-2005 (Reference 5) version of the code.

2.0 DETAILED DESCRIPTION

The proposed revision to the Braidwood Station tornado licensing basis is based on the NRC approved methodology as detailed in topical reports: EPRI NP-768, "Tornado Missile Risk Analysis," May 1978 (Reference 3), EPRI NP-769, "Tornado Missile Risk Analysis – Appendices," May 1978 (Reference 4) and EPRI NP-2005, "Tornado Missile Risk Evaluation Methodology," August 1981 (Reference 5). These reports address utilization of the TORMIS Computer Code. TORMIS uses a Monte Carlo simulation technique to assess, through a Probabilistic Risk Assessment (PRA) methodology, the probability of multiple missile hits causing unacceptable damage to unprotected safety-significant components at a plant. For each tornado strike, the tornado windfield is simulated, missiles are injected and flown, and missile impacts on structures and equipment are analyzed. These models are linked to form an integrated, time-history simulation methodology. By repeating these simulations, the frequencies of missiles impacting and damaging individual components (targets) and groups of targets are estimated. Statistical convergence of the results is achieved by performing multiple replications with different random number seeds. The statistical confidence bounds of the results can then be estimated using conventional methods.

For the Braidwood Station TORMIS analysis, the plant was divided into two separate models because of the remote location of the Essential Service Water (SX) discharge pipes in the middle of the Ultimate Heat Sink (UHS) cooling pond, nearly a mile from the closest other safety-significant targets. The Main Site Model is used to analyze all targets on and around the Reactor and Auxiliary Buildings. The SX Model is used to analyze the SX discharge pipe targets only. The plant safety envelope for the SX Model has the same area and shape as the envelope for the Main Site Model but is centered on the SX discharge pipes to allow the use of the same tornado hazard inputs for both models." The information presented below is primarily focused on the Main Site Model.

Over 27.7 billion TORMIS tornado missile simulations were performed for each of the Braidwood Station models. Each simulation consists of sampling and flying a missile for a simulated tornado strike on the plant. A total of 2.31 million tornado strikes on the plant were simulated in the TORMIS analysis for each of the models.

The TORMIS results are estimated frequencies of tornado missile hit and damage, and have the units of yr-1. They represent the modeled-output frequencies of tornado missile hit/damage to a target, or group of targets. There were 74 individual unprotected safety-significant targets modeled in TORMIS as shown in Attachment 1-1, Table 1, "TORMIS Results by Individual TORMIS Target." The average missile hit and damage frequencies were developed from 60 TORMIS replications.

Table 2-1 below shows the arithmetic sum of damage frequencies for all target groups affecting the individual units (i.e., Unit 1 plus common unit components and Unit 2 plus common unit components). Note that these values include the damage frequency from the SX Model for the SX discharge pipes which are the only common unit targets at Braidwood Station (see Attachment 1-1, Table 3). A damage frequency acceptance value of 1.0E-06 per year was established in the Standard Review Plan, Section 2.2.3, "Evaluation of Potential Accidents." The acceptance value of 1.0E-06 per year was also endorsed in Reference 2 and Reference 8.

As shown in Table 2-1, if no additional missile protection is provided for the unprotected safety-significant targets, the damage frequency exceeds the acceptance value of 1.0E-06 per year for both Unit 1 and Unit 2; however, if the Refueling Water Storage Tank (RWST) hatches (i.e., Attachment 1-1, Table 1, Target Numbers 1 and 2) are protected, the damage frequency acceptance criteria are satisfied for both units. Braidwood Station will install missile protection on the Unit 1 and Unit 2 RWST hatches prior to implementation of the TORMIS methodology after approval of the proposed amendment. None of the other safety-significant targets are assumed to have additional tornado missile protection installed.

Table 2-1
Mean Damage Frequency by Unit
(With RWST Hatches Protected)

	Damage Frequency (yr^{-1})	
	Unit 1	Unit 2
Arithmetic Sum over all Target Groups	1.19E-06	1.29E-06
Arithmetic Sum Following Protection of RWST Hatches	5.26E-07	5.80E-07

Additional information regarding the TORMIS analysis results is presented in Section 3.3.3 below.

The current tornado design basis and licensing basis for tornado missile protection is discussed in the following UFSAR sections.

UFSAR Section 3.3, "Wind and Tornado Loadings"
UFSAR Section 3.5, "Missile Protection"

As noted above, these UFSAR sections will be revised in accordance with 10 CFR 50.59 to incorporate the TORMIS analysis after approval of the proposed amendment. Draft markups of the proposed changes to these UFSAR sections are presented in Attachment 1-3 for information. Note that the Braidwood Station UFSAR is a common "Byron/Braidwood" UFSAR. The majority of the UFSAR revisions implemented in support of the recently approved Byron Station TORMIS license amendment are also applicable to Braidwood Station. The marked up UFSAR pages presented in Attachment 1-3 only show revisions to the "current" UFSAR pages which have already incorporated the Byron Station TORMIS-related changes.

Other UFSAR sections, impacted by the changes in Sections 3.3 and 3.5, will also be revised in accordance with 10 CFR 50.59 after approval of the proposed amendment; however, are not included with this submittal.

3.0 TECHNICAL EVALUATION

The evaluation and description of the Braidwood Station TORMIS analysis and the associated results supporting the proposed UFSAR changes, is presented below in the following sections.

Section 3.1, "Current Licensing Basis for Tornado Missile Protection," describes the current tornado missile protection licensing basis.

Section 3.2, "Tornado Missile Concerns at Braidwood Station Prompting TORMIS Analysis," briefly describes the past issues pertaining to Braidwood Station missile protection which are, in part, prompting this request.

Section 3.3, "TORMIS Methodology and Analysis Results," summarizes the TORMIS methodology, including the use of Boolean Logic. This section also summarizes the analysis results and confirms compliance with the TORMIS SER (Reference 1) and NRC RIS 2008-14 (Reference 2).

It is worthy to note that the Braidwood Station TORMIS analysis closely parallels the Byron Station TORMIS analysis documented in Reference 13. In Reference 14, EGC also responded to an NRC request for additional information regarding the Byron Station TORMIS analysis. The information provided in Reference 14 has been reviewed and incorporated in the below evaluation where applicable.

3.1 Current Licensing Basis for Tornado Missile Protection

The current licensing basis for tornado missile protection is presented in UFSAR Sections 3.5.3, "Barrier Design Procedures," and 3.5.4, "Analysis of Missiles Generated by a Tornado." Most safety related systems and components are located inside structures designed to protect them from tornado-generated missiles as discussed in UFSAR Section 3.5.3.

UFSAR Section 3.5.4 describes the licensing basis for safety-related components located outdoors. Section 3.5.4 states the following:

> *"Effects of tornado missiles have been assessed for safety-related components located outdoors. These components are the SXCTs [essential service water cooling towers] (Byron only), the emergency diesel generator exhaust stacks, the emergency diesel generator ventilation and combustion air intakes, the emergency diesel generator crankcase vents, and the main steam safety and power operated relief valve tailpipes (Braidwood only)."*

Section 3.5.4 provides a discussion addressing the existing configuration and why the lack of tornado missile protection is acceptable.

3.2 Tornado Missile Concerns at Braidwood Station Prompting TORMIS Analysis

In NRC Inspection Report, "Byron Station, Units 1 and 2, Integrated Inspection Report 05000454/2009004; 05000455/2009004," dated November 5, 2009, Byron Station received a non-cited violation, NCV 05000454/2009004-02; 05000455/2009004-02, for failure to protect the Emergency Diesel Generator (EDG) Diesel Oil Storage Tank (DOST) vent lines from tornado-generated missiles. During the extent of condition review to address this violation, additional safety related pipes vulnerable to tornado-generated missiles were identified (i.e., the Steam Generator Power Operated Relief Valve (PORV) tailpipes, the Main Steam Safety Valve (MSSV) tailpipes, and the Auxiliary Feedwater (AF) Diesel exhaust stacks). These same missile vulnerabilities were also applicable to Braidwood Station. Compensatory measures regarding tornado missile protection for the Diesel Oil Storage Tank vent lines were discussed in Braidwood Station Condition Report AR 01051105, "Potential Compensatory Measures for DOST Vent Lines," dated March 31, 2010. Braidwood Station Operability Evaluation 10-004, "DOST-DG Vent Lines Crimp vs Break," also addressed tornado missile concerns; confirmed operability and has been closed.

On May 25, 2016, Braidwood Station issued Event Notification Report No. 51959, "Discovery of Non-Conforming Conditions During Tornado Hazards Analysis." This Notification Report documents non-conforming conditions in the plant design such that specific Technical Specifications equipment on both units is considered to be inadequately protected from tornado missiles. These conditions are being addressed in accordance with Enforcement Guidance Memorandum 15-002, "Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance," Revision 1, dated February 7, 2017 (Reference 9) and DSS-ISG-2016-01, "Clarification of Licensee Actions in Receipt of Enforcement Discretion Per Enforcement Guidance Memorandum EGM 15-002, 'Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance,'" Revision 1, dated November 2017 (Reference 10).

To resolve the above concerns, Braidwood Station has decided to pursue NRC approval to utilize the TORMIS Computer Code methodology for assessing tornado-generated missile protection of the Braidwood Station SSCs. Unprotected targets needed for safe shutdown after a tornado are included in the TORMIS analysis. NRC approval of the TORMIS methodology will allow Braidwood Station to avoid modifications to provide tornado missile protection to the subject unprotected equipment. The appropriate sections of the UFSAR will then be modified under the 10 CFR 50.59 process to reflect these results. In addition, as noted in RIS 2008-14, "Once the TORMIS methodology has been approved for the plant and incorporated in the plant licensing basis, it can be used to address additional tornado missile vulnerabilities identified in the future without seeking NRC approval, provided its use is consistent with the approved licensing basis of the plant."

3.3 TORMIS Methodology and Analysis Results

As noted in Section 2.0 above, TORMIS uses a Monte Carlo simulation technique to assess, through a PRA methodology, the probability of multiple missile hits causing unacceptable damage to unprotected safety-significant components at a plant. Over 27.7 billion TORMIS tornado missile simulations were performed for each of the Braidwood Station models (i.e., Main Site Model and SX Model). Each simulation consists of sampling and flying a missile for a simulated tornado strike on the plant. A total of 2.31 million tornado strikes on the plant were simulated in the TORMIS analysis for each of the models.

The TORMIS results are estimated frequencies of tornado missile hit and damage. They represent the modeled-output frequencies of tornado missile hit/damage to a target, or group of targets. There were 74 individual unprotected safety-significant targets modeled in TORMIS. The average missile hit and damage frequencies were developed from 60 TORMIS replications.

The TORMIS results for the 74 individual safety-significant targets are presented in Attachment 1-1, Table 1, "TORMIS Results by Individual TORMIS Target." Note that, although Braidwood Station and Byron Station are of similar design, Byron Station had a significantly larger number of unprotected targets (i.e., 153 targets) primarily due to the design of the SX Cooling Towers.

3.3.1 Target Hit and Damage Frequency

Target missile hit frequencies, shown in Attachment 1-1, Table 1, reflect the frequency of at least one tornado missile hitting a target over a period of one year. For very large targets, tornado-generated missiles are likely to hit the building for almost every tornado strike and hence the missile hit frequency may approach or be essentially equal to the tornado strike frequency for such targets. As the target size reduces, as the target is shielded by other structures, or if only one surface of the target is exposed, the missile hit frequency reduces accordingly. In general, tornado missile hit frequencies are dependent on many geometrical factors as well as missile types, numbers, and proximity. The degree to which the elevation of the target is above the elevation of the nearby missile sources can also be a critical factor.

The damage frequencies, shown in Attachment 1-1, Table 1, reflect the modeling of damage in TORMIS. For many targets, there is a notable reduction in the damage frequency from the hit frequency. The term "target damage" is used in a general sense to mean any damage (or "loss of function") criteria caused by a tornado missile hitting the target. Target damage is not necessarily the same as target hit, but hit can equal damage for fragile equipment. The accepted (i.e., built-in) TORMIS penetration, spall, and perforation equations were used to evaluate damage for selected targets. Missile impact and velocity exceedance was also used to evaluate damage for several targets.

It should be noted that the damage frequency values for the Division 1 and Division 2 MEER ventilation system exhaust openings for each unit (i.e., Attachment 1-1, Table 1, Target Numbers 63, 64, 67 and 68) assume some amount of acceptable tornado missile damage. The MEER exhaust openings were modeled in TORMIS using the pipe penetration feature to determine the missile damage frequency. When using the pipe penetration feature, exhaust system components (e.g., HELB and/or fire dampers) within the wall opening may be impacted such that the exhaust path is blocked due to physical damage or debris accumulation. Necessary equipment, such as instrument inverters and battery chargers, are contained in the MEERs; therefore, manual action is relied on to restore ventilation. The associated manual actions entail simple activities to open doors (to provide an exhaust path) and restart supply fans.

Structural response damage can be evaluated within TORMIS using the results from offline structural response calculations. For the Braidwood Station TORMIS analysis, a finite element analysis (FEA) was performed to provide the required missile damage threshold velocity for each missile type to cause damage to three different types of targets (shown below). Specifically, the FEA was performed to determine the critical impact velocities for crimping damage. The critical impact velocity is defined as the minimum velocity required to crimp the pipe to its critical area. In that the intended purpose of all the targets is to release exhaust products, the critical area is the area at which proper target function would be impeded. Analyses were performed to assess three target structures subjected to a select seven TORMIS missiles. These fragility results were extended to the remaining TORMIS missiles using a conservative energy scaling approach. The fragility results are used as inputs to the TORMIS analyses of the three targets. These three target types represent 12 of the 74 targets modeled for the analysis. The three target types evaluated for crimping in the finite element analysis include:

- Diesel Auxiliary Feed Pump (DAFP) exhaust pipe (Targets 59 and 61)
- DAFP exhaust cover plates (Targets 60 and 62)
- Power Operated Relief Valve (PORV) tailpipes (Targets 43-50)

For these targets, damage is evaluated by comparing the missile velocity to the damage threshold velocity for the particular missile type and target group. If the missile velocity meets or exceeds 90% of the critical velocity, it is scored as damage. No damage is scored if the velocity of the impacting missile is less than 90% of the critical velocity (developed in the analysis). The critical closure values are 60% for the DAFP and 90% for the PORVs.

The following conservatisms were applied when determining the damage threshold velocities:

- In general, the finite element analysis missile models were built to be conservatively strong and stiff given the materials and connections used in their structure. Conversely, target models were built conservatively to maximize the degree of potential crimping.

- The threshold velocity for missiles causing damage to the DAFP exhaust pipes, DAFP exhaust cover plates and PORV tailpipes were input into TORMIS as 90% of the critical velocities calculated in the finite element analysis.

UFSAR Table 3.5-4, "Impact Velocities of Design-Basis Tornado-Generated Missiles," provides a list of the Design-Basis tornado missiles and their associated assumed horizontal impact velocities. It should be noted that TORMIS does not use the missile velocities listed in Table 3.5-4 of the UFSAR. Instead, TORMIS simulates 3-D missile trajectories by integrating the equations of motion. Simulated missile trajectories consider the physical properties of each missile, including missile dimensions, weight and aerodynamic shape as they are released into a simulated tornado wind field. This approach produces simulated missile velocities at impact that include site specific missile sources and target characteristics.

In TORMIS, the damage threshold velocity can be specified for each target and each missile type. This approach was built into TORMIS to allow for target-specific damage calculations where analysis outside of TORMIS could be used to determine the missile impact velocity thresholds that could produce failure of the target. The damage threshold velocities are input to TORMIS for each target-missile pair.

There was no attempt to show that the above three unprotected targets were capable of withstanding UFSAR missile impact design velocities. The UFSAR missile velocities are still retained as they are applicable for the Design Basis structures (i.e., non-TORMIS targets). The purpose of the finite element analysis is to determine the missile hit velocity for each TORMIS missile that results in unacceptable crimping damage of the three subject targets.

3.3.2 Boolean Logic Approach

Hit and damage frequencies for groups of targets evaluated in TORMIS are commonly combined using Boolean operators (U and ∩) to aid in summarizing the results and understanding the effects of the system redundancies. The union (U) operator means that if any one of the targets is damaged in a tornado, the system is assumed to fail. The intersection (∩) operator means that all the intersected components must be damaged in a tornado strike for the system to fail. Combinations of union and intersection operators can be put together to describe multi-component system failure logic for plant systems and subsystems. Note that no Boolean combinations presented in the Braidwood Station analysis use the intersection (∩) operator.

Several safety-significant components were broken into multiple targets within the Braidwood Station TORMIS models to account for different parts of single systems or to account for multiple failure modes of individual components. In these cases, Boolean union logic is used to prevent over counting of tornado missile damage.

Boolean union logic is applied to each TORMIS simulated tornado to determine if the missile damage results in a loss of function within each target group. For example, the unprotected PORV tailpipes are modeled as two separate targets to address two separate failure modes: 1) pipe penetration pass through, and 2) crimping due to velocity exceedance. A TORMIS tornado simulation that results in either missiles passing through the tailpipe opening (i.e., pipe penetration failure mode) or causes unacceptable crimping of the tailpipe (i.e., velocity exceedance failure mode) results in loss of PORV function. If both of these targets are failed in the same simulated tornado, only a single failure is counted towards the damage frequency for the system for that tornado; therefore, the Boolean Union logic is used to account for these two failures as a single loss of PORV function when determining the damage frequency for that PORV target group.

The 74 individual targets were grouped together into 26 groups according to target type and/or function. Attachment 1-1, Table 2, "Average Hit and Damage Frequency (per year) for Target Groups," presents the missile hit and damage frequencies for the 26 target groups as previously defined in Attachment 1-1, Table 1 (i.e., the frequency values for each of the 26 groups in

Table 2 are the Boolean union of the individual target damage frequencies for those targets assigned to each group as shown in Table 1). These values are shown graphically in Attachment 1-2, Figure 2, "Target Group Hit and Damage Frequencies."

3.3.3 TORMIS Analysis Results

The final results for the damage frequency for all Braidwood Station target groups, utilizing the Boolean Logic approach, are presented in Attachment 1-1, Table 3, "Mean Damage Frequency (per Year) for Braidwood Station Target Groups."

Table 3.3.3-1 below shows a summary of the arithmetic sum of damage frequencies for all target groups affecting the individual units (i.e., Unit 1 plus common unit components and Unit 2 plus common unit components). As shown in Table 3.3.3-1, if no additional missile protection is provided for the unprotected safety-significant targets, the damage frequency exceeds the acceptance value of 1.0E-06 per year for both Unit 1 and Unit 2; however, if the RWST hatches (i.e., Attachment 1-1, Table 1, Target Numbers 1 and 2) are protected, the damage frequency acceptance criteria is satisfied for both units. Braidwood Station will install missile protection for the RWST hatches prior to implementation of the TORMIS methodology after approval of the proposed amendment. None of the other safety-significant targets are assumed to have additional tornado missile protection installed.

Table 3.3.3-1
Mean Damage Frequency

	Damage Frequency (yr^{-1})	
	Unit 1	Unit 2
Arithmetic Sum over all Target Groups	1.19E-06	1.29E-06
Arithmetic Sum Following Protection of RWST Hatches	5.26E-07	5.80E-07
*Composite Site Damage Frequency for all Target Groups Following Protection of RWST Hatches	9.96E-07	

* The composite site damage frequency value is provided for information only.

Note that the acceptance criterion is applied on a unit-specific basis as documented in the NRC Safety Evaluation for use of the TORMIS methodology at the Donald C. Cook Nuclear Plant; i.e., in a letter from J. F. Stang (NRC) to R. P. Powers (Indiana Michigan Power Company), "Donald C. Cook Nuclear Plant, Units 1 and 2 – Issuance of Amendments," dated November 17, 2000 (Reference 12); and at Byron Station; i.e., in a letter from Joel S. Wiebe (NRC) to B. C. Hansen (EGC), "Byron Station, Unit Nos. 1 and 2 – Issuance of Amendments Regarding Use of TORMIS for Assessing Tornado Missile Protection," dated August 10 2017 (Reference 15).

It is worthy to note that the composite site damage frequency (following installation of missile protection for the RWST hatches) also meets the acceptance criteria. The composite site value is simply the sum of the Unit 1 and Unit 2 damage frequencies minus the damage frequency of common unit targets such that the common unit target damage frequencies are not counted twice. The SX Discharge Pipes are the only common unit targets at Braidwood Station (see Attachment 1-1, Table 3).

Specifically: Composite Site Damage Frequency = 5.26E-07 + 5.80E-07 – 1.10E-07 = 9.96E-07.

In Reference 14, Byron Station specifically validated applying the acceptance criteria on a unit-specific basis. Similar to Byron Station, multiple time periods for Braidwood Station correspond to outage and non-outage conditions. Outage time periods have additional missile sources, which are treated by introducing additional potential missiles in the appropriate zones that reflect materials, equipment, new trailers, etc. that exist during outage conditions. These potential outage missile sources are modeled in distinct TORMIS runs representing outage time periods. Three time periods were simulated with TORMIS: (1) Unit 1 in an outage state with Unit 2 operational; (2) Unit 2 in an outage state with Unit 1 operational; and (3) Unit 1 and Unit 2 operational. Based on review of outage times, each unit was conservatively assumed to be in an outage condition 18% of the time. These three time periods were combined to calculate a per-unit and composite site damage frequency, consistent with the methodology in NP-2005 (Reference 5).

3.3.4 TORMIS Analysis Conservatisms

There are many conservatisms in the TORMIS modeling to offset the simplification and limitations of TORMIS. The Braidwood Station TORMIS analysis is conservative for the following reasons:

1. In TORMIS, the effects of local obstructions, buildings, and structures are neglected in simulating the tornado winds. Thus, for example, tornado winds flow through the Turbine Building without consideration of either terrain/site roughness or blockage/interference of the reinforced concrete and heavy steel frame structures.

2. All the postulated missiles at Braidwood Station were treated as minimally restrained in which each sampled missile is injected near the peak aerodynamic force, thus maximizing the transport range and impact speed and, consequently, the missile hit and damage frequency.

3. A 100% missile inventory method was used for structure-origin and zone-origin missiles. The approach for structure-origin missiles conservatively assumes that all the structural missiles become minimally restrained for high intensity tornadoes. A maximum number of 363,778 missiles are simulated for the EF 1- 5 tornadoes. The missile density considers all missile sources to a distance of 2500 feet and covers all land areas around the targets.

4. Outage related increases in missile populations were estimated through observation of outage missiles during the walkdown and interviews with Braidwood Station staff regarding the staging of outage related equipment and materials. These outage related missile populations were included in the analysis using a temporal averaging approach. A conservative 5% increase in the mean surveyed missile population was used for all zone and structure origin missiles.

5. The missile injection heights used in the study were chosen conservatively. All missiles that originate from structures are injected into the tornado wind field at the appropriate height above grade.

6. The TORMIS transport model produces missile trajectories and missile impact speeds that are conservative when compared to ballistic (drag only) trajectory models. The highest missile speeds attained in TORMIS easily exceed the missile speeds adopted by the NRC for deterministic design.

7. The size of the safety targets vulnerable to "offset" hits was increased to account for "offset" hits. These safety components were increased in size by 1.5 feet for each free face in the three-dimensional modeling. This TORMIS modeling approach therefore conservatively estimated the damage to these targets for near misses by tumbling tornado missiles.

8. The analysis conservatively did not increase the size of missile shielding targets for offset hits. This approach produces a conservative result in compliance with the RIS comment on "tumbling missiles."

9. Statistical convergence of the TORMIS damage frequencies has been achieved for Braidwood Station through 27.7 billion tornado missile simulations.

10. The analysis uses of 90% of the critical missile velocities for evaluation of crimping damage to the DAFP exhausts and PORV exhausts.

11. In general, the finite element analysis missile models were built to be conservatively strong and rigid. Conversely, target models were built to be conservatively weak to maximize the degree of potential crimping.

12. The TORMIS results for damage frequency also contains inherent conservatism. This conservatism stems from the assumption that a tornado missile strike that results in "target damage" also causes a radioactive release rather than performing specific evaluations to determine whether the damage can actually cause a release.

The degree of conservatism associated with these combined items has not been quantified; however, the net effect of eliminating or reducing these conservatisms is expected to result in a notable reduction in the TORMIS methodology estimated tornado missile damage frequencies for Braidwood Station.

3.3.5 Compliance with the NRC Safety Evaluation Report (SER) Acceptance Criteria

In Reference 1 (i.e., the TORMIS SER), the NRC stated that licensees using the EPRI approach (i.e., the TORMIS methodology) must consider the following points and provide the following information:

1. *Data on tornado characteristics should be employed for both broad regions and small areas around the site. The most conservative values should be used in the risk analysis or justification provided for those values selected.*

2. *The EPRI study proposes a modified tornado classification, F'-scale, for which the velocity ranges are lower by as much as 25% than the velocity ranges originally proposed in the Fujita, F-scale. Insufficient documentation was provided in the studies in support of the reduced F'-scale. The F-scale tornado classification should therefore be used in order to obtain conservative results.*

3. *Reductions in tornado wind speed near the ground due to surface friction effects are not sufficiently documented in the EPRI study. Such reductions were not consistently accounted for when estimating tornado wind speeds at 33 feet above grade on the basis of observed damage at lower elevations. Therefore, users should calculate the effect of assuming velocity profiles with ratios V_o (speed at ground level) / V_{33} (speed at 33 feet elevation) higher than that in the EPRI study. Discussion of sensitivity of the results to changes in the modeling of the tornado wind speed profile near the ground should be provided.*

4. *The assumptions concerning the locations and numbers of potential missiles presented at a specific site are not well established in the EPRI studies. However, the EPRI methodology allows site specific information on tornado missile availability to be incorporated in the risk calculation. Therefore, users should provide sufficient information to justify the assumed missile density based on site specific missile sources and dominant tornado paths of travel.*

5. *Once the EPRI* [i.e., TORMIS] *methodology has been chosen, justification should be provided for any deviations from the calculational approach* [i.e., from the original EPRI methodology].

The following information summarizes how the Braidwood Station TORMIS analysis satisfies the above criteria.

1. *Data on Tornado Characteristics Employed to Identify Braidwood Station Sub-Region*

   A site-specific analysis has been performed to generate a tornado hazard curve for Braidwood Station and a data set for the TORMIS analysis. The National Oceanic Atmospheric Administration (NOAA) Storm Prediction Center Severe Weather Database was used to identify a homogenous sub-region around the station. Tornadoes have been mapped for a large region and statistical tests have been performed to identify a suitable sub-region. The sub-region tornado occurrence rate, EF-scale intensities, path length, width, and direction variables have been analyzed for use in the TORMIS analysis.

The analysis examines both broad and small regions around the site and provides justification for the final sub-region selected. Two Hundred Twenty-five (225) 1° latitude-longitude blocks and 25 3° blocks were analyzed to determine a homogeneous sub-region and to assess variation of risk within the sub-region. A tornado hazard curve for Braidwood Station was developed and the EF-scale wind speeds were used in this analysis in accordance with NUREG/CR-4461, Revision 2 (Reference 6).

Additional detail regarding the derivation of the occurrence rate value may be of interest. To develop the tornado frequency characteristics for Braidwood Station, a broad 15° longitude x 15° latitude square, centered longitudinally at the plant, was used as the starting region (this area corresponds the 225 1° latitude-longitude blocks and 25 3° blocks noted above). This large area covered 668,222 square miles and included 18,926 tornados in the NOAA Storm Prediction Center data set. Within this broad region, the tornado risk was quantified for subareas of 1° longitude by 1° latitude (i.e., 1° x 1° blocks) and 3° longitude by 3° latitude (i.e., 3° x 3° blocks). A statistical method, termed Cluster Analysis, was used to determine how the distinct subarea blocks grouped into similar clusters of tornado risk. These procedures were performed separately for both the 1° x 1° block and 3° x 3° block areas. The 1° x 1° block cluster results coupled with the 3° x 3° block cluster results were used to select the final Braidwood Station tornado sub-region.

The Braidwood Station tornado sub-region includes 76 1° blocks that surround the site and provides a conservative area to develop the site-specific tornado risk and has the desirable features of connectivity and broad statistical homogeneity for tornado risk analysis. This area also includes the tornado small area "hot spots" identified in the 1° block analysis; therefore, this modeling approach meets the intent of the TORMIS SER requirement to use data on tornado characteristics for both broad regions and small areas around the plant.

A total of 9282 tornadoes were reported in the 64-year period (i.e., 1950-2013), producing an average of 145.03 per year. The mean unadjusted occurrence rate is:

$$\upsilon = \eta / t_0 A = 5.29\text{E-}04 \text{ tornadoes / square mile / year}$$

In this equation, η = 9282 tornadoes, t_0 = 64 years, and A = 274,085 square miles

A correction for annual reporting trends and reporting inefficiencies are part of the TORMIS methodology. The adjusted occurrence rate is 1.04E-03 tornadoes / square mile / year.

The calculated adjusted tornado occurrence rate of 1.04E−03 tornadoes / square mile / year (noted above) is consistent with the current values given in the UFSAR. UFSAR Section 2.3.1.2.2, "Tornadoes and Severe Winds," estimated the mean tornado probability values for 1° x 1° blocks (approximately 3600 mi^2) for the periods of 1953-1962 and 1955-1967. These values were 1.7 tornado/year and 3.3 tornado/year, respectively. As noted, these values have units of "tornadoes per year" whereas the TORMIS values have unit of “tornadoes per square mile per year."

Converting the UFSAR values to units of "tornadoes per square mile per year" you get the following:

υ = 1.7 tornado/year ÷ 3600 mi^2 = 4.72E-04 tornadoes/mi^2/year (1953 – 1962 data)
υ = 3.3 tornado/year ÷ 3600 mi^2 = 9.17E-04 tornadoes/mi^2/year (1955 – 1967 data)

As can be seen, these values are generally consistent with the TORMIS-calculated adjusted tornado occurrence rate of 1.04E−03 tornadoes / square mile / year.

As discussed below in RIS 2008-14, Item 1.a "Justification for Tornado Frequency," the Braidwood Station site-specific tornado risk used in the TORMIS analysis has been shown to be conservative when compared to the NRC Region I criteria given in NUREG/CR-4461, "Tornado Climatology of the Contiguous United States, (PNNL-15112, Rev 2)," Revision 2.

UFSAR Section 2.3.1.2.2 will be revised to acknowledge the tornado parameters and tornado frequency values used in TORMIS. Since the TORMIS methodology only applies to a limited set of unprotected targets, the UFSAR will also retain the existing UFSAR information that continues to apply to the majority of the plant structures.

2. *Tornado Wind Speed Intensity*

The 1983 SER calls for the use of the F scale of tornado intensity in terms of assigning tornado wind speeds to each intensity category (F1-F5). However, the NRC has adopted the EF scale and confirmed in previous discussions on TORMIS that the EF scale could be used in place of the F scale. The use of the EF scale is consistent with the recently endorsed positions of NRC Regulatory Guide (RG) 1.76, Revision 1, that are based on NUREG/CR-4461, Revision 2 (Reference 6).

It is recognized that the Braidwood Station Design Basis windspeed (290 mph rotational velocity) is consistent with the 1974 version of RG 1.76 and exceeds the EF5 windspeed of 230 mph shown below in Table 3.3.4-1; however, the use of the EF scale wind speeds is limited to evaluation of unprotected equipment using TORMIS. There is no intent to update the entire licensing basis to utilize RG 1.76, Revision 1. UFSAR Section 3.5.5, "Probabilistic Tornado Missile Risk Analysis," (included in Attachment 1-3), specifically notes the use of the EF scale in TORMIS simulations (see Attachment 1-3, UFSAR Section 3.5.5.3.a on page 3.5-26c).

3. *Characterization of Tornado Wind Speed as a Function of Height Above Ground Elevation*

The TORMIS simulations were performed with the TORMIS rotational velocity Profile 3, which has increased near ground wind speeds over Profile 5, which was used in the 1981 EPRI TORMIS reports (see Attachment 1-2, Figure 3, "Tornado Rotational Wind Velocity Profiles"). Therefore, the Braidwood Station runs were made with higher near ground wind speeds than in the EPRI study. The sensitivity study was conducted by running the original EPRI profiles (i.e., Profile 5). All 60 replications that contributed to the target group results in Attachment 1-1, Table 2 were run and compared to the Profile 3 results Boolean group by Boolean group. Note that Figure 3 is a scan of Figure II-12(b) from Reference 5.

The comparison showed that differences in results were negligible for missile hit (see Attachment 1-2, Figure 4, "Plot of Frequencies with Profile 5 versus Profile 3"). Some sensitivity was observed for targets with very low damage frequencies (i.e., <1.0E-08); however, differences were negligible when aggregated over the target groups. Hence, the use of Profile 3 produces results comparable to Profile 5.

4. *Missile Characterization and Site-Structure Models*

A detailed plant survey was performed during an outage to quantify the number of potential missiles. The Braidwood missile survey walkdown was performed by ARA using ARA's plant walkdown procedures. The survey walkdown uses a systematic, documented process to provide input on what missiles are in each missile zone, the minimum and maximum injection heights for all missiles by missile type, the building characteristics for structures in the missile zone, and pictures of the missiles and buildings surveyed. This information was developed into the plant modeling inputs for the TORMIS analysis. The mean number of potential missiles simulated for EF5 tornadoes was 383,420, including structural failure missile sources. This number also includes additional missiles in several zones to conservatively anticipate future conditions. The missiles consist of both zone missile and structure origin missiles. The missiles are distributed throughout the plant based on the missile survey. Tornadoes from any direction that strike the plant will interact with numerous missiles within 2500 feet of the targets.

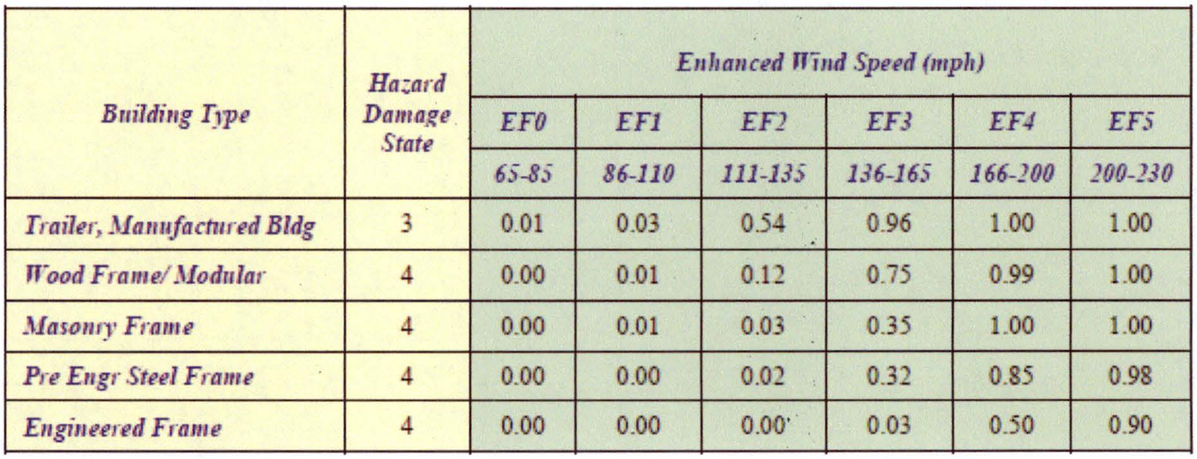
The plant site is described by specifying the geometry, location, and material properties of the structures/components and the location of potential missile sources. Missile sources (buildings, houses, storage areas, vehicles, etc.) are modeled to a distance of approximately 2500 feet in all directions from safety-significant targets. This distance is based on a sensitivity study performed in the original TORMIS research (References 3 and 4). The sensitivity study concluded that missiles beyond 2000 feet did not need to be considered in the risk assessment. This value has been increased to 2500 feet in modern TORMIS analyses to be conservative. This process includes the development of missile origin zones around the plant (shown in Attachment 1-2, Figure 5, "Zone Layout for Braidwood Station Main Site Model TORMIS Analysis," and Figure 6, "Zone Layout for Braidwood Station SX Model TORMIS Analysis") and surveying the types and quantities of missiles in each zone. The Braidwood Station missiles include the standard TORMIS missiles in EPRI NP-769 (Reference 4), including structural sections, pipes, wood members, other construction materials, and an automobile category. For each set, the cross-sectional geometry and the missile aspect ratio (L/d) are deterministic.

The structure-origin missiles represent the maximum number of missiles produced given destruction of the buildings. The number of missiles produced from this total inventory depends on the wind speeds (i.e., EF scale) experienced by the building. For example, light damage might be expected in 100 mph winds, while catastrophic failure might occur in 200 mph winds. Research performed in the development of the HAZUS wind model (Reference 7) is used to determine the number of missiles available for each building type for each wind speed level considered in the TORMIS runs. When specific wind fragilities of building components are known, the calculated building fragilities are used to produce the number of available missiles in place of the HAZUS functions.

The HAZUS vulnerability models are based on detailed 3-D modeling of buildings and simulated hurricane winds. For each simulated storm, the wind pressures are estimated over the building envelope. The wind load is then computed for each component and compared to the component resistance. Component failures occur when the load exceeds the resistance. This simulation process is repeated for all components as the storm is tracked by the building for each time step. Internal pressurization of the structure is modeled when the envelope is breached by a missile or a failed opening (window or door).

Table 3.3.5-1 below summarizes the wind speed missile functions, defined at the wind speeds for which TORMIS is typically run to produce missile fragilities in support of License Amendment Requests with the Enhanced Fujita scale wind speeds from the HAZUS research. The damage state for each building type was selected based on sufficient failure to produce structural component missiles. These criteria correspond to "Damage State 4-Destruction" for all building types except manufactured buildings, where Damage State 3 was determined to be sufficient to produce significant structural missiles.

Table 3.3.5-1
HAZUS Damage State Exceedence Probabilities for EF-Scale Mid-Point Wind Speeds



Building Type	*Hazard Damage State*	*Enhanced Wind Speed (mph)*					
		EF0	*EF1*	*EF2*	*EF3*	*EF4*	*EF5*
		65-85	*86-110*	*111-135*	*136-165*	*166-200*	*200-230*
Trailer, Manufactured Bldg	3	0.01	0.03	0.54	0.96	1.00	1.00
Wood Frame/ Modular	4	0.00	0.01	0.12	0.75	0.99	1.00
Masonry Frame	4	0.00	0.01	0.03	0.35	1.00	1.00
Pre Engr Steel Frame	4	0.00	0.00	0.02	0.32	0.85	0.98
Engineered Frame	4	0.00	0.00	0.00	0.03	0.50	0.90

A stochastic missile modeling approach was used to model the numbers of potential missiles at the plant during outage and non-outage conditions. All the postulated missiles at Braidwood Station were treated as minimally restrained in which each sampled missile is injected near the peak aerodynamic force, thus maximizing the transport range and impact speed and, consequently, the missile hit and damage frequency. A summary of the total missile populations used in the TORMIS Main Site Model is given in Table 3.3.5-2 below.

Table 3.3.5-2
Number of Braidwood Station TORMIS Simulated Missiles (Stochastic Model Main Site)

EF Scale	*Zone Origin*			*Structure Origin*			*Total (All Sources)*		
	Min	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*
EF 1	44,990	51,565	60,993	2,635	2,885	3,219	47,788	54,450	63,903
EF 2	44,990	51,565	60,993	26,278	29,361	33,638	73,082	80,926	94,020
EF 3	44,990	51,565	60,993	166,645	184,231	205,374	213,841	235,796	265,756
EF 4	44,990	51,565	60,993	274,723	298,174	328,705	321,919	349,740	389,087
EF 5	44,990	51,565	60,993	308,081	331,855	365,379	355,277	383,420	425,761

A summary of the total missile populations used in the TORMIS SX Model is given in Table 3.3.5-3 below. Note that the simulated missiles from the Main Site Model and the SX Model have no impact on the opposite model due to the distance between the Reactor and Auxiliary Buildings, and the SX discharge pipes (i.e., greater than 2500 feet apart).

Table 3.3.5-3
Number of Braidwood Station TORMIS Simulated Missiles (SX Model)

EF Scale	*Zone Origin*			*Structure Origin*			*Total Missiles (All Sources)*		
	Min	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*
EF 1	12,612	14,075	16,119	47	50	57	12,660	14,125	16,176
EF 2	12,612	14,075	16,119	303	367	477	12,926	14,442	16,596
EF 3	12,612	14,075	16,119	1,044	1,212	1,507	13,699	15,287	17,626
EF 4	12,612	14,075	16,119	2,595	2,975	3,386	15,366	17,050	19,220
EF 5	12,612	14,075	16,119	3,546	4,170	4,973	16,426	18,245	20,200

It should be emphasized that the TORMIS methodology does consider vertical missiles. Specifically, the approved TORMIS methodology explicitly considers all x, y, and z components of the missile velocity vector. The 3-D simulations integrate the equations of motion for each missile and the resulting trajectories include a continuum of trajectory paths, including horizontal, vertical, and oblique trajectory paths. NP-2005 Volume 2, Section IV, describes missile motion and orientation models. The missile velocity vector at the instant of impact; therefore, inherently includes vertical and horizontal motions of the missile. As such, a continuum of missile velocity vector orientations at impact can occur, including horizontal, near- horizontal, oblique, near vertical, and vertical.

5. *Deviations from the Original EPRI Methodology:*

The Braidwood Station TORMIS analysis was performed by Applied Research Associates, Inc. (ARA) using TORMIS_14, an updated version of the original EPRI NP-2005 version of the code (Reference 5).

The TORMIS code is a legacy FORTRAN computer code that has been ported to modern computers and compilers and has had bug fixes and other enhancements since 1981. The updates and enhancements made to TORMIS since 1981 are documented in ARA TORMIS reports and Code Manuals. These changes include: porting the legacy code from mainframe to minicomputer to PC computers, post processing data routines, updates to the random number generation, ensure aerodynamic function of box/beam for C/t greater than 4 to match Figure 3-8 of Reference 4 and replace the exponential tip loss function with an equivalent polynomial (i.e., replaced the exponential function in Equation 3.10 in Reference 4 with the Hoerner suggested polynomial); enhanced output options; and addressing compiler differences and numerical round-off issues in various functions from the legacy code. All code changes have been checked and verified through comparisons to the preceding version.

Also included in the updates were the replacement of the original mainframe based random number generator with a machine-independent algorithm and re-dimensioning of the code to allow larger numbers of targets and missiles.

The TORMIS code verification includes duplications and comparison to each preceding TORMIS version as well as the original TORMIS Sample Problem in EPRI NP 2005 (Reference 5). These statistical comparisons show that the basic TORMIS code calculational approach produces comparable results to that of the original version.

An enhanced method for evaluating missiles passing through openings, such as pipe penetrations in reinforced concrete walls was used for the Braidwood Station analysis. This method uses a screening of missile impact conditions to screen-out missile impacts that can obviously not pass through an opening. The screening is done in the processing of the missile impact data without modifying the TORMIS physics engine in the IMPACT subroutine. This calculation approach for pipe penetration type targets was introduced as an option in previous versions of TORMIS and was used in several analyses prior to the Braidwood Station analysis. This approach provides an additional output option that is conservative for estimating the probabilities of missiles passing through small openings in concrete barriers. Both the TORMIS hit probability and the pipe penetration probability is reported for all such targets where the screening approach is used. The results for individual targets are given in Attachment 1-1, Table 1.

There was also a single change made to the code of a purely "software" nature, which was not related to the approved TORMIS physics engine and calculation approach; i.e., the dimensioned number of possible missile types was increased to 24 for evaluation of damage from missile velocity exceedance and pipe penetration pass through. This change was made, verified and exactly reproduces previous TORMIS outputs. Note that the missiles used for the Braidwood Station FEA calculations were identical to those used for the Byron Station analysis (approved in Reference 15) with the exception of the roof paver missile which was omitted for the Braidwood Station analysis (i.e., the Braidwood Station analysis used 23 missiles) as there are no pavers on building roofs at Braidwood Station.

In addition, it should be noted that TORSCR_MF was updated to accommodate up to 40,000 tornadoes (up from 15,000) to be evaluated for each TORMIS replication. Note that TORSCR is a FORTRAN computer code that is used to post-process TORMIS output files. Its primary function is to compute Boolean combinations of target hit and damage probabilities over multiple targets.

Note that all the above deviations from the original EPRI Methodology were previously identified in the Byron Station TORMIS License Amendment Request; i.e., in a letter from D. M. Gullott (EGC) to NRC, "License Amendment Request to Utilize the TORMIS Computer Code Methodology, " dated October 7, 2016. (Reference 13). This proposed license amendment was subsequently approved by the NRC in letter from J. S. Wiebe (NRC) to B. C. Hansen (EGC), "Byron Station, Unit Nos. 1 and 2 – Issuance of Amendments Regarding Use of TORMIS for Assessing Tornado Missile Protection," dated August 10, 2017 (Reference 15).

3.3.6 Compliance with NRC RIS 2008-14 Criteria

Subsequent to the original NRC TORMIS SER (Reference 1), the NRC issued Regulatory Issue Summary 2008-14 (Reference 2) to inform licensees of the NRC's experience with shortcomings identified in submitted licensee TORMIS analyses. The RIS specifically identified items licensees should address to confirm the TORMIS methodology and computer code have been properly applied and implemented. These issues identified in the RIS are presented below.

1. *Licensees did not fully satisfy the first four points identified in the SER approving the TORMIS methodology. Examples include the following:*

    a. *not providing adequate justification that the analysis used the most conservative value for tornado frequency*
    b. *not including the entire TORMIS missile spectrum defined for use in the TORMIS computer code as appropriate for the plant*
    c. *not providing adequate explanation for the number and adequacy of tornado simulations and histories*
    d. *not providing sufficient information regarding the development and use of area ratios*

2. *Licensees did not fully address the fifth point identified in the SER and explain how the methodology was implemented when the parameters used differed from those specified in the TORMIS methodology. Examples include the following:*

    a. *inappropriately limiting the number of targets modeled*
    b. *failing to address missile tumbling when modeling targets*
    c. *failing to properly consider and use the variance reduction techniques and parameters specified by TORMIS*
    d. *taking credit for nonstructural members*
    e. *failing to consider risk significant, non-safety-related equipment*

3. *Licensees used the TORMIS methodology to address situations for which the methodology was not approved. Examples include the following:*

    a. *proposing the elimination of existing tornado barriers*
    b. *proposing Technical Specifications (TS) changes*
    c. *proposing plant modifications*

Braidwood Station considered these observations in the development of the TORMIS analysis and addressed each of them as shown below.

1.a. Justification for Tornado Frequency:

To meet the regulatory requirements for modeling tornado risk, TORMIS uses a statistical approach that considers both broad regions and small areas around the plant. A basic sub-region data set for Braidwood Station is identified and analyzed. The sub-region data is analyzed to produce the tornado input files needed in TORMIS. Tornado hazard curves are developed using a TORMIS-derived code called TORRISK. TORRISK is a specialized version of TORMIS that produces tornado hazard curves distinct from the missile risk analysis features of TORMIS. The TORRISK hazard curves provide control points to ensure that the TORMIS simulations track the Braidwood Station site-specific hazard curve and are conservative for missile risk analysis.

The tornado frequency value conservatively considers regions around the plant and corrects for reporting trend and tornado classification error and random encounter errors, per the TORMIS methodology (References 3, 4, and 5). The developed tornado hazard curve for Braidwood Station is conservative when compared to NRC Region I criteria given in NUREG/CR-4461, Revision 2 (Reference 6). A comparison of Braidwood Station hazard curve (i.e., the "BRW 2015 Plant EF" curve) and NUREG/CR-4461 (i.e., the "BRW NUREG EF" curve) is shown in Attachment 1-2, Figure 7, "TORMIS Simulation of Braidwood Station Tornado Hazard for Plant Safety Envelope."

1.b. Spectrum of Missiles Considered:

The Braidwood Station study included the missile spectrum (26 missile aerodynamic subsets) developed for use in TORMIS. A total of 23 missile types were used for Braidwood Station, including two plant specific missiles. One plant specific missile type was the precast concrete roof deck panels found on several buildings. The second plant specific missile was the existing metal siding missile which was modified to be plant specific based on the characteristics of the insulated metal siding on the exterior of the Braidwood Turbine Building. Note that the missiles used for the Braidwood Station FEA calculations were identical to those used for the Byron Station analysis (approved in Reference 15) with the exception of the roof paver missile which was omitted for the Braidwood Station analysis as there are no pavers on building roofs at Braidwood Station.

1.c. Justification for the Number and Adequacy of Tornado Simulations:

A replication approach was used for the simulations. A total of 60 complete TORMIS replications were run with different random number seeds and missile populations for each TORMIS model. A total of 462 million missile simulations were performed for each replication, for a total of 27.7 billion missile simulations over all 60 replications. The standard deviations (σ) of these replications were computed and the standard error (ε) in the aggregate mean probability (μ) was computed from $\varepsilon = \sigma/\sqrt{n}$. The 95% confidence bounds in the mean probability were conservatively approximated by $\mu \pm 2 \cdot \varepsilon$.

Attachment 1-2, Figure 8, "Target Group Hit and Damage Frequency with Confidence Intervals," plots the two-sided 95% confidence intervals. As an example, the running 95%

two-sided confidence bounds for Group 8 are illustrated in Attachment 1-2, Figure 9, "Convergence Plot for Damage Frequency for Target Group 8 (U1 MSSV Group 1 NE)," to demonstrate that reasonable statistical convergence had been obtained with 60 replications.

1.d. *Use of Area Ratios:*

No area ratios have been used as a method to adjust the TORMIS outputs for small targets, based on a ratio of hit probabilities from a large target or surface. A variance reduction approach is available in TORMIS and was used for Braidwood Station that allows for increasing the volume or size of small targets explicitly within the code. TORMIS applies the input variance reduction weight (k_a) in the TORMIS scoring equation. These adjustments are used within TORMIS for the single missile impact probability. They are not used to "ratio down" the multiple missile impact probabilities following a TORMIS simulation. Ratioing down the results at the end of TORMIS is not technically acceptable and can lead to an underestimation of the multiple missile risk.

2.a. *Inappropriately Limiting of the Number of Targets Modeled:*

The Braidwood Station TORMIS model includes plant components, identified as necessary to safely shutdown the plant and maintain a shutdown condition, located in areas not fully protected by missile barriers designed to resist impact from design basis tornado missiles. The Braidwood Station TORMIS analysis includes 74 potential missile targets (see Attachment 1-1, Table 1).

A number of unprotected targets were reviewed and not included in the Braidwood Station TORMIS model based on the following criteria:

1. Alternate protected systems or components are available to perform the required function, or

2. Analysis or evaluation to show that a postulated tornado missile impact will not result in the loss of a safe shutdown function.

The following are examples of the equipment not included in the Braidwood Station TORMIS model with associated justification as documented in an engineering evaluation.

- The unprotected non-safety related Condensate Storage Tanks (CST) and piping from the CSTs to the AF pumps located in the Turbine Building are not included in the Braidwood TORMIS model. The safety related essential service water system is used as the backup suction source for the AF pumps if the CSTs or piping from the CSTs are damaged during a tornado event. The secondary effects (i.e., local flooding) from a CST rupture, caused by a tornado missile strike, were also considered. There are no safety-related SSCs near the CST that would be adversely affected by a CST rupture.

- The unprotected portion of the safety related Emergency Diesel Generator (EDG) exhaust stacks are not included in the TORMIS model. To prevent loss of diesel availability due to exhaust stack damage, a rupture disc pressure relief device is installed on each diesel exhaust line. This relief device is located inside a missile protected structure.

- Each EDG engine is provided with a crank case breather vent line that is routed to the outdoors. Where the lines penetrate the auxiliary building the vent lines could be damaged by tornado missiles blocking the crank case vent path. Design analysis has been completed and demonstrates that the crankcase vent lines can be blocked without adversely affecting the ability of the associated EDG to perform its design function.

- The Diesel Oil Storage Tanks (DOST) and EDG Day Tanks contain vent lines which provide a path to allow the tanks to fill and drain without developing excessive internal pressure or vacuum. The vent lines could be crimped by tornado missiles blocking the vent path at the point where they penetrate the auxiliary building. In the event the normal tank vent is blocked, an adequate alternate vent path for the DOSTs and EDG Day Tanks is provided by the DOST overflow lines and the piping that connects the air spaces of the DOSTs and EDG Day Tanks. These alternate vent paths are located inside the auxiliary building and are properly protected from tornado missiles.

- The normal fill path to the DOSTs (which are missile protected, located inside the auxiliary building) is from either the 125,000-gallon or 50,000-gallon, Category II outdoor oil storage tanks utilizing gravity flow. The 125,000-gallon and 50,000-gallon oil storage tanks are not protected from tornado missiles. The outside fill connection is also not protected from tornado missiles. The DOSTs are designed to provide adequate fuel supply for 7 days of post-accident load operation.

- The AF Pump Diesel Engine Day Tanks contain vent lines which provide a path to allow the tanks to fill and drain without developing excessive internal pressure or vacuum. The vent lines could be crimped by tornado missiles blocking the vent path at the point where they penetrate the auxiliary building. For the Unit 1 AF Pump Diesel Engine Day Tank, if the normal vent path is completely blocked, an adequate alternate vent path would be provided by the tank overflow line to the 1C DOST. This alternate vent path is located inside the auxiliary building and is properly protected from tornado missiles. For the Unit 2 AF Pump Diesel Engine Day Tank, the vent line has a different configuration; therefore, a revision was made to the Abnormal Operating Procedure to establish operator compensatory actions to address a potential vent line crimp due to a tornado missile impact.

- As discussed in the Section 3.5.2 of the original Braidwood Station Safety Evaluation Report (SER), although the fuel-handling building is designed to be tornado missile resistant, the rollup freight door which is a large opening in the building is not capable of resisting tornado-missile impact. A tornado or tornado missile could destroy the door and may allow a relatively lightweight missile of large area, such as a steel panel or the door itself to travel inside the fuel-handling building. However, the spent fuel pool is sufficiently far from the door that any resulting tornado missile and debris could not enter the spent fuel pool and cause damage to the spent fuel assemblies or block coolant flow. This is due to the low trajectory that the missile would have to follow through the door and toward the fuel pool. Further, it would then be required to turn 90° in order to enter the fuel pool.

- An unprotected six-inch vent pipe runs from the top of each RWST into the Fuel Handling Building. The loss of RWST vent function (i.e., a missile hit completely crimps the vent and prevents air from entering the tank) has been analyzed to show no adverse impact on the RWST pressure boundary function. The pumps that draw suction from the RWST have been evaluated to show adequate Net Positive Suction Head is available without the vent function.

- The underground pipe tunnels from the RWSTs to the Auxiliary Building have an outdoor access shaft and hatch. The hatch cover is ¼" thick steel plate that is not designed as a missile barrier. An evaluation determined that no equipment required for safe shutdown would be damaged by tornado missiles that enter the hatch and travel down the access shaft into the pipe tunnel.

- Doors and ventilation openings between the Auxiliary Building and the Turbine Building below Elevation 451' are protected from tornado missiles by the concrete slabs, various Turbine building concrete walls, and large equipment located on elevations 426' and 401' of the Turbine Building.

It is also worthy to note that other targets were considered and include, for example, buildings that are expected to fail in a tornado and produce missiles (i.e., missile source targets) and buildings that are not assumed to fail during a tornado (such as reinforced concrete structures or heavy steel frames). Targets can be stacked on the top of one another to create, for example, a missile source on top of a safety-significant reinforced concrete building. For each target, the material type and strength are specified for each surface of the target, which is generally modeled as a prismatic box shape. These missile source targets are identified based on the site plans and aerial photos as well as plant walkdowns. Potential missiles generated by missile source buildings are estimated based on the site walkdown and building break-up models.

Missile shielding targets are buildings and other structures that are assumed to not fail in the tornado and provide missile shielding to the safety significant targets. Plant components modeled as shielding targets (also referred to as blockage) are constructed of reinforced concrete that is at least one foot thick, or clad with steel plate that is at least one inch thick. For example, the concrete structure of the Reactor Building is modeled as a missile shield target.

TORMIS target worksheets were completed for each safety-significant target. These worksheets are used to document the location, dimensions, material properties, references, and special modeling considerations for each of the safety-significant targets. Each worksheet also includes copies of the photos taken during the target walkdown and three-dimensional CAD representations of the targets as modeled for TORMIS.

Attachment 1-1, Table 4, "Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets," contains a list of all the safety-significant, shielding, and missile source targets included in the Braidwood Station TORMIS model. Also shown in the table is the target group to which each of the safety-significant targets belongs.

2.b. *Consideration of Missile Tumbling:*

All safety-significant targets (with the exception of pipe penetrations) were modeled to allow for tumbling missile hits (i.e., offset hits) in accordance with the TORMIS technical reports (References 3, 4, and 5). Pipe penetration targets were not increased in size to reflect tumbling missiles since offset missiles cannot result in penetration of a small opening in a concrete wall.

EPRI TORMIS Report NP-769 (Reference 4) discusses consideration of finite missile size in modeling targets in Section 4.2.3. Since TORMIS tracks the missile as a point, missiles that just miss a target are actually likely to have hit the target by virtue of an "offset" hit. The analysis in Reference 4 shows that each safety target dimension should be increased by L/8 for each free face or direction, where L is the mean length of the missiles. Each shielding target can be increased by L/4 in each free direction. Thus, if a safety target has two free faces in the X direction, its actual X dimension, would be increased by L/8 × 2. This increase in target size accounts for the potential near misses (which are actually "offset" hits) that are not treated in TORMIS.

The determination of the appropriate offset hit dimension is an iterative process because a TORMIS model of a given plant needs to be run with its plant description and actual missile inventory. This was accomplished for Braidwood Station by creating a TORMIS model of the plant with an offset hit dimension of 1.5 feet per free edge.

The Braidwood Station TORMIS analysis conservatively did not increase the size of missile shielding targets for offset hits. This approach produces a conservative result in compliance with the RIS comment on "tumbling missiles."

2.c. *Use of Variance Reduction Techniques:*

Due to the very large simulation/replication sizes, no variance reduction techniques were used for tornado wind speed, tornado offset, tornado direction, tornado orientation, missile type, missile injection height, missile impact orientation, or trajectory termination. Variance reduction techniques were used for missile zone population and target size (k_a by target surface).

2.d. *Inappropriate Credit for Non-Structural Members:*

The Braidwood Station TORMIS analysis did not take credit for missile resistance for non-structural members.

2.e. *Failure to Consider Risk Significant, Non-Safety-Related Equipment:*

Plant walkdowns were performed in support of the TORMIS analysis. Risk-significant targets (both safety-related and non-safety-related) were considered. Seventy-four (74) unprotected targets were ultimately identified and are included at the TORMIS analysis target set. Also see discussion under Item 2.a.

3.a. Using TORMIS for the Elimination of Existing Tornado Barriers

TORMIS is not being used to propose the elimination of tornado barriers.

3.b. Using TORMIS to Propose TS Changes

TORMIS is not being used to propose TS changes.

3.c. Using TORMIS for Plant Modifications

TORMIS is not being used to design new plant equipment modifications.

4.0 REGULATORY EVALUATION

4.1 Applicable Regulatory Requirements/Criteria

The TORMIS methodology was developed to estimate the probability of tornado missile impact and damage to nuclear power plant SSCs. The proposed change to utilize the TORMIS Computer Code for assessing tornado-generated missile protection of unprotected plant SSCs, is consistent with this methodology and the requirements and acceptance criteria specified in the below documents:

- Electric Power Research Institute Report – EPRI NP-768, "Tornado Missile Risk Analysis," May 1978 (Reference 3)
- Electric Power Research Institute Report – EPRI NP-769, "Tornado Missile Risk Analysis - Appendices," May 1978 (Reference 4)
- Electric Power Research Institute Report – EPRI NP-2005 Volumes, I and 2, "Tornado Missile Risk Evaluation Methodology," August 1981 (Reference 5)
- NRC Standard Review Plan (SRP) (i.e., NUREG-0800), Section 2.2.3, "Evaluation of Potential Accidents," Revision 2, July 1981

Specific information regarding TORMIS approval and acceptance criteria is contained in the following documents.

<u>NRC TORMIS Safety Evaluation Report</u>

The TORMIS methodology (References 3, 4 and 5) has been reviewed and accepted for nuclear power plant tornado missile risk analyses, as documented in the NRC Safety Evaluation Report (SER) – Electric Power Research Institute (EPRI) Topical Reports Concerning Tornado Missile Probabilistic Risk Assessment (PRA) Methodology, dated October 26, 1983 (ML080870291) (Reference 1). The NRC SER concluded that:

> *"... the EPRI methodology can be utilized when assessing the need for positive tornado protection for specific safety-related plant features."*

The SER also states that licensees using the EPRI approach (i.e., the TORMIS methodology) must consider five specific points and provide the appropriate information. This information is provided in Section 3.4.5 above.

NRC Memorandum on Use of Probabilistic Risk Assessment in Tornado Licensing Actions

NRC Memorandum from Harold R. Denton to Victor Stello, "Position of Use of Probabilistic Risk Assessment in Tornado Licensing Actions," dated November 7, 1983 (ML030020331), endorsed the acceptance criteria stated in NUREG-0800, Section 2.2.3. The memorandum states:

> *"Therefore, the guidance in SRP Section 2.2.3 is applicable to tornado missiles. This guidance, which we will use in our probabilistic tornado reviews, states that an expected rate of occurrence of potential exposures in excess of the 10 CFR 100 guidelines of approximately 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the risk can be expected to be lower."*

NRC Regulatory Issue Summary 2008-14

The NRC subsequently issued Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008. This RIS provided additional guidance on the use of TORMIS for assessing nuclear power plant tornado missile protection. The RIS states that:

> *"The TORMIS methodology is approved for situations where (1) a licensee identifies existing plant SSCs that do not comply with the current licensing basis for positive tornado missile protection of the plant and (2) it would require costly modifications to bring the plant into compliance with the current licensing basis."*

In addition, the RIS identified specific items licensees should address to confirm the TORMIS methodology and computer code have been properly applied and implemented. This information is presented in Section 3.4.6 above. The RIS also reconfirms that the guidance in SRP Section 2.2.3 is applicable to tornado missiles.

4.2 Precedent

The NRC previously approved use of the TORMIS methodology for use at the following facilities:

Byron Station, Units 1 and 2

This amendment is documented in a letter from J. S. Wiebe (NRC) to B. C. Hansen (EGC), "Byron Station, Unit Nos. 1 and 2 – Issuance of Amendments Regarding Use of TORMIS for Assessing Tornado Missile Protection," dated August 10, 2017 (Reference 15).

In this amendment, the NRC explicitly acknowledged that it is appropriate to apply the acceptance criterion established in SRP 2.2.3 of 10^{-6} per year on a unit-specific basis. The Braidwood Station approach to justify application of the acceptance criteria on a unit-specific bases is the same as that used for Byron Station.

In Reference 15, the NRC also specifically approved the use of Boolean Logic. The NRC stated the following:

> *"The Boolean Logic was created for the UHS based on the minimum tower requirement as described in the licensee's letter dated October 7, 2016, Section 3.4.3. The licensee stated that the Boolean Logic was modeled in the analysis with the TORMIS post-processor TORSCR using the Boolean intersection (n) operator. The licensee's application dated October 7, 2016, Section 3.4.2 described that TORSCR is a FORTRAN computer code used to post-process TORMIS output files. Its primary function is to compute Boolean combinations of target hit and damage probabilities over multiple targets. The intersection operator was only used for the UHS in the Byron TORMIS analysis because multiple components need to be damaged to cause a failure of the UHS."*
>
> *"Based on the use of the intersection operator to evaluate failures that need multiple components damaged from tornado missiles, the NRC staff finds that the licensee's use of the intersection operator to be acceptable for the components of the UHS."*

In Reference 15, the NRC also approved a number of deviations from the original EPRI methodology (see References 3, 4 and 5). These deviations are similar to the deviations utilized in the Braidwood Station TORMIS analysis as discussed in Section 3.3.5, Item 5, above. Specifically, the NRC noted the following:

> *The licensee stated that the TORMIS code, a legacy FORTRAN computer code, has been updated to modern computers. The updates and enhancements include: porting the legacy code from the mainframe to minicomputer to PC computers; post processing data routines; updating the random number generation; updating the aerodynamic tip loss function, and addressing compiler differences and numerical round-off issues in various functions from the legacy code. An enhanced method was used for evaluating missiles passing through openings such as pipe penetrations in concrete walls. This method uses a screening of missile impact conditions to evaluate missile impacts that can obviously not pass through an opening. This approach provides an additional output option for estimating the probabilities of missiles passing through small openings in concrete barriers. Based on its review, the NRC staff finds that these methods are reasonable and are therefore acceptable.*

Fermi 2

This amendment is documented in a letter from T. J. Wengert (NRC) to J. H. Plona (DTE Electric Company), "Fermi 2 – Issuance of Amendment Re: Revise the Fermi 2 Licensing Basis Concerning Protection from Tornado-Generated Missiles," dated March 10, 2014 (Reference 11).

In this amendment, the NRC also approved a number of deviations from the original EPRI methodology (see References 3, 4 and 5). These deviations are similar to the deviations utilized in the Braidwood Station TORMIS analysis as discussed in Section 3.3.5, Item 5, above. Of particular note, the NRC stated that following:

> *"An enhanced method was used for evaluating missiles passing through openings such as pipe penetrations in concrete walls, in addition to the standard TORMIS hit probability for such targets. This provides supplemental outputs intended to cover special cases of missiles going through wall openings."*

Donald C. Cook Nuclear Plant, Units 1 and 2

This amendment is documented in a letter from J. F. Stang (NRC) to R. P. Power (Indiana Michigan Power Company), "Donald C. Cook Nuclear Plant, Units 2 and 2 – Issuance of Amendments," dated November 17, 2000 (Reference 12).

In this amendment, the NRC explicitly acknowledged that the acceptance criterion established in SRP 2.2.3 of 10^{-6} per year is applied on a unit-specific basis.

4.3 No Significant Hazards Consideration

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit or early site permit," and 10 CFR 50.59, "Changes, tests, and experiments," paragraph (c)(2)(viii), Exelon Generation Company, LLC, (EGC) requests amendments to Renewed Facility Operating License Nos. NPF-72 and NPF-77 for Braidwood Station, Units 1 and 2. This amendment request proposes to revise the Braidwood Station licensing basis for protection from tornado-generated missiles. Specifically, the Updated Final Safety Analysis Report (UFSAR) will be revised to identify the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of unprotected plant structures, systems and components (SSCs); and to describe the results of the Braidwood Station site-specific tornado hazard analysis. The results from the Braidwood Station TORMIS analysis will be used to credit unprotected equipment for post-tornado safe shutdown. Revisions to the affected UFSAR sections will be performed in accordance with 10 CFR 50.59, "Changes, tests and experiments," after approval of the proposed amendment. Note that there are no Technical Specifications changes associated with this request.

The Braidwood Station TORMIS analysis utilizes a probabilistic approach performed in accordance with the guidance described in the NRC TORMIS Safety Evaluation Report dated October 26, 1983, as clarified by Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008.

According to 10 CFR 50.92, "Issuance of amendment," paragraph (c), a proposed amendment to an operating license involves no significant hazards consideration if operation of the facility in accordance with the proposed amendment would not:

(1) Involve a significant increase in the probability or consequences of an accident previously evaluated; or

(2) Create the possibility of a new or different kind of accident from any accident previously evaluated; or

(3) Involve a significant reduction in a margin of safety.

EGC has evaluated the proposed change for Braidwood Station, using the criteria in 10 CFR 50.92, and has determined that the proposed change does not involve a significant hazards consideration. The following information is provided to support a finding of no significant hazards consideration.

Criteria

1. Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

   Response: No.

   The NRC TORMIS Safety Evaluation Report states the following:

   > *"The current Licensing criteria governing tornado missile protection are contained in [NUREG-0800] Standard Review Plan (SRP) Section 3.5.1.4, [Missiles Generated by Natural Phenomena] and 3.5.2 [Structures, Systems and Components to be Protected from Externally Generated Missiles]. These criteria generally specify that safety-related systems be provided positive tornado missile protection (barriers) from the maximum credible tornado threat. However, SRP Section 3.5.1.4 includes acceptance criteria permitting relaxation of the above deterministic guidance, if it can be demonstrated that the probability of damage to unprotected essential safety-related features is sufficiently small."*

   As permitted by these SRP sections, the combined probability will be maintained below an allowable level, i.e., an acceptance criterion threshold, which reflects an extremely low probability of occurrence. SRP Section 2.2.3, "Evaluation of Potential Accidents," established this threshold as approximately 1.0E-06 per year if, "when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower." The Braidwood Station analysis approach assumes that if the sum of the individual probabilities calculated for tornado missiles striking and damaging portions of safety-significant SSCs is greater than or equal to 1.0E-06 per year per unit, then installation of tornado missile protection barriers would be required for certain components to lower the total cumulative damage probability below the acceptance criterion of 1.0E-06 per year per unit. Conversely, if the total cumulative damage probability remains below the acceptance criterion of 1.0E-06 per year per unit, no additional tornado missile protection barriers would be required for any of the unprotected safety-significant components.

   With respect to the probability of occurrence or the consequences of an accident previously evaluated in the UFSAR, the possibility of a tornado impacting the Braidwood Station site and causing damage to plant SSCs is a licensing basis event currently addressed in the UFSAR. The change being proposed (i.e., the use of the TORMIS methodology for assessing tornado-generated missile protection of unprotected plant SSCs), does not affect the probability of a tornado strike on the site; however, from a licensing basis perspective, the proposed change does affect the probability that missiles generated by a tornado will strike and damage certain safety-significant plant SSCs. There are a defined number of safety-significant components that could theoretically be struck and damaged by tornado-generated missiles. The probability of tornado-generated missile hits on these "important" systems and components is calculated using the TORMIS probabilistic methodology. The combined probability of damage for unprotected safety-significant equipment will be maintained below the acceptance criterion of 1.0E-06 per year per unit to ensure adequate equipment remains available to safely shutdown the reactors, and maintain overall plant safety, should a tornado strike occur. Consequently, the proposed change does not constitute a significant increase in the probability of occurrence or the consequences of an accident based on the extremely low probability of damage caused by tornado-generated missiles and the commensurate extremely low probability of a radiological release.

Finally, the use of the TORMIS methodology will have no impact on accident initiators or precursors; does not alter the accident analysis assumptions or the manner in which the plant is operated or maintained; and does not affect the probability of operator error.

Based on the above discussion, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?

   Response: No.

   The impact of a tornado strike on the Braidwood Station site is a licensing basis event that is explicitly addressed in the UFSAR. The proposed change simply involves recognition of the acceptability of using an analysis tool (i.e., the TORMIS methodology) to perform probabilistic tornado missile damage calculations in accordance with approved regulatory guidance. The proposed change does not result in the creation of any new accident precursors; does not result in changes to any existing accident scenarios; and does not introduce any operational changes or mechanisms that would create the possibility of a new or different kind of accident.

   Therefore, the proposed change will not create the possibility of a new or different kind of accident than those previously evaluated.

3. Does the proposed change involve a significant reduction in a margin of safety?

   Response: No.

   The existing Braidwood Station licensing basis regarding tornado missile protection of safety-significant SSCs assumes that missile protection barriers are provided for safety-significant SSCs; or the unprotected component is assumed to be unavailable post-tornado. The results of the Braidwood Station TORMIS analysis have demonstrated that there is an extremely low probability, below an established regulatory acceptance limit, that these "important" SSCs could be struck and subsequently damaged by tornado-generated missiles. The change in licensing basis from protecting safety-significant SSCs from tornado missiles, to demonstrating that there is an extremely low probability that safety-significant SSCs will be struck and damaged by tornado-generated missiles, does not constitute a significant decrease in the margin of safety.

   Therefore, the proposed change to use the TORMIS methodology does not involve a significant reduction in the margin of safety.

Based on the above, EGC concludes that the proposed amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92, and accordingly, a finding of "no significant hazards consideration" is justified.

4.4 Conclusions

The TORMIS methodology was developed to estimate the probability of tornado missile impact and damage to nuclear power plant structures and components. The TORMIS methodology has been reviewed and accepted for nuclear power plant tornado missile risk analyses, as discussed in the NRC TORMIS SER (Reference 1). The NRC SER concluded that the methodology "...can be utilized when assessing the need for positive tornado missile protection for specific safety-related plant features." Each of the five points in the NRC's SER has been addressed in this evaluation; i.e., (1) conservative site-specific tornado characteristics, (2) use of EF-Scale wind speeds per updated Regulatory Guide 1.76 (that are based on NUREG/CR-4461, Revision 2), (3) use of enhanced near ground tornado wind speeds, (4) conservative characterization of plant site-specific missiles; and (5) justified deviations from the calculational approach.

The conservatisms utilized in the TORMIS analysis provides high confidence that the Braidwood Station mean damage frequency values for each unit are conservatively high and "the risk can be expected to be lower," consistent with the acceptance criteria stated in SRP Section 2.2.3.

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the site licensing basis and Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

5.0 ENVIRONMENTAL CONSIDERATION

EGC has evaluated this proposed operating license amendment consistent with the criteria for identification of licensing and regulatory actions requiring environmental assessment in accordance with 10 CFR 51.21, "Criteria for and identification of licensing and regulatory actions requiring environmental assessments." EGC has determined that these proposed changes to utilize the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of plant structures, systems and components (SSCs), meet the criteria for a categorical exclusion set forth in paragraph (c)(9) of 10 CFR 51.22, "Criterion for categorical exclusion; identification of licensing and regulatory actions eligible for categorical exclusion or otherwise not requiring environmental review," and as such, has determined that no irreversible consequences exist in accordance with paragraph (b) of 10 CFR 50.92, "Issuance of amendment." This determination is based on the fact that these changes are being proposed as an amendment to the license issued pursuant to 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," which changes a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, "Standards for Protection Against Radiation," or which changes an inspection or a surveillance requirement, and the amendment meets the following specific criteria:

(i) The amendment involves no significant hazards consideration.

As demonstrated in Section 4.3, "No Significant Hazards Consideration," the proposed change does not involve any significant hazards consideration.

(ii) There is no significant change in the types or significant increase in the amounts of any effluent that may be released offsite.

The proposed change does not result in an increase in power level, does not increase the production nor alter the flow path or method of disposal of radioactive waste or byproducts. It is expected that all plant equipment would operate as designed in the event of an accident to minimize the potential for any leakage of radioactive effluents. The proposed changes will have no impact on the amounts of radiological effluents released offsite during normal at-power operations or during the accident scenarios.

Based on the above evaluation, the proposed change will not result in a significant change in the types or significant increase in the amounts of any effluent released offsite.

(iii) There is no significant increase in individual or cumulative occupational radiation exposure.

There is no change in individual or cumulative occupational radiation exposure due to the proposed change. Specifically, the change to utilize the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of plant SSCs has no impact on any radiation monitoring system setpoints. The proposed action will not change the level of controls or methodology used for processing of radioactive effluents or handling of solid radioactive waste, nor will the proposed action result in any change in the normal radiation levels within the plant.

Therefore, in accordance with 10 CFR 51.22, paragraph (b), no environmental impact statement or environmental assessment need be prepared regarding the proposed amendment.

6.0 REFERENCES

1. NRC Safety Evaluation Report, "Electric Power Research Institute (EPRI) Topical Reports Concerning Tornado Missile Probabilistic Risk Assessment (PRA) Methodology," dated October 26, 1983 (ML080870291)

2. NRC Regulatory Issue Summary 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008 (ML080230578)

3. Electric Power Research Institute Report – EPRI NP-768, "Tornado Missile Risk Analysis," May 1978

4. Electric Power Research Institute Report – EPRI NP-769, "Tornado Missile Risk Analysis - Appendices," May 1978

5. Electric Power Research Institute Report – EPRI NP-2005 Volumes, I and 2, "Tornado Missile Risk Evaluation Methodology," August 1981

6. NUREG/CR-4461, Revision 2, "Tornado Climatology of the Contiguous United States, (PNNL-15112, Rev 2)," Ramsdell and Rishel, 2007

7. FEMA (2007), "Multi-hazard Loss Estimation – Hurricane Model, HAZUS MH MR3 Technical Manual"

8. NRC Memorandum from Harold R. Denton to Victor Stello, "Position of Use of Probabilistic Risk Assessment in Tornado Licensing Actions," dated November 7, 1983 (ML080870287)

9. Enforcement Guidance Memorandum 15-002, "Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance," Revision 1, dated February 7, 2017

10. DSS-ISG-2016-01, "Clarification of Licensee Actions in Receipt of Enforcement Discretion Per Enforcement Guidance Memorandum EGM 15-002, 'Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance,'" Revision 1, dated November 2017

11. Letter from T. J. Wengert (NRC) to J. H. Plona (DTE Electric Company), "Fermi 2 – Issuance of Amendment Re: Revise the Fermi 2 Licensing Basis Concerning Protection from Tornado-Generated Missiles," dated March 10, 2014

12. Letter from J. F. Stang (NRC) to R. P. Powers (Indiana Michigan Power Company), "Donald C. Cook Nuclear Plant, Units 1 and 2 – Issuance of Amendments," dated November 17, 2000

13. Letter from D. M. Gullott (EGC) to NRC, "License Amendment Request to Utilize the TORMIS Computer Code Methodology, " dated October 7, 2016

14. Letter from D. M. Gullott (EGC) to NRC, "Response to Request for Additional Information Regarding the License Amendment Request to Utilize the TORMIS Computer Code Methodology," dated March 20, 2017

15. Letter from J. S. Wiebe (NRC) to B. C. Hansen (EGC), "Byron Station, Unit Nos. 1 and 2 – Issuance of Amendments Regarding Use of TORMIS for Assessing Tornado Missile Protection," dated August 10, 2017

ATTACHMENT 1A

SUMMARY OF REGULATORY COMMITMENTS

The following table identifies commitments made in this document. (Any other actions discussed in the submittal represent intended or planned actions. They are described to the NRC for the NRC's information and are not regulatory commitments.)

COMMITMENT	**COMMITTED DATE OR "OUTAGE"**	**COMMITMENT TYPE**	
		ONE-TIME ACTION (Yes/No)	**PROGRAMMATIC (Yes/No)**
Tornado missile protection will be installed on the Unit 1 and Unit 2 RWST hatches.	Prior to implementing the TORMIS methodology after NRC approval.	Yes	No

ATTACHMENT 1-1

TORMIS Results
Tables 1-4

BRAIDWOOD STATION
UNITS 1 AND 2

Docket Nos. 50-454 and 50-455

Renewed Facility Operating License Nos. NPF-37 and NPF-66

Table 1
TORMIS Results by Individual TORMIS Target

Group Number	Target Group	Target Number	Description	Failure Mode	Crimping Type	Missile Hit	Damage
1	RWST Hatches	1	RWST Hatch Unit 2	V > Vdam	N/A	7.05E-07	7.05E-07
		2	RWST Hatch Unit 1	V > Vdam	N/A	6.68E-07	6.68E-07
2	U2 MSSV Group 1 (SE)	3	MSSV-SE-1-1-p	Pipe Penetration	N/A	5.04E-07	5.35E-10
		4	MSSV-SE-1-2-p	Pipe Penetration	N/A	5.18E-07	6.99E-10
		5	MSSV-SE-1-3-p	Pipe Penetration	N/A	4.95E-07	5.22E-10
		6	MSSV-SE-1-4-p	Pipe Penetration	N/A	5.19E-07	1.62E-09
		7	MSSV-SE-1-5-p	Pipe Penetration	N/A	4.90E-07	7.99E-10
3	U2 MSSV Group 2 (SE)	8	MSSV-SE-2-1-p	Pipe Penetration	N/A	4.69E-07	5.13E-10
		9	MSSV-SE-2-2-p	Pipe Penetration	N/A	4.95E-07	3.62E-10
		10	MSSV-SE-2-3-p	Pipe Penetration	N/A	4.45E-07	3.69E-10
		11	MSSV-SE-2-4-p	Pipe Penetration	N/A	5.02E-07	4.57E-10
		12	MSSV-SE-2-5-p	Pipe Penetration	N/A	4.63E-07	1.36E-09
4	U2 MSSV Group 1 (SW)	13	MSSV-SW-1-1-p	Pipe Penetration	N/A	4.12E-07	1.08E-09
		14	MSSV-SW-1-2-p	Pipe Penetration	N/A	4.28E-07	1.37E-09
		15	MSSV-SW-1-3-p	Pipe Penetration	N/A	4.09E-07	1.13E-09
		16	MSSV-SW-1-4-p	Pipe Penetration	N/A	4.74E-07	6.41E-10
		17	MSSV-SW-1-5-p	Pipe Penetration	N/A	4.29E-07	8.22E-10
5	U2 MSSV Group 2 (SW)	18	MSSV-SW-2-1-p	Pipe Penetration	N/A	1.63E-07	3.43E-10
		19	MSSV-SW-2-2-p	Pipe Penetration	N/A	1.36E-07	2.97E-10
		20	MSSV-SW-2-3-p	Pipe Penetration	N/A	1.90E-07	2.01E-10
		21	MSSV-SW-2-4-p	Pipe Penetration	N/A	1.59E-07	5.69E-10
		22	MSSV-SW-2-5-p	Pipe Penetration	N/A	2.43E-07	9.40E-10
6	U1 MSSV Group 1 (NW)	23	MSSV-NW-1-1-p	Pipe Penetration	N/A	8.65E-08	2.22E-10
		24	MSSV-NW-1-2-p	Pipe Penetration	N/A	7.20E-08	7.02E-10
		25	MSSV-NW-1-3-p	Pipe Penetration	N/A	8.03E-08	1.97E-10
		26	MSSV-NW-1-4-p	Pipe Penetration	N/A	7.00E-08	1.03E-10
		27	MSSV-NW-1-5-p	Pipe Penetration	N/A	7.90E-08	2.59E-10
7	U1 MSSV Group 2 (NW)	28	MSSV-NW-2-1-p	Pipe Penetration	N/A	2.55E-07	3.48E-10
		29	MSSV-NW-2-2-p	Pipe Penetration	N/A	2.79E-07	4.00E-10
		30	MSSV-NW-2-3-p	Pipe Penetration	N/A	2.78E-07	4.30E-10
		31	MSSV-NW-2-4-p	Pipe Penetration	N/A	3.14E-07	3.81E-10
		32	MSSV-NW-2-5-p	Pipe Penetration	N/A	2.97E-07	4.43E-10
8	U1 MSSV Group 1 (NE)	33	MSSV-NE-1-1-p	Pipe Penetration	N/A	2.50E-07	7.90E-10
		34	MSSV-NE-1-2-p	Pipe Penetration	N/A	2.99E-07	1.66E-09
		35	MSSV-NE-1-3-p	Pipe Penetration	N/A	2.99E-07	9.16E-10
		36	MSSV-NE-1-4-p	Pipe Penetration	N/A	3.45E-07	8.39E-10
		37	MSSV-NE-1-5-p	Pipe Penetration	N/A	3.79E-07	2.10E-09
9	U1 MSSV Group 2 (NE)	38	MSSV-NE-2-1-p	Pipe Penetration	N/A	2.74E-07	1.01E-09
		39	MSSV-NE-2-2-p	Pipe Penetration	N/A	2.89E-07	3.49E-10
		40	MSSV-NE-1-3-p	Pipe Penetration	N/A	3.08E-07	1.14E-09
		41	MSSV-NE-1-4-p	Pipe Penetration	N/A	3.57E-07	1.16E-09
		42	MSSV-NE-1-5-p	Pipe Penetration	N/A	3.89E-07	2.61E-09
10	U2 PORV SE 1	43	PORV-SE-1-c	V > Vdam	PORV	2.05E-06	2.30E-09
11	U2 PORV SE 2	44	PORV-SE-2-c	V > Vdam	PORV	1.20E-06	4.62E-10
12	U2 PORV SW 1	45	PORV-SW-1-c	V > Vdam	PORV	9.04E-07	8.14E-11
13	U2 PORV SW 2	46	PORV-SW-2-c	V > Vdam	PORV	4.15E-07	4.69E-11
14	U1 PORV NW 1	47	PORV-NW-1-c	V > Vdam	PORV	1.19E-07	0.00E+00
15	U1 PORV NW 2	48	PORV-NW-2-c	V > Vdam	PORV	2.63E-07	0.00E+00
16	U1 PORV NE 1	49	PORV-NE-1-c	V > Vdam	PORV	1.56E-06	3.80E-10
17	U1 PORV NE 2	50	PORV-NE-2-c	V > Vdam	PORV	4.85E-07	2.94E-10
10	U2 PORV SE 1	51	PORV-SE-1-p	Pipe Penetration	N/A	4.05E-07	6.02E-10
11	U2 PORV SE 2	52	PORV-SE-2-p	Pipe Penetration	N/A	3.89E-07	1.20E-09
12	U2 PORV SW 1	53	PORV-SW-1-p	Pipe Penetration	N/A	4.65E-07	4.59E-10
13	U2 PORV SW 2	54	PORV-SW-2-p	Pipe Penetration	N/A	2.90E-07	5.20E-10
14	U1 PORV NW 1	55	PORV-NW-1-p	Pipe Penetration	N/A	1.10E-07	4.42E-10
15	U1 PORV NW 2	56	PORV-NW-2-P	Pipe Penetration	N/A	2.93E-07	3.29E-10
16	U1 PORV NE 1	57	PORV-NE-1-p	Pipe Penetration	N/A	2.11E-07	3.86E-10
17	U1 PORV NE 2	58	PORV-NE-2-p	Pipe Penetration	N/A	2.13E-07	5.58E-10
18	DAFP U2	59	Diesel Auxiary Feed Pump Exhaust U2 -- Lower portion	V > Vdam	DAFP Pipe	7.11E-06	2.82E-08
		60	Diesel Auxiary Feed Pump Exhaust U2 -- Upper portion	V > Vdam	DAFP Cover Plate	2.09E-06	3.03E-07
19	DAFP U1	61	Diesel Auxiary Feed Pump Exhaust U1 -- Lower portion	V > Vdam	DAFP Pipe	6.22E-06	2.39E-08
		62	Diesel Auxiary Feed Pump Exhaust U1 -- Upper portion	V > Vdam	DAFP Cover Plate	2.06E-06	2.99E-07
20	U1 Division 2 MEER	63	U1 Division 2 MEER Opening	Pipe Penetration	N/A	1.91E-06	3.34E-08
21	U1 Division 1 MEER	64	U1 Division 1 MEER Opening	Pipe Penetration	N/A	6.91E-07	5.78E-09
24	U1 CR HVAC	65	U1 Control Room HVAC Intake Opening	Pipe Penetration	N/A	6.98E-07	2.18E-10
25	U2 CR HVAC	66	U2 Control Room HVAC Intake Opening	Pipe Penetration	N/A	6.19E-07	1.82E-10
22	U2 Division 1 MEER	67	U2 Division 1 MEER Opening	Pipe Penetration	N/A	7.15E-07	1.06E-08
23	U2 Division 2 MEER	68	U2 Division 2 MEER Opening	Pipe Penetration	N/A	1.95E-06	6.58E-08
20	U1 Division 2 MEER	69	Pipe West of U1 Division 2 MEER Opening	Perforation	N/A	1.79E-05	1.89E-08
21	U1 Division 1 MEER	70	Pipe West of U1 Division 1 MEER Opening	Perforation	N/A	1.39E-05	1.66E-08
22	U2 Division 1 MEER	71	Pipe West of U2 Division 1 MEER Opening	Perforation	N/A	1.43E-05	1.54E-08
23	U2 Division 2 MEER	72	Pipe West of U2 Division 2 MEER Opening	Perforation	N/A	1.82E-05	2.60E-08
26	SX Discharge Pipes	73	SX Discharge Pipe-1	V > Vdam	N/A	6.46E-08	6.46E-08
		74	SX Discharge Pipe-2	V > Vdam	N/A	4.63E-08	4.63E-08

Table 2
Average Hit and Damage Frequency (per year) for Target Groups

Group Number	Target Group	Failure Logic	Missile Hit	Damage
1	RWST Hatches	1 U 2	1.37E-06	1.37E-06
2	U2 MSSV Group 1 (SE)	3 U 4 U 5 U 6 U 7	2.51E-06	4.18E-09
3	U2 MSSV Group 2 (SE)	8 U 9 U 10 U 11 U 12	2.35E-06	3.06E-09
4	U2 MSSV Group 1 (SW)	13 U 14 U 15 U 16 U 17	2.13E-06	5.05E-09
5	U2 MSSV Group 2 (SW)	18 U 19 U 20 U 21 U 22	8.86E-07	2.35E-09
6	U1 MSSV Group 1 (NW)	23 U 24 U 25 U 26 U 27	3.87E-07	1.48E-09
7	U1 MSSV Group 2 (NW)	28 U 29 U 30 U 31 U 32	1.41E-06	2.00E-09
8	U1 MSSV Group 1 (NE)	33 U 34 U 35 U 36 U 37	1.56E-06	6.30E-09
9	U1 MSSV Group 2 (NE)	38 U 39 U 40 U 41 U 42	1.61E-06	6.27E-09
10	U2 PORV SE 1	43 U 51	2.45E-06	2.90E-09
11	U2 PORV SE 2	44 U 52	1.59E-06	1.67E-09
12	U2 PORV SW 1	45 U 53	1.37E-06	5.40E-10
13	U2 PORV SW 2	46 U 54	7.05E-07	5.67E-10
14	U1 PORV NW 1	47 U 55	2.28E-07	4.42E-10
15	U1 PORV NW 2	48 U 56	5.55E-07	3.29E-10
16	U1 PORV NE 1	49 U 57	1.76E-06	7.66E-10
17	U1 PORV NE 2	50 U 58	6.96E-07	8.52E-10
18	DAFP U2	59 U 60	9.07E-06	3.31E-07
19	DAFP U1	61 U 62	8.18E-06	3.23E-07
20	U1 Division 2 MEER	63 U 69	1.97E-05	5.23E-08
21	U1 Division 1 MEER	64 U 70	1.46E-05	2.24E-08
22	U2 Division 1 MEER	67 U 71	1.50E-05	2.60E-08
23	U2 Division 2 MEER	68 U 72	2.00E-05	9.19E-08
24	U1 CR HVAC	65	6.98E-07	2.18E-10
25	U2 CR HVAC	66	6.19E-07	1.82E-10
26	SX Discharge Pipes	73 U 74	1.10E-07	1.10E-07

Table 3
Mean Damage Frequency (per Year) for Braidwood Station Target Groups

Target Identified by BRW	**Corresponding Target Groups**	**Target Group Approach**	**Source Table for Damage Frequency**	**Unit 1 Damage Frequency (yr^{-1})**	**Unit 2 Damage Frequency (yr^{-1})**
Diesel Aux FW Pump Exhausts	DAFP	Boolean Union of over separate targets for exhaust pipe and cover plate. Separate damage frequencies computed for each unit. Damage to DAFP exhaust pipes and cover plates based on Finite Element Analysis specifically for BRW.	Table 2	3.23E-07	3.31E-07
PORV Tailpipes	PORV 1	Boolean Union of targets modeled for pipe crimping and pipe penetration pass through. Separate damage frequencies computed for each PORV on each unit. Pipe crimping damage based on Finite Element Analysis completed specifically for BRW.	Table 2	4.42E-10	2.90E-09
	PORV 2			3.29E-10	1.67E-09
	PORV 3			7.66E-10	5.40E-10
	PORV 4			8.52E-10	5.67E-10
MSSV Tailpipes	MSSV 1	Boolean Union of over 5 MSSVs on each respective Main Steam line. Separate damage frequencies computed for each set of 5 MSSVs on each unit.	Table 2	1.48E-09	4.18E-09
	MSSV 2			2.00E-09	3.06E-09
	MSSV 3			6.30E-09	5.05E-09
	MSSV 4			6.27E-09	2.35E-09
RWST Hatches	RWST Hatch	Missile hit probability on single target representing the RWST hatch for each unit.	Table 1	6.68E-07	7.05E-07
MEER Openings	MEER Div 2 Opening	Boolean Union of missiles passing through equivalent pipe penetration and perforating the pipe blocking the opening	Table 2	5.23E-08	9.19E-08
	MEER Div 1 Opening			2.24E-08	2.60E-08
	CR HVAC Intake Opening	Missiles passing through equivalent pipe penetration		2.18E-10	1.82E-10
SX Discharge Pipes	SX Pipes	Boolean Union of missile hit probability on the two exposed SX Discharge Pipes in the lake.	Table 2	1.10E-07	1.10E-07
Arithmetic Sum over all Target Groups				**1.19E-06**	**1.29E-06**
Arthimetic Sum assuming protection of RWST Hatches				**5.26E-07**	**5.80E-07**

Table 4
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 1 of 4)

TORMIS Target #	BRW Target Group	TORMIS Target Description	I_{safety}	I_{shield}	I_{source}
1	RWST Hatches	RWST Hatch Unit 2	1		
2		RWST Hatch Unit 1	2		
3	U2 MSSV Group 1 (SE)	MSSV-SE-1-1-p	3		
4		MSSV-SE-1-2-p	4		
5		MSSV-SE-1-3-p	5		
6		MSSV-SE-1-4-p	6		
7		MSSV-SE-1-5-p	7		
8	U2 MSSV Group 2 (SE)	MSSV-SE-2-1-p	8		
9		MSSV-SE-2-2-p	9		
10		MSSV-SE-2-3-p	10		
11		MSSV-SE-2-4-p	11		
12		MSSV-SE-2-5-p	12		
13	U2 MSSV Group 1 (SW)	MSSV-SW-1-1-p	13		
14		MSSV-SW-1-2-p	14		
15		MSSV-SW-1-3-p	15		
16		MSSV-SW-1-4-p	16		
17		MSSV-SW-1-5-p	17		
18	U2 MSSV Group 2 (SW)	MSSV-SW-2-1-p	18		
19		MSSV-SW-2-2-p	19		
20		MSSV-SW-2-3-p	20		
21		MSSV-SW-2-4-p	21		
22		MSSV-SW-2-5-p	22		
23	U1 MSSV Group 1 (NW)	MSSV-NW-1-1-p	23		
24		MSSV-NW-1-2-p	24		
25		MSSV-NW-1-3-p	25		
26		MSSV-NW-1-4-p	26		
27		MSSV-NW-1-5-p	27		
28	U1 MSSV Group 2 (NW)	MSSV-NW-2-1-p	28		
29		MSSV-NW-2-2-p	29		
30		MSSV-NW-2-3-p	30		
31		MSSV-NW-2-4-p	31		
32		MSSV-NW-2-5-p	32		
33	U1 MSSV Group 1 (NE)	MSSV-NE-1-1-p	33		
34		MSSV-NE-1-2-p	34		
35		MSSV-NE-1-3-p	35		
36		MSSV-NE-1-4-p	36		
37		MSSV-NE-1-5-p	37		
38	U1 MSSV Group 2 (NE)	MSSV-NE-2-1-p	38		
39		MSSV-NE-2-2-p	39		
40		MSSV-NE-1-3-p	40		
41		MSSV-NE-1-4-p	41		
42		MSSV-NE-1-5-p	42		
43	U2 PORV SE 1	PORV-SE-1-c	43		
44	U2 PORV SE 2	PORV-SE-2-c	44		
45	U2 PORV SW 1	PORV-SW-1-c	45		
46	U2 PORV SW 2	PORV-SW-2-c	46		
47	U1 PORV NW 1	PORV-NW-1-c	47		
48	U1 PORV NW 2	PORV-NW-2-c	48		
49	U1 PORV NE 1	PORV-NE-1-c	49		

Table 4
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 2 of 4)

TORMIS Target #	BRW Target Group	TORMIS Target Description	I_{safety}	I_{shield}	I_{source}
50	U1 PORV NE 2	PORV-NE-2-c	50		
51	U2 PORV SE 1	PORV-SE-1-p	51		
52	U2 PORV SE 2	PORV-SE-2-p	52		
53	U2 PORV SW 1	PORV-SW-1-p	53		
54	U2 PORV SW 2	PORV-SW-2-p	54		
55	U1 PORV NW 1	PORV-NW-1-p	55		
56	U1 PORV NW 2	PORV-NW-2-P	56		
57	U1 PORV NE 1	PORV-NE-1-p	57		
58	U1 PORV NE 2	PORV-NE-2-p	58		
59	DAFP U2	Diesel Auxiary Feed Pump Exhaust U2 -- Lower portion	59		
60		Diesel Auxiary Feed Pump Exhaust U2 -- Upper portion	60		
61	DAFP U1	Diesel Auxiary Feed Pump Exhaust U1 -- Lower portion	61		
62		Diesel Auxiary Feed Pump Exhaust U1 -- Upper portion	62		
63	Div 12 MEER	U1 Division 2 MEER Opening	63		
64	Div 11 MEER	U1 Division 1 MEER Opening	64		
65	MCR Makeup Air Intake U1	U1 Control Room HVAC Intake Opening	65		
66	MCR Makeup Air Intake U2	U2 Control Room HVAC Intake Opening	66		
67	Div 21 MEER	U2 Division 1 MEER Opening	67		
68	Div 22 MEER	U2 Division 2 MEER Opening	68		
69	Div 12 MEER	Pipe West of U1 Division 2 MEER Opening	69		
70	Div 11 MEER	Pipe West of U1 Division 1 MEER Opening	70		
71	Div 21 MEER	Pipe West of U2 Division 1 MEER Opening	71		
72	Div 22 MEER	Pipe West of U2 Division 2 MEER Opening	72		
73	Missile Shielding Targets	Reserved		1	
74		Reserved		2	
75		Reserved		9	
76		Reserved		10	
77		Reserved		11	
78		Main TB		12	
79		Left Side Section TB		13	
80		Right U1 RB		14	
81		FHB		15	
82		Right Shared Section of RB		16	
83		Lower Right Section RB into Reactor		17	
84		Upper Right Section RB into Reactor		18	
85		Right U2 RB		19	
86		U1 Reactor		20	
87		U2 Reactor		21	
88		U1 SE box lower		22	
89		U1 SE box upper		23	
90		U1 SW box lower		24	
91		U1 SW box upper		25	
92		U2 NE box lower		26	
93		U2 NE box upper		27	
94		U2 NW box lower		28	
95		U2 NW box upper		29	
96		RWST 1		30	
97		RWST 2		31	
98		U1 Aux FW Shield South		32	
99		U1 Aux FW Shield West		33	
100		U1 Aux FW Shield North		34	
101		U2 Aux FW Shield South		35	
102		U2 Aux FW Shield West		36	
103		U2 Aux FW Shield North		37	
104		U1 MS Helb 2		38	

Table 4
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 3 of 4)

TORMIS Target #	BRW Target Group	TORMIS Target Description	I_{safety}	I_{shield}	I_{source}
105	Missile Shielding Targets *continued*	U1 MS Helb 3		39	
106		U2 MS Helb 5		40	
107		U2 MS Helb 6		41	
108		Under Helb 2-3		42	
109		Between Helb		43	
110		Under Helb 5-6		44	
111	Missile Source Targets	Gate House			1
112		Gate House 2			2
113		Service Building Add 1			3
114		Service Building Add 2			4
115		Fukushima Trailer			5
116		CA Facility Unit 2			6
117		IEMA Building			7
118		CA Facility Unit 1			8
119		Old Building			9
120		Security-7			10
121		Gas Storage Area			11
122		Waste Treatment Building			12
123		Storage Shed-9			13
124		Warehouse-10			14
125		Recieving Building			15
126		Decontamination Facility			16
127		Supply Warehouse 1			17
128		Supply Warehouse 2			18
129		Supply Warehouse 3			19
130		Excelon			20
131		Excelon A			21
132		Excelon B			22
133		Excelon C			23
134		Office-15			24
135		Office-16-1			25
136		Office-16-2			26
137		Office-16-3			27
138		Warehouse-16			28
139		Warehouse-Attachment			29
140		Shed-17			30
141		Warehouse-485			31
142		Iron Fab Shop			32
143		Garage			33
144		Central Warehouse			34
145		Warehouse 18-1			35
146		Warehouse 18-2			36
147		Shop-To Be Removed			37
148		Access			38
149		New Training Facility			39
150		Training Shop			40
151		Fit for Duty			41
152		Security Screening			42
153		Fukushima Building			43
154		Trailer-24			44
155		Salt Shed			45
156		ISFSI Storage			46
157		Building-25			47
158		Switch Yard House 1			48
159		Switch Yard House 2			49
160		Checkpoint			50
161		North Houses-30			51
162		Mid Houses-30			52
163		South Houses-30			53

Table 4
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 4 of 4)

TORMIS Target #	BRW Target Group	TORMIS Target Description	I_{safety}	I_{shield}	I_{source}
164	Missile Source Targets *continued*	Houses-31			54
165		Single House-31			55
166		North Houses-32			56
167		East Houses-32			57
168		West Houses-32			58
169		Houses-33			59
170		Yoga Building			60
171		Park Sheds			61
172		Public Water			62
173		BBall Building			63
174		Clubhouse			64
175		Trailer-33			65
176		House-33			66
177		Screening House			67
178		U2 Operating Floor			68
179		U1 Operating Floor			69
180		TSC Roof			70
181		Operating Building			71
182		U2 Building Operating Floor			72
183		Radwaste			73
184		Outage-3			74
185		Outage Trailers -4			75
186		Outage Trailer-17			76
187		East Wall TB 1			77
188		West Wall TB			78
189		North Wall TB			79
190		South Wall TB			80
191		U1 RB Cladding			81
192		U2 RB Cladding			82
193		Service Building			83
194		TB Roof			84
195		Houses-28			85
196		Train Car Shed			86
197		Fukushima-3			87
198		Outage Trailers-2			88
199		Outage Trailer-22			89
200		East Wall TB 2			90
201		East Wall TB 3			91
202		Contractors Facility			92
203		Heater Bay Roof			93
204		SouthWestTB			94
205		ISFSI Warehouse			95

ATTACHMENT 1-2

TORMIS Results
Figures 1-8

BRAIDWOOD STATION
UNITS 1 AND 2

Docket Nos. 50-454 and 50-455

Renewed Facility Operating License Nos. NPF-37 and NPF-66

Figure 1
Individual Target Hit and Damage Frequencies

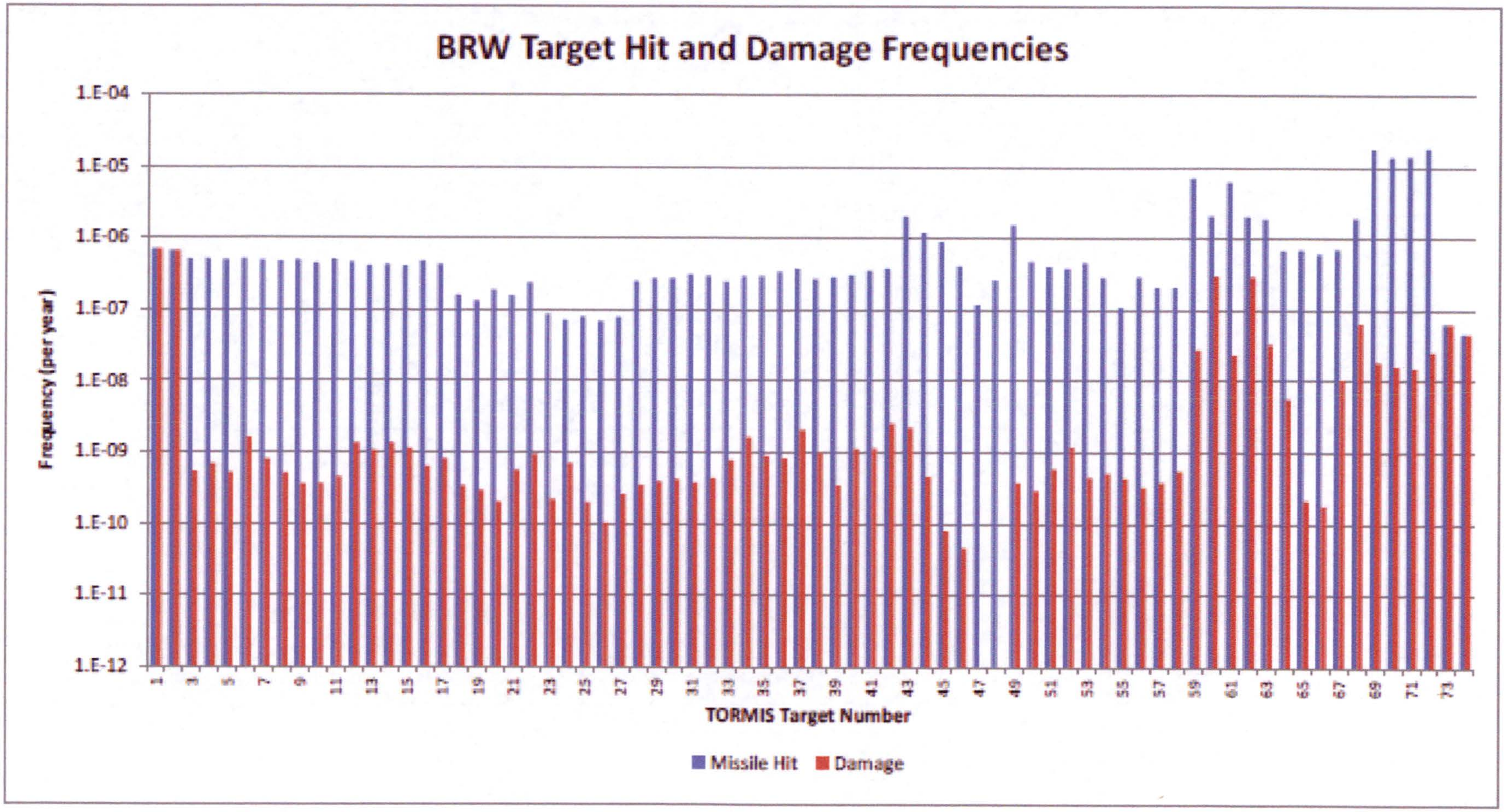


Figure 2
Target Group Hit and Damage Frequencies

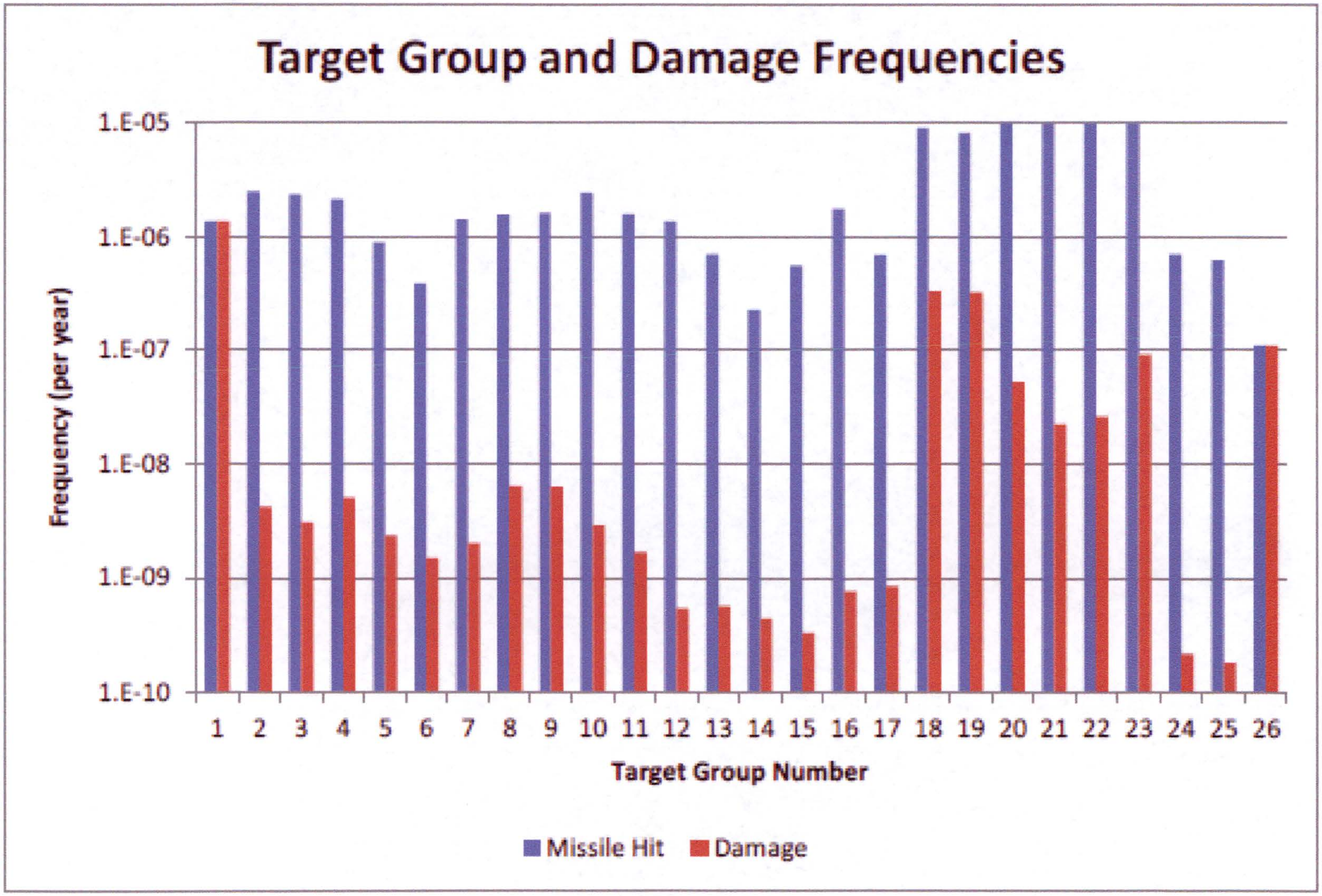
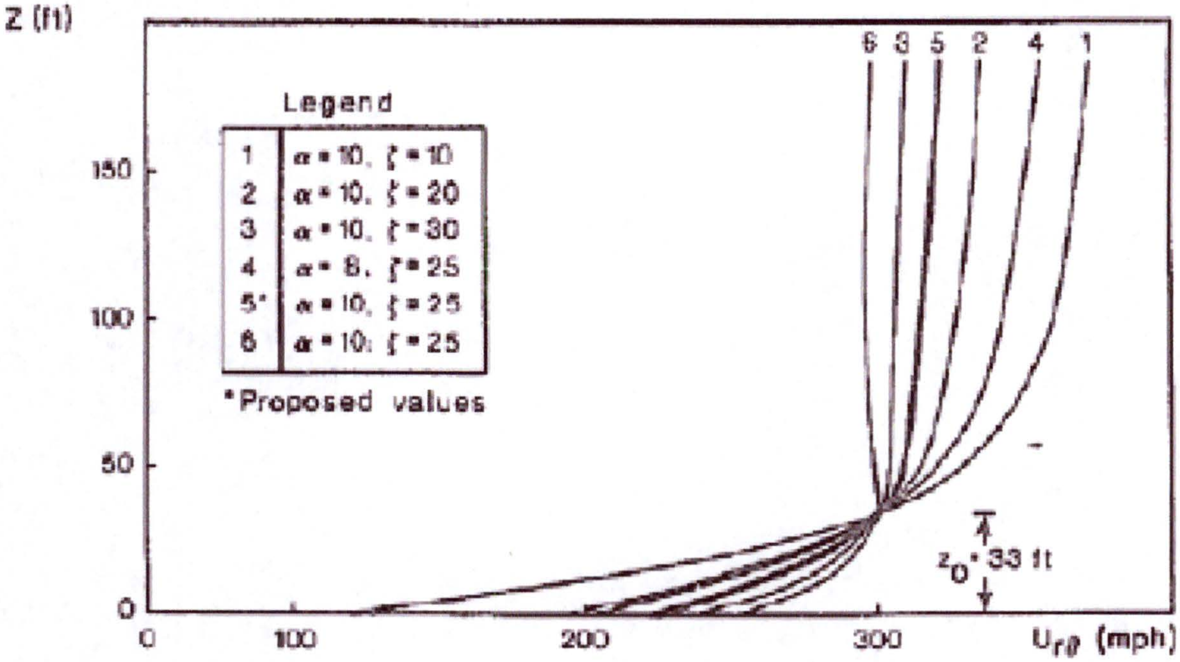
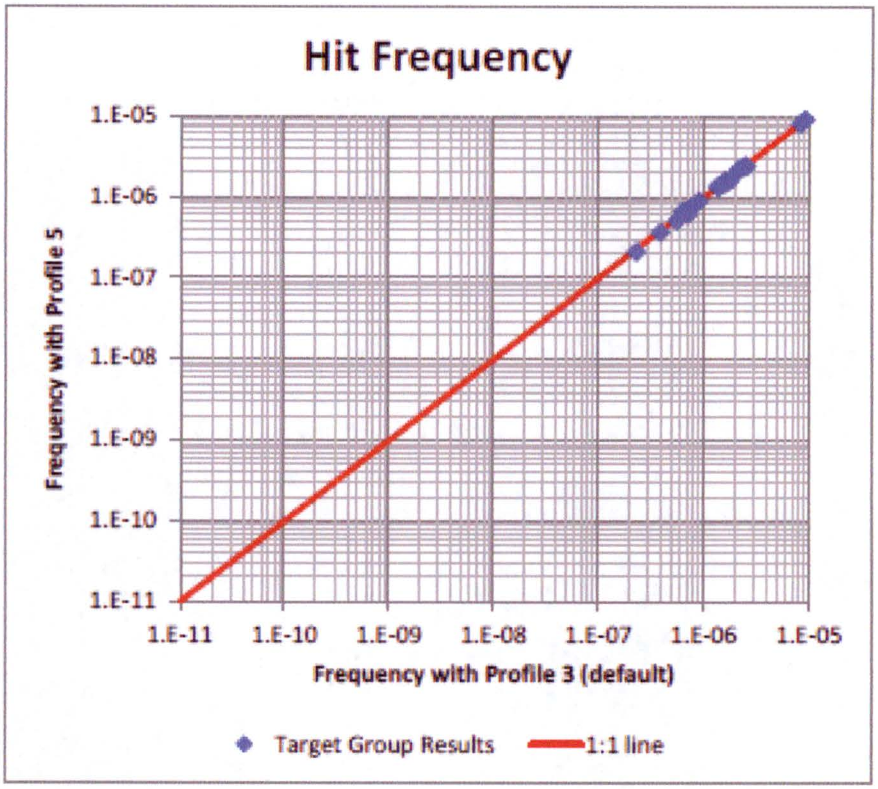


Figure 3
Tornado Rotational Wind Velocity Profiles
(Figure II-12(b) from NP-2005 Volume 2)



(b) Rotational Velocity

Figure 4
Plot of Frequencies with Profile 5 versus Profile 3


Hit Frequency

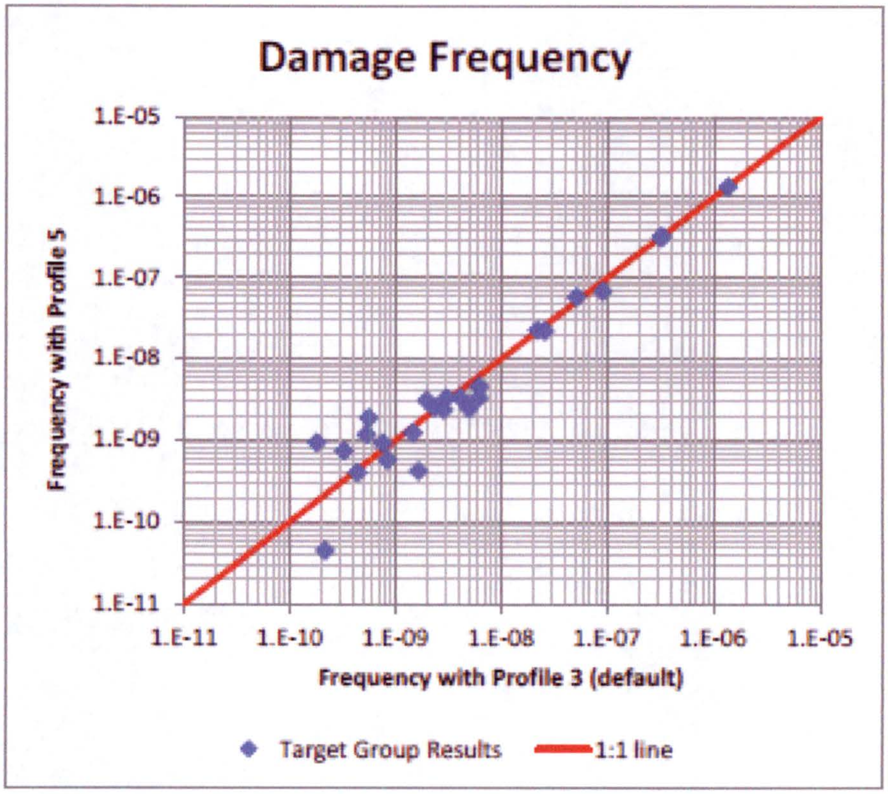

Damage Frequency

Figure 5
Zone Layout for Braidwood Station Main Site Model TORMIS Analysis

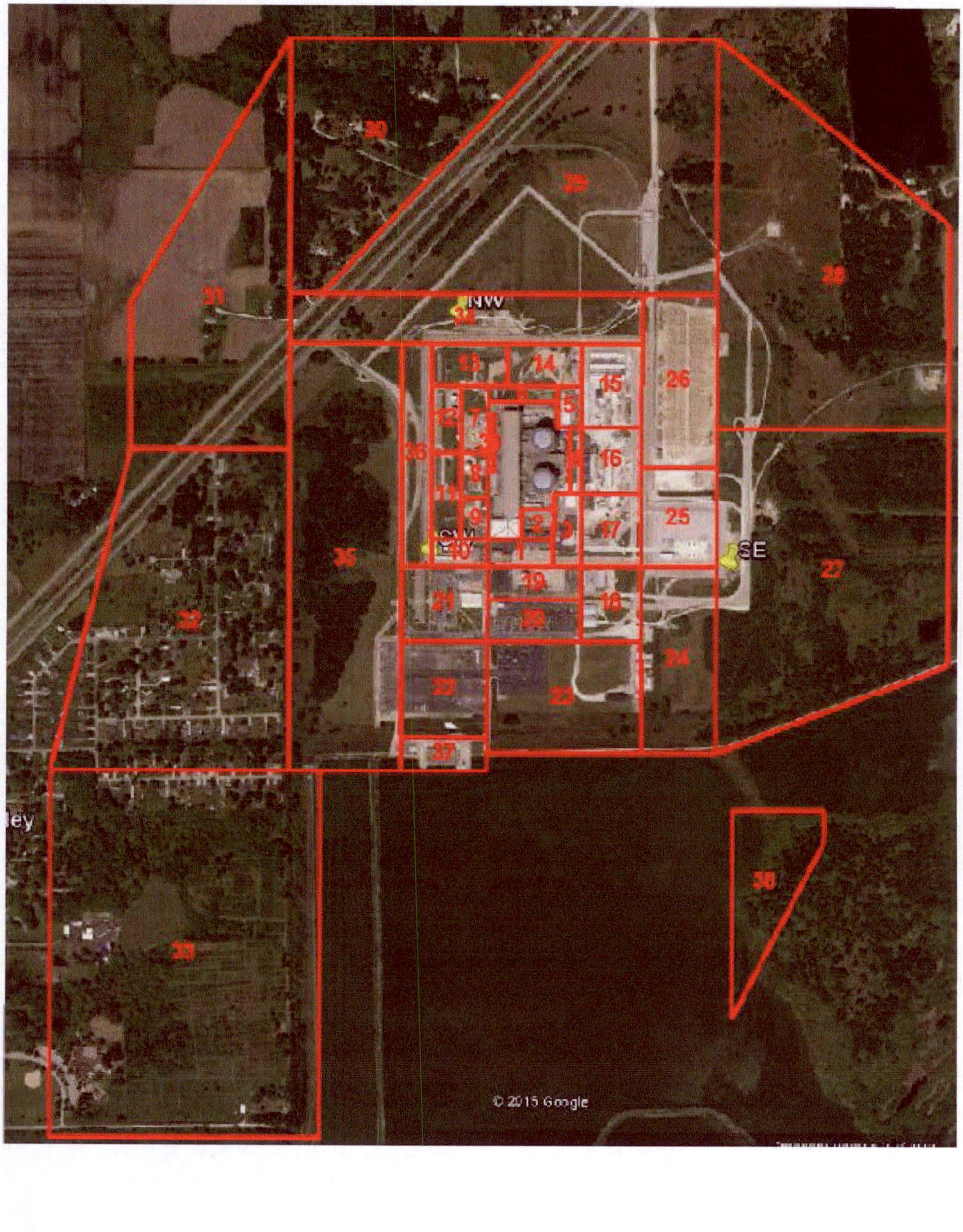


Figure 6
Zone Layout for Braidwood Station SX Model TORMIS Analysis

Figure 7
TORMIS Simulation of Braidwood Station Tornado Hazard for Plant Safety Envelope

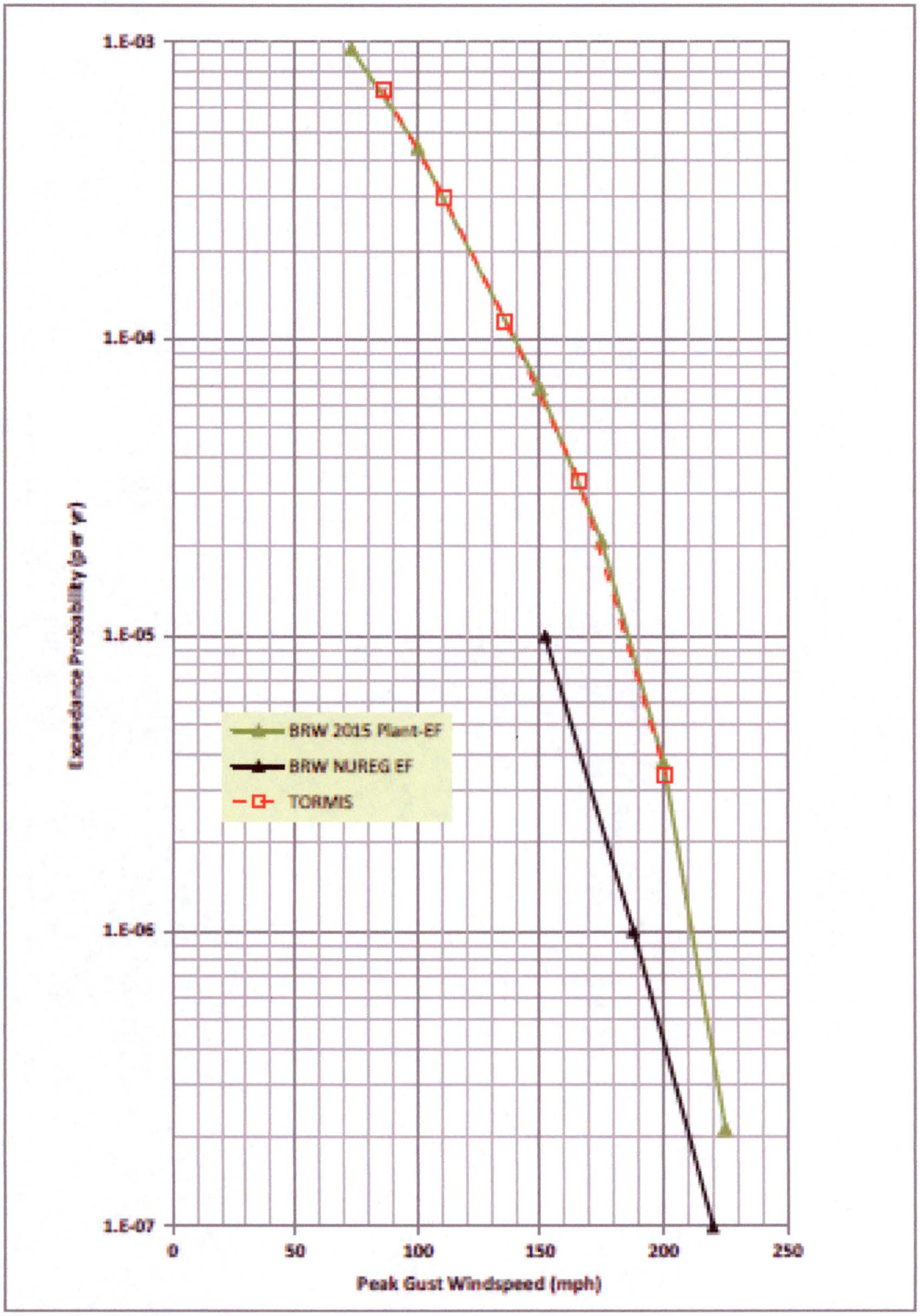
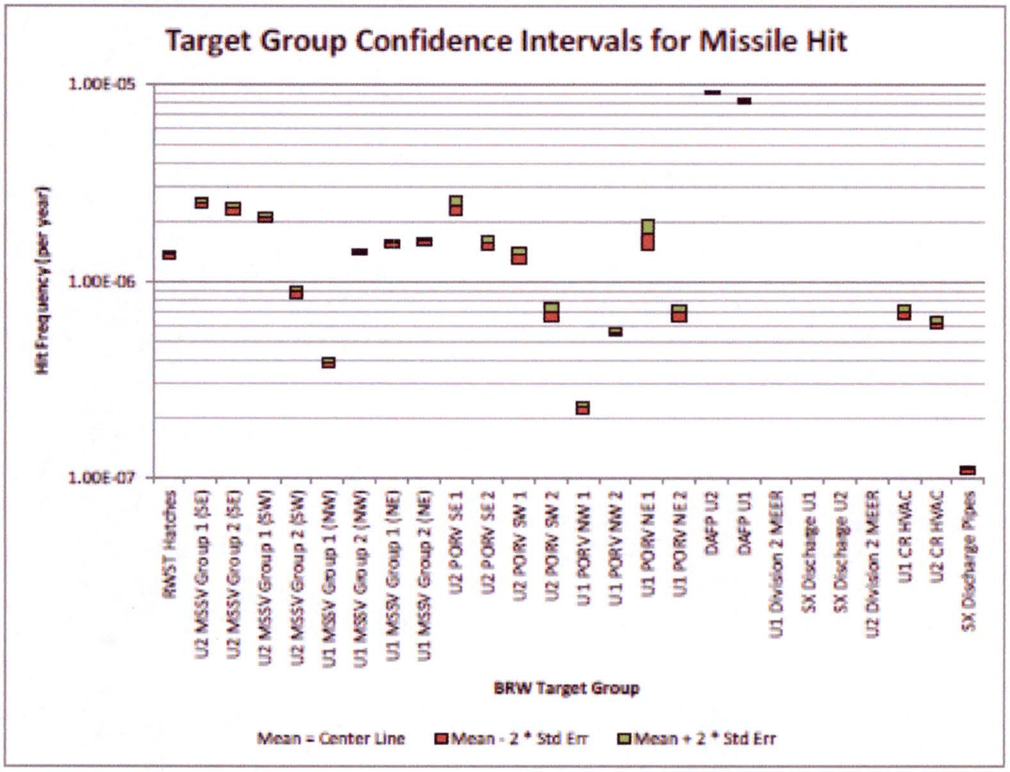


Figure 8
Target Group Hit and Damage Frequency with Confidence Intervals



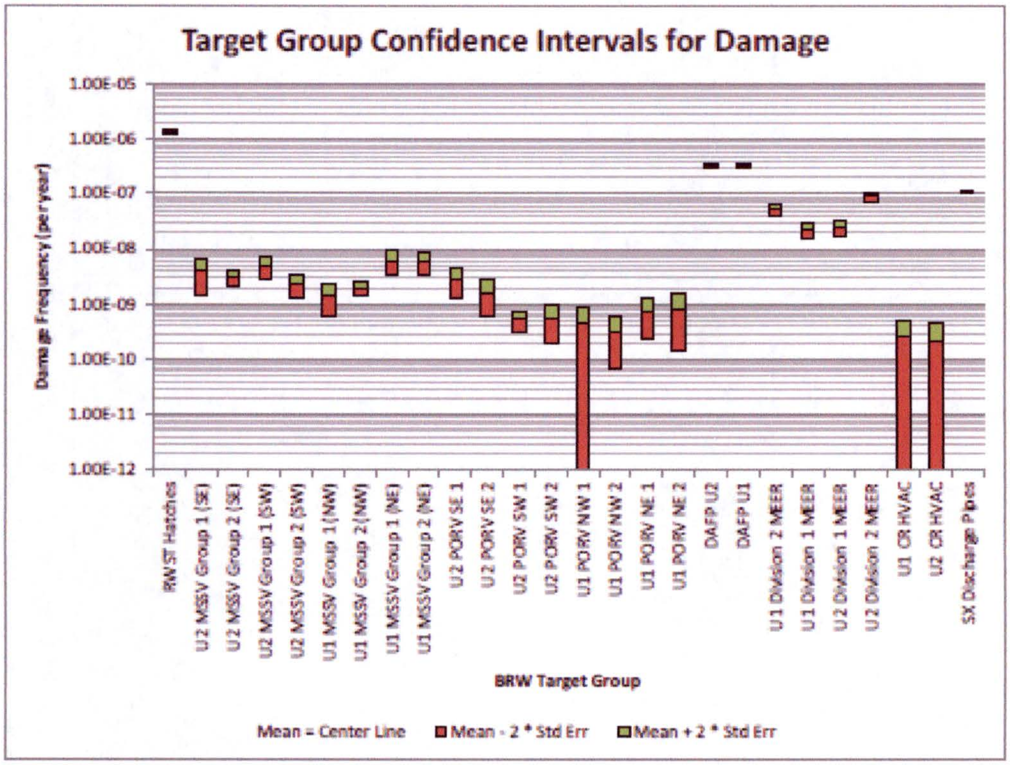
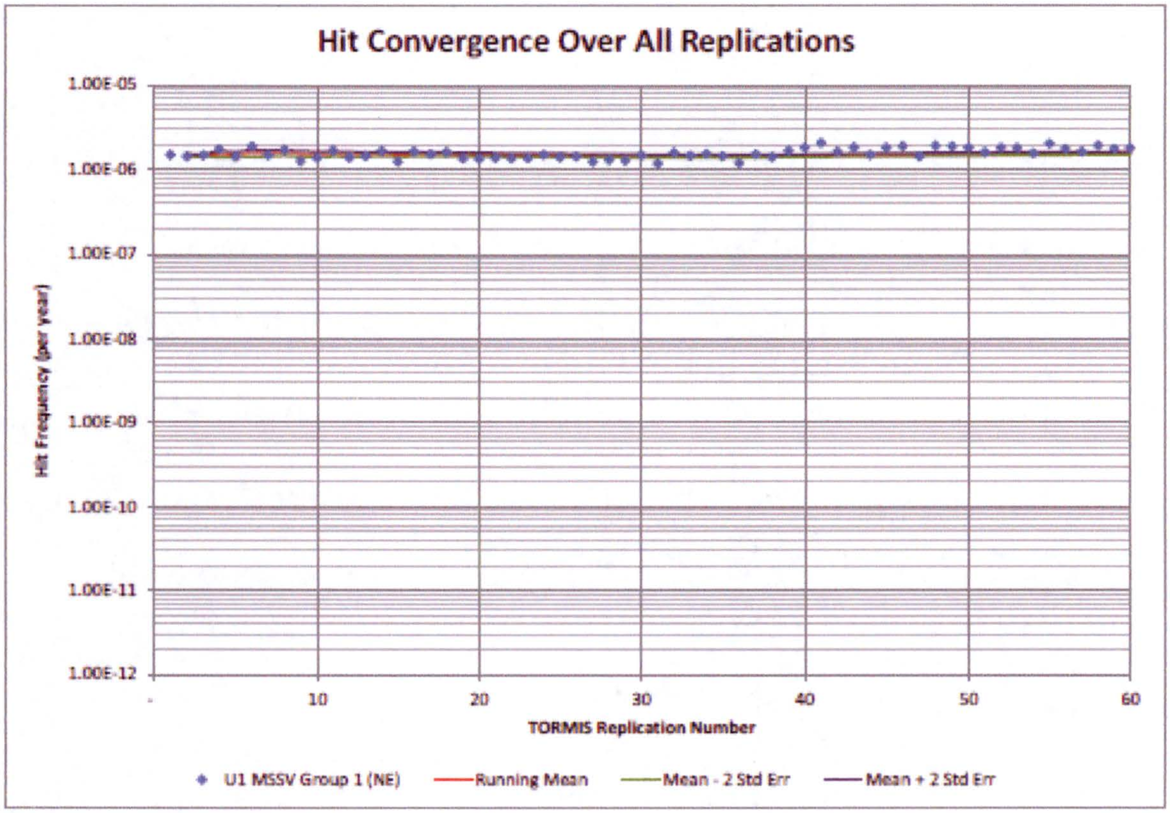
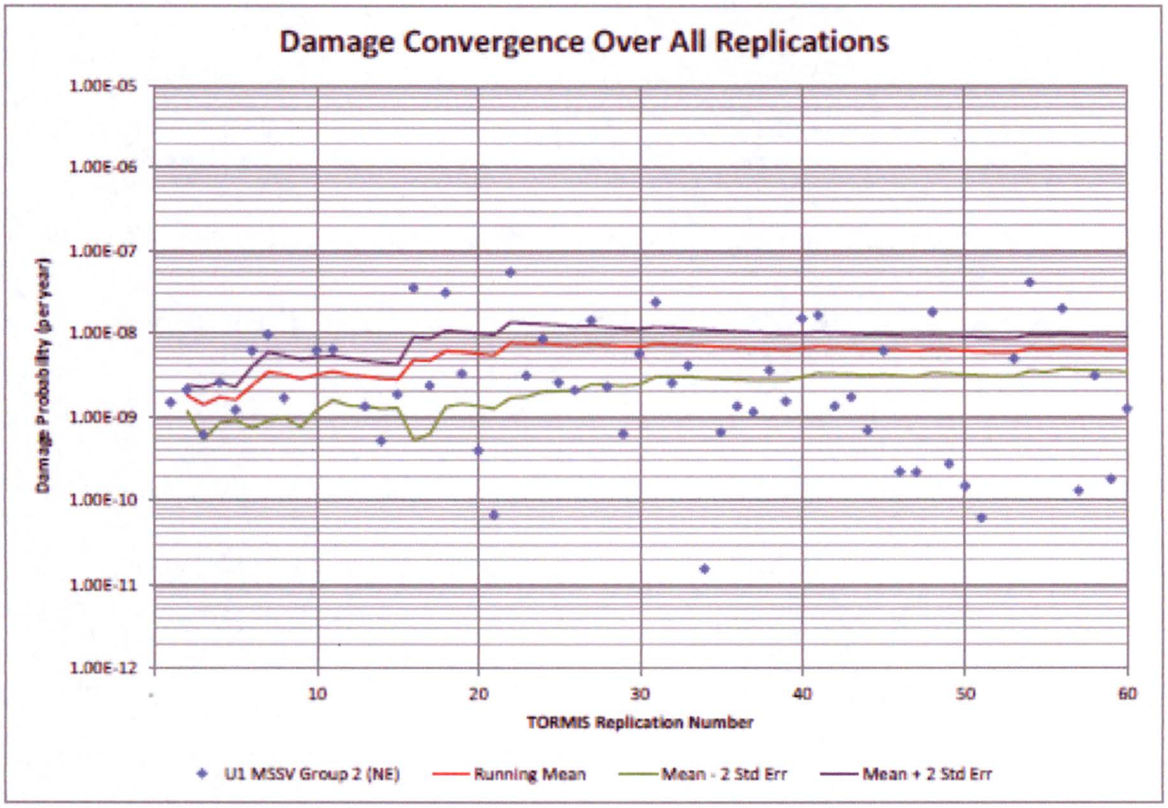


Figure 9
Convergence Plot for Damage Frequency for Target Group 8 (U1 MSSV Group 1 NE)





ATTACHMENT 1-3

Draft Markup of Updated Final Safety Analysis Report Pages

BRAIDWOOD STATION
UNITS 1 AND 2

Docket Nos. 50-454 and 50-455

Renewed Facility Operating License Nos. NPF-37 and NPF-66

REVISED UFSAR PAGES

3.3-1
3.3-2
3.3-3 (no changes; included for continuity)
3.3-4
3.3-5

3.5-11
3.5-21 (no changes; included for continuity)
3.5-21a
3.5-25
3.5-25a (no changes; included for continuity)
3.5-26
3.5-26a-d
3.5-27 (no changes; included for continuity)
3.5-28
3.5-48
3.5-49 (no changes; included for continuity)
3.5-50

3.3 WIND AND TORNADO LOADINGS

3.3.1 Wind Loadings

3.3.1.1 Design Wind Velocity

A design wind velocity of 85 mph, based upon a 100-year mean recurrence interval, is used in the design of Seismic Category I structures.

For Category II structures a design wind velocity of 75 mph is used, based upon a 50-year mean recurrence interval.

The vertical velocity distribution and gust factors employed for the wind velocities are based on Table 5 of Reference 1 for exposure Type C.

3.3.1.2 Determination of Applied Forces

The dynamic wind pressures are converted to an equivalent static force by considering appropriate pressure coefficients. The applied forces were derived in accordance with the provisions of Table 7, Reference 1, using external pressure coefficients, Cp of 0.8 and -0.5 for windward and leeward walls respectively, and -0.7 for side walls and roofs.

For structural shapes other than rectangular appropriate pressure coefficients are used in accordance with Reference 2.

3.3.2 Tornado Loadings

3.3.2.1 Applicable Design Parameters

The following are the parameters for the design-basis tornado (Reference 3):

Tangential velocity: 290 mph

Translational velocity: 70 mph

Radius of maximum rotational velocity from center of tornado: 150 feet

Pressure drop at the center of vortex: 3 psi

Rate of pressure drop: 2 psi/sec.

The characteristics and spectrum of design-basis tornado-generated missiles are found in Subsection 3.5.1.4.

The tornado parameters used in the probabilistic tornado missile risk analysis (TORMIS) described in Section 3.5.5 are found in References 5 and 6.

Deleted: Byron only

Load Factor

Since the postulated tornado loading is an extreme environmental condition with a very low probability of occurrence, a load factor of 1.0 is used.

3.3.2.2 Determination of Forces on Structures

The Category I structures which have wind tornado loads, design-basis tornado generated missiles, and/or combination of these loads addressed in their design are as follows:

a. containment building,

b. auxiliary building,

c. fuel handling building,

d. main steam tunnel,

e. auxiliary feedwater tunnel,

f. essential service water cooling tower (Byron),

g. essential cooling pond (Braidwood),

h. deep well enclosures (Byron),

i. lake screen house substructure (Braidwood),

j. isolation valve room, and

k. essential service water discharge (Braidwood).

Several individual essential service water cooling tower components (Byron), and the essential service water discharge pipes (Braidwood) not fully protected from tornado generated missiles are addressed in the probabilistic tornado missile risk analysis (TORMIS) described in Section 3.5.5.

Deleted: Byron only

3.3.2.2.1 Transformation of Tornado Winds Into Effective Pressure

All tornado wind pressure and differential pressure effects are considered as static loads since the natural period of building structures and their exposed structural elements is very short compared to the rate of variation of the applied loads.

The effects of the design-basis tornado are translated into forces on structures with the use of a tornado model (Reference 4) that incorporates parameters defined in Subsection 3.3.2.1.

The tornado model considers a velocity distribution based on the following equations:

$$v(r) = V_c \frac{r}{R_c} + V_t \text{, for } \frac{r}{R_c} \leq 1 \tag{3.3-1}$$

$$v(r) = V_c \frac{R_c}{r} + V_t \text{, for } \frac{r}{R_c} \geq 1 \tag{3.3-2}$$

where:

$v(r)$ = wind velocity at radius r,

r = distance from the center of the tornado,

V_c = maximum tangential velocity,

R_c = distance from the center of the tornado, to the locus of the maximum wind velocity, and

V_t = translational velocity.

The distribution of the pressure drop with the radius from the tornado is as follows:

$$p(r) = 3.0\,[1 - 0.5\,(r/R_c)^2] \text{, for } \frac{r}{R_c} < 1 \tag{3.3-3}$$

$$p(r) = 1.5\,(R_c/r)^2 \text{, for } \frac{r}{R_c} \geq 1 \tag{3.3-4}$$

where:

$p(r)$ = pressure drop in psi.

The tornado velocity is converted into an equivalent static pressure using equations given in ANSI A58.1-1972 (Reference 1). Neither a "gust factor" nor any change in velocity with height is considered. Figure 3.3-1 shows the variation in wind velocity and differential pressure as per Equations 3.3-1, 3.3-2, 3.3-3, and 3.3-4. Figure 3.3-2 shows the windward and leeward wind pressure components of the tornado.

The load combination equation used for tornado load and tornado generated missiles is $W_t = 448$ psf $+ W_m$. Figure 3.3-3 shows the resulting surface pressure when the effect of tornado wind and pressure drop components are added together.

The load combination equations as per SRP Section 3.3.2 using load parameters of UFSAR Section 3.3 are as follows:

1. $W_t = W_w$ i.e., $W_t = 265$ psf
2. $W_t = W_p$ i.e., $W_t = 432$ psf
3. $W_t = W_p = W_m$
4. $W_t = W_w + .5\ W_p$ i.e., $W_t = 340.1$ psf
5. $W_t = W_w + W_m$ i.e., $W_t = 265$ psf $+ W_m$
6. $W_t = W_w + .5\ W_p + W_m$ i.e., $W_t = 340.1$ psf $+ W_m$.

The equation ($W_t = 448$ psf $+ W_m$) used in design is more conservative than the SRP equations above.

3.3.2.2.2 Venting of the Structure

Venting of concrete structures is not relied upon to reduce the differential pressure loadings. However, all siding and roof decking of the Turbine Building above the floor at elevation 451 feet 0 inch is designed and detailed to blow off at tornado pressures exceeding 105 psf. Above this pressure only bare framework is considered to be exposed to design-basis tornado loads.

3.3.2.2.3 Tornado Generated Missiles

The characteristics and spectrum of tornado generated missiles for the design-basis tornado are found in Subsection 3.5.1.4. The characteristics and spectrum of tornado generated missiles considered in the probabilistic tornado missile risk analysis (TORMIS) described in Section 3.5.5 are found in References 5 and 6. The procedures used for designing for the impactive dynamic effects of a point load resulting from tornado generated missiles are found in Subsection 3.5.3.

Deleted: Byron only

3.3.2.2.4 Tornado Loading Combinations

Refer to Tables 3.8-3 through 3.8-9 for the load factors and load combinations associated with tornado loading. In designing for the postulated design-basis tornado, the structure in consideration is placed in various locations of the pressure field to determine the maximum critical effects of shear, overturning moment, and torsional moment on the structure.

3.3.2.3 Effect of Failure of Structures or Components Not Designed for Tornado Loadings

All non-safety-related structures which are connected to safety-related structures are designed to prevent collapse under the design tornado loading. The only exceptions are the fuel handling building train shed, the Essential Service Water Cooling Tower Security Booth Tower Walkway (applicable to Byron only) and Walkway Access Stair Tower (applicable to Byron only) and the equipment staging structures installed adjacent to the emergency hatches. The collapse of these structures under tornado loading does not affect the structural integrity of any safety-related structures.

All other non-safety-related structures are separated from safety-related structures by a distance exceeding the height of the non-safety-related structure. This ensures that the failure of non-safety-related structures will not affect safety-related structures. Missiles generated by the collapse of non-safety-related structures were evaluated to be less critical than those considered in Subsection 3.5.1.4 or were evaluated in Section 3.5.5.

Deleted: Byron only

3.3.3 References

1. ANSI A58.1-1972, "Building Code Requirements for Minimum Design Loads in Buildings and Other Structures," American National Standards Institute, Inc., New York, New York, 1972.

2. "Task Committee on Wind Forces, Committee on Loads and Stresses, Wind Forces on Structures, Final Report," Paper No. 3269, Transactions, ASCE, Vol. 26.rg 1961.

3. USNR Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plant," April 1974.

4. J. D. Stevenson, "Tornado Design of Class I Structures for Nuclear Power Plants," Proceedings of Symposium on Structural Design of Nuclear Power Plant Facilities, University of Pittsburgh, December 1972.

5. Design Analysis ARA-002116, "Tornado Missile TORMIS Analysis of [Byron Generating Station] BGS," Revision 3.

6. Design Analysis ARA-002431, "Tornado Missile TORMIS Analysis of [Braidwood Generating Station] BRW," Revision 0.

the piping pressure element assemblies are less severe than those of Table 3.5-2b.

The missile characteristics of the reactor coolant pump temperature sensor, the instrumentation well of the pressurizer, and the pressurizer heaters are given in Table 3.5-2c. A 10 degree expansion half angle water jet has been assumed.

3.5.1.3 Turbine Missiles

The turbine-generators at the Byron/Braidwood Stations are manufactured by the Westinghouse Electric Corporation. Each unit consists of four double-flow turbine cylinders: one high pressure, and three low pressure. The low pressure stages employ 40-inch last row blades. The rated speed of the turbine-generator is 1800 rpm.

The current approach to evaluating turbine missile protection focuses on the probability of turbine failure resulting in the ejection of turbine disc (or internal structure) fragments through the turbine casing (P_1). A risk assessment will be performed each refueling outage to ensure that the probability of a turbine missile, P_1, remains at an acceptably low value. Based on this low probability, the turbine missile hazard is not considered a design-basis event for these stations. The details of the approach to ensure turbine missile protection are provided in Section 10.2.3.

For details on turbine overspeed protection, valve testing, and turbine characteristics, refer to Subsection 10.2.2.

3.5.1.4 Missiles Generated By Natural Phenomena

Tornadoes are the only natural phenomenon occurring in the vicinity of the Byron/Braidwood Stations that can generate missiles. The characteristics of postulated design-basis tornado-generated missiles are given in Table 3.5-3. The impact velocities of these missiles resulting from the design-basis tornado (Subsection 3.3.2) are shown in Table 3.5-4. Missiles A, B, C, D, and E are considered at all elevations, and missiles F and G are postulated at elevations up to 30 feet above grade level. These missiles are assumed to be capable of striking in all directions.

The characteristics of tornado-generated missiles considered in the probabilistic tornado missile risk analysis (TORMIS) described Section 3.5.5 are found in References 15 and 22.

Deleted: in Byron only

3.5.2 Systems to be Protected

All systems and equipment which may require protection are listed in Table 3.2-1. Onsite storage locations for compressed gases are provided in Table 3.5-10. Table 15.1-2 must be evaluated for protection against missiles postulated in Section 3.5.

The following safety-related components are located outdoors, away from the main building complex, installed above grade and have missile protection to the extent indicated:

Byron Station

a. At the river screen house, the essential service water makeup pumps, and associated diesel-engine drives and fuel oil storage tanks are installed at elevation 702 feet 0 inch. The building does not protect the components from tornado missiles. Refer to Subsection 9.2.5.2 and Drawing M-20.

b. The mechanical draft fans and their respective electric motor drives are located at the essential service water cooling towers (SXCTs) (refer to Drawings NCT-683-4H and -14H). The fans and motors are not fully protected from missiles and are evaluated in Section 3.5.5. A combination of TORMIS analysis and tornado protection was used for the piping within the SXCTs.

c. The outside air intake openings for the SXCT ESF Switchgear rooms are not protected from a tornado missile and are evaluated in Section 3.5.5.

d. The onsite wells and pumps at Byron, although not safety-related, are each protected by missile-proof walls and roofs. The onsite wells supply makeup water to the SXCTs in the event that a tornado missile renders the essential service water makeup pumps inoperative. Missile protected check valves (0SX284A/B) are installed in the essential service water makeup lines to prevent back flow from the SXCT basins to the river screen house.

e. Safety-related electrical cables are adequately protected against tornado-generated missiles by the reinforced concrete ducts around them. Embedded conduits in the auxiliary building south wall and associated cable vaults supporting operation of the SXCTs and deep well pumps are evaluated in Section 3.5.5.

Braidwood Station

The Essential Service Water Discharge Pipes are located in the middle of the Essential Service Water Cooling Pond and are not fully protected from missiles. The Essential Service Water Discharge Pipes are evaluated in Section 3.5.5.

Deleted: There are no safety-related component located outdoors at Braidwood Station.¶

All safety-related electrical components which are located outdoors are listed in Subsection 8.3.1.4.4 (Class 1E Equipment in Remote Structures).

All Category I buried pipes on Byron/Braidwood sites and the Category II (Non-Safety Related) Well Water (WW) piping from the onsite wells and pumps to the SXCTs at Byron have adequate soil cover for protection from tornado-generated missiles. These pipes are buried to depths greater than the required minimum depth of 4 feet 1 inch, determined using Young's method.

Safety-related HVAC system air intakes and exhausts are indicated on the plant arrangement Drawings M-5, M-6, M-14, M-15 and M-22-2.

Auxiliary Building and Containment Purge (VA, VQ)

Intakes

Intake louvers are shown as listed above. Protection is provided by missile walls.

Exhaust

The exhaust stacks are shown as listed above. Vertical stack connected to horizontal exhaust tunnel affords missile protection.

Diesel-Generator Room Intake (VD)

The diesel-generator room intake is shown as listed above. Protection is provided by missile walls.

Safety-related electrical cables are adequately protected against tornado-generated missiles by the reinforced concrete ducts around them.

Control Room Intake (VC)

The control room intake is shown as listed above. Protection is provided by missile walls. The control room turbine building makeup air intakes are evaluated in Section 3.5.5.

Deleted: Byron

Deleted: Byron only

3.5.4 Analysis of Missiles Generated by a Tornado

Effects of tornado missiles have been assessed for safety-related components located outdoors. These components are the SXCTs (Byron only), the emergency diesel generator exhaust stacks, the emergency diesel generator ventilation and combustion air intakes, the emergency diesel generator crankcase vents, the fuel handling building railroad freight door, the main steam safety and power operated relief valve tailpipes, and the essential service water discharge extension lines (Braidwood only).

Deleted: and

3.5.4.1 Essential Service Water Cooling Towers (Byron)

A temperature and inventory analysis of the UHS after the loss of SXCT fans due to tornado-generated missiles was performed. The analysis also considers out of service fans and postulated single failures. The number of fans lost due to tornado missiles is based on the results of the TORMIS analysis described in Section 3.5.5.

Based on the results of the TORMIS analysis, the deep well pumps remain available to provide makeup water if the SX makeup pumps are damaged during the tornado event.

The analysis was performed using SXCT performance curves generated using the method described in Section 9.2.5.3.1.1.2. Various outside air wet bulb temperatures were considered in the analysis. The results of the analysis are used to establish operating limits on the number of SXCT fans required to be operable based on the outside air wet bulb temperature and number of units operating. The analysis credits the following operator actions:

a. Manual initiation of the deep well pump(s) is assumed to occur 1.5 hours into the event,
b. Isolation of essential service water blowdown within two hours,
c. Isolation of the auxiliary feedwater telltale drains within two hours, and
d. Isolation of the SXCT riser leakoff drains within two hours

The analyses determined the SXCTs are capable of providing adequate heat removal and timely safe shutdown of both units.

3.5.4.2 Emergency Diesel Generator Exhaust Stacks

The diesel generator exhausts are completely protected up to the point where they penetrate the tornado proof concrete enclosure on the auxiliary building roof. Above this point, they are exposed for about 35 feet as they travel vertically. Analysis has established that the stacks can be damaged to the extent that the flow area is reduced to 50% of the original flow area without reducing the diesel power output (Braidwood only).

To prevent loss of diesel availability due to the exhaust stack damage, a rupture disc pressure relief device is installed on each diesel exhaust line. This relief device is located downstream of the silencer and inside the missile protection structure on the roof of the auxiliary building. Upon blockage of the stack, the rupture disc will open prior to backpressure increasing to the point that required diesel power is not available. The emergency diesel generators will therefore remain functional following any postulated tornado missile impact.

3.5.4.3 Emergency Diesel Generator Ventilation and Combustion Air Intakes and Crankcase Vents

Ventilation and combustion air for the emergency diesels is inducted through tornado proof intakes in the auxiliary building roof. The emergency diesel engine crankcase vents are exposed to tornado missiles. Reference 14 demonstrates that the crankcase vent lines can be blocked without adversely affecting the ability of the associated diesel to perform its design function.

3.5.4.4 Fuel Handling Building Railroad Freight Door

The railroad freight door is not designed to be tornado proof. In the event the door is missing or open, missiles would potentially enter the tunnel to the fuel handling building. To reach the fuel handling area, missiles would have to travel over 100 feet down the tunnel which is approximately 25 feet square. The two most vulnerable areas are the fuel pool heat exchangers on the lower level and fuel storage area on the upper level. After negotiating the tunnel, the missile would have to make a 90 degree turn and penetrate a wall to damage either of the heat exchangers (which are redundant) or make two 90 degree turns (up and right) to reach the fuel storage area. Based on this assessment, it is concluded that tornado missiles pose no hazard to the fuel handling building.

3.5.4.5 Main Steam Safety and Power Operated Relief Valve Tailpipes

The main steam safety valve 16 inch diameter 1/2 inch thick tailpipes extend approximately 1 foot above the MSSV roof and a maximum of 1.5 inches above a guard pipe. The guard pipe is a 20 inch diameter, 1/2 inch thick pipe.

Deleted: The combination of a short height above the roof and the installed guard pipe practically eliminates the possibility of a horizontal missile denting or crimping the MSSV tailpipes. The exhaust of the power operated relief valve is in a recessed area between the valve room upper roof and the containment wall, and is, therefore, protecte from horizontal missiles.

The main steam safety and power operated relief valve tailpipes are evaluated in Section 3.5.5.

Deleted: Byron

Deleted: Byron only

3.5.4.6 Essential Service Water Discharge Extension Lines (Braidwood only)

The Non-Safety Related portions of the Essential Service Water (SX) discharge extension lines extend approximately 3 feet above lake level and they are attached to the safety related portion of the SX discharge piping at the discharge structure via a flanged connection.

Deleted: Analysis has demonstrated that the flange connection will fail and separate before the SX extension pipe stress reaches the yield stress of the pipe material, i.e. the extension pipe section will remain in the elastic behavior zone without plastic deformation due to a force generated by a horizontal missile. Therefore, the SX discharge flow path is not adversely impacted by a Tornado generated horizontal missile striking the exposed SX discharge extension lines.

The Braidwood essential service water discharge extension lines are evaluated in Section 3.5.5.

3.5.5 Probabilistic Tornado Missile Risk Analysis

A probabilistic tornado missile risk analysis was completed for Byron (Reference 15) and Braidwood (Reference 22) using the TORMIS computer code which is based on the NRC approved methodology detailed in References 16, 17 and 18. The TORMIS analysis was performed in accordance with the guidance described in the NRC TORMIS Safety Evaluation Report (Reference 19) and as clarified by Regulatory Issue Summary (RIS) 2008-14 (Reference 20).

Deleted: (Reference 15)

3.5.5.1 Scope

The TORMIS analysis (References 15 and 22) includes plant components, identified as necessary to safely shutdown the plant and maintain a shutdown condition, located in areas not fully protected by missile barriers designed to resist impact from design-basis tornado missiles. The targets included in the TORMIS analysis are listed in Tables 3.5-17 (Byron) and 3.5-18 (Braidwood) and additional details regarding targets (i.e., specific location and identification) are included in Volume 3 of References 15 (Byron) and 22 (Braidwood).

Deleted: Reference 15,

3.5.5.2 Computer Codes

3.5.5.2.1 TORMIS

TORMIS (TORnado MISsile Risk Analysis Methodology Computer Code) uses a Monte Carlo simulation method that simulates tornado strikes on a plant. For each tornado strike, the tornado wind field is simulated, missiles are injected and flown (including vertical and near vertical missile impacts), and missile impacts on structures and equipment are analyzed. These models are linked to form an integrated, time-history simulation methodology.

By repeating these simulations, the frequencies of missiles impacting and damaging individual components (targets) and groups of targets are estimated. Statistical convergence of the results is achieved by performing multiple replications with different random number seeds.

3.5.5.2.2 TORRISK

TORRISK (TORnado RISK Analysis Methodology Computer Code) is a specialized version of TORMIS that produces tornado hazard curves distinct from the missile risk analysis features of TORMIS. TORRISK is a fast-running version of TORMIS and was spun-off in 1983 specifically for the purpose of tornado wind probability analysis for the different types of geometrical targets, like points, buildings, sites and transmission lines. TORRISK uses the same tornado input data as TORMIS and produces tornado wind hazard risks only. TORRISK produces a more accurate wind hazard curve than TORMIS since it is not encumbered with all of the TORMIS missile simulation variance reduction methods.

3.5.5.2.3 TORSCR

TORSCR is a FORTRAN computer code that is used to post-process TORMIS output files. Its primary function is to compute Boolean combinations of target hit and damage probabilities over multiple targets.

3.5.5.2.4 LS-DYNA

LS-DYNA is a nonlinear explicit finite element code for the dynamic analysis of structures. Since 1987, the LS-DYNA code has been extensively developed and supported by the Livermore Software Technology Corporation and is used for a wide variety of crash, blast and impact applications. LS-DYNA was used to develop missile threshold damage velocities for selected targets which are used as an input in the TORMIS model.

3.5.5.3 Analysis

The TORMIS tornado missile risk analysis results show that the arithmetic sum of damage frequencies for all target groups affecting the individual units (i.e., Unit 1 plus common unit components and Unit 2 plus common unit components) for both Byron and Braidwood are lower than the acceptable threshold frequency of 1.0E-06 per year established in SRP Section 2.2.3 and Reference 21.

Deleted: Byron

The following limiting inputs and assumptions were used in the analysis (refer to References 15 and 22 for additional assumptions and engineering judgments used in the analysis):

a. A site specific tornado hazard curve and data set for Byron and Braidwood was developed using statistical analysis of the NOAA/National Weather Service Storm Prediction Center tornado data for the years 1950 thru 2013. The analysis utilizes the Enhanced Fujita (EF) scale wind speeds in the TORMIS simulations.

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b. A TORMIS wind profile (#3) that adequately models increased near ground wind speeds

c. The missile characteristics and locations are based on a plant walk down survey and plant drawings. The plant walk down survey was performed during a unit outage to capture both non-outage and outage conditions during the survey. A stochastic (time-dependent) model of the missile population is implemented in TORMIS. The stochastic approach to the missile population varies the missile populations in each of the TORMIS replications to account for predictable changes in plant conditions (i.e., increased missiles during outages) and the randomness inherent in the total number of missiles present at the plant at any given time.

d. Finite element calculations were performed to provide the missile damage threshold velocity for each missile type to cause unacceptable crimping damage for the SXCT riser pipes (Byron only), diesel driven auxiliary feedwater pump exhaust pipes and cover plates and the main steam power operated relief valve tailpipes.

e. For the UHS (Byron only), one or two SXCT cells are assumed to be randomly out of service for maintenance. A postulated single failure of an electrical bus is assumed resulting in the loss of power to two additional SXCT cells. For the TORMIS analysis, success is defined as at least 3 of the remaining 5 cells surviving when one cell is out of service or 2 of the remaining 4 cells surviving when two cells are out of service.

Hit and damage frequencies for groups of targets evaluated in TORMIS are commonly combined using Boolean operators (∪ and ∩) to aid in summarizing the results and understanding the effects of the system redundancies. The union (∪) operator means that if any one of the targets is damaged in a tornado, the system is assumed to fail. The intersection (∩) operator means that all the intersected components must be damaged in a tornado strike for the system to fail. Combinations of union and intersection operators can be put together to describe multi-component system failure logic for plant systems and subsystems. The Braidwood Station analysis only used the ∪ operator while the Byron Station analysis used both the ∪ and ∩ operators.

For Byron Station, the arithmetic sum of damage frequencies for all target groups affecting the individual units would exceed the acceptance criteria of 1.0E-06 per year per unit. Boolean combinations of targets were developed to aid in summarizing the results and understanding the effects of system redundancies. This approach yielded acceptable results. Boolean Logic is applied to target groups to account for redundancy in the structural or system design or TORMIS modeling of a component as multiple targets. With redundancy in the design, the system function could be met even with one or more individual targets damaged by postulated tornado missiles. The Boolean intersection operator was used for UHS targets to credit redundancy in the design. The logic is applied to each TORMIS simulated tornado to determine if the missile damage results in a loss of function of the target group.

Deleted: T

There was a single change made to the TORMIS code of a purely "software" nature which was not related to the approved TORMIS physics engine and calculation approach; i.e., the dimensioned number of possible missile types was increased to 24 for evaluation of damage from missile velocity exceedance and pipe penetration pass through. Note that the 24th missile type (roof paver missile) was omitted for the Braidwood Station TORMIS analysis as there are no pavers on building roofs at Braidwood Station.

3.5.6 References

1. J. M. Vallance, A Study of the Probability of an Aircraft Using Waukegan Memorial Airport Hitting the Zion Station, Pickard, Lowe and Associates, Inc., Washington, D.C., 1972.

2. Clair Billington, FAA, Telephone conversations with H. H. Hitzeman, Senior Engineering Analyst, Sargent & Lundy, August 5, 1977 and August 9, 1977.

3. John W. Ryan, FAA, Telephone conversation with H. H. Hitzeman, Senior Engineering Analyst, Sargent & Lundy, September 7, 1977.

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6. A. Amirikian, "Design of Protective Structures," Bureau of Yards and Docks, Publication No. NAVDOCKS P-51, Department of the Navy, Washington, D.C., August 1950.

7. J. M. Doyle, H. J. Klein, and H. Shah, "Design of Missile Restraint Concrete Panels," Second International Conference on Structural Mechanical in Reactor Technology, Berlin, Germany, September 1973.

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9. R. A. Williamson and R. R. Alvy, "Impact Effect of Fragments Striking Structural Elements," Holmes and Naver, Inc., Revised November 1973.

10. ACI 349, Code Requirements for Nuclear Safety Related Concrete Structures, 1976.

11. P. Gottlieb, "Estimation of Nuclear Power Plant Aircraft Hazards," Probabilistic Analysis of Nuclear Reactor Safety, Proceedings of the American Nuclear Society Topical Meeting (May 8-10, 1978, Los Angeles, California), p. VIII.8, 1 to 8.

12. "A Manual for the Prediction of Blast and Fragment Loadings On Structures," DOE/TIC-11268, U.S. Department of Energy, November 1980.

13. A. H. Motloch, "Rotational Capacity of Hinging Regions in Reinforced Concrete Beams," from Proceedings of the International Symposium on Flexural Mechanics of Reinforced Concrete, American Society of Civil Engineers, 1965.

14. Design Analysis 3101-0039-01, "Calculation of EDG (Emergency Diesel Generator) Crankcase Pressure Assuming the Crankcase Vent Line is Blocked."

15. Design Analysis ARA-002116, "Tornado Missile TORMIS Analysis of [Byron Generating Station] BGS," Revision 3.

16. Electric Power Research Institute Report-EPRI NP-768, "Tornado Missile Risk Analysis," May 1978.

17. Electric Power Research Institute Report-EPRI NP-769, "Tornado Missile Risk Analysis Appendices," May 1978.

18. Electric Power Research Institute Report-EPRI NP-2005 Volumes 1 and 2, "Tornado Missile Risk Evaluation Methodology," August 1981.

19. NRC Safety Evaluation Report - "Electric Power Research Institute (EPRI) Topical Reports Concerning Tornado Missile Probabilistic Risk Assessment (PRA) Methodology," dated October 26, 1983 (ML080870291).

20. NRC Regulatory Issue Summary 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008 (ML080230578).

21. Memorandum from Harold Denton, NRR Director to Victor Stello, Deputy Executive Director for Regional Operations and Generic Requirements, "Position of Use of Probabilistic Risk Assessment in Tornado Licensing Actions," dated November 7, 1983 (ML030020331).

22. Design Analysis ARA-002431, "Tornado Missile TORMIS Analysis of [Braidwood Generating Station] BRW," Revision 0.

TABLE 3.5-17

TARGETS EVALUATED IN BYRON TORMIS ANALYSIS

TARGET	NUMBER OF TARGETS	FAILURE MODE(S)	NOTES
SXCT Riser Pipes	8	Perforation and Crimping	SXCT Cells A-H
SXCT Fan Motors and Power Feeds	8	Missile Hit	SXCT Cells A-H
SXCT Fan Gear Box Oil Level Gauges	8	Missile Hit	SXCT Cells A-H
SXCT Personnel Hatches	8	Perforation	SXCT Cells A-H
SXCT Fan Inspection Hatches	8	Perforation	SXCT Cells A-H
SXCT Fan Blades	8	Missile Hit	SXCT Cells A-H
SXCT Anti-Vortex Boxes and Trash Screens	2	Perforation	North and South
SXCT Switchgear Room Ventilation Louvers	4	Perforation	Division 11 (Bus 131Z), 12 (Bus 132Z), 21 (Bus 231Z) and 22 (Bus 232Z)
Diesel Driven Auxiliary Feedwater Pump Exhaust Pipes	2	Crimping	Unit 1 and Unit 2
Diesel Driven Auxiliary Feedwater Pump Exhaust Cover Plates	2	Crimping	Unit 1 and Unit 2
Steam Generator Power Operated Relief Valve Tailpipes	8	Pipe Penetration and Crimping	Unit 1 (4) and Unit 2 (4)

TABLE 3.5-17 (cont'd)

TARGET	NUMBER OF TARGETS	FAILURE MODE(S)	NOTES
Main Steam Safety Valve Tailpipes	40	Pipe Penetration	Unit 1 (20) and Unit 2 (20)
Deep Well Pump Enclosures	2	Spall	Pumps 0A and 0B
Embedded Conduits (Auxiliary Building South Wall)	4	Perforation	Division 11 (Bus 131Z), 12 (Bus 132Z, 21 (Bus 231Z) and 22 (Bus 232Z)
Cable Vaults - Division 11 (Bus 131Z), 12 (Bus 132Z), 21 (Bus 231Z) and 22 (Bus 232Z)	6	Spall	Division 11 (1G1), 12 (1H2 and 1J2), 21 (2G1) and 22 (2H2 and 2J2)
Auxiliary Building L Line Openings	2	Pipe Penetration	0A and 0B Main Control Room Turbine Building Makeup Air Intakes
Auxiliary Building L Line Openings	4	Pipe Penetration	Division 11, 12, 21 and 22, Miscellaneous Electrical Equipment Room Exhaust*
Non-ESF Switchgear Room Conduits	5	Perforation	Division 11 and 21 SXCT Power and Control Cables (Evaluated in Segments)

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*In a limited number of cases, the exhaust path may be impacted. Therefore, manual action is relied on to restore ventilation. These manual actions entail simple activities to open doors (to provide an exhaust path) and restart supply fans.

TABLE 3.5-18

TARGETS EVALUATED IN BRAIDWOOD TORMIS ANALYSIS

TARGET	NUMBER OF TARGETS	FAILURE MODE(S)	NOTES
Diesel Driven Auxiliary Feedwater Pump Exhaust Pipes	2	Crimping	Unit 1 and Unit 2
Diesel Driven Auxiliary Feedwater Pump Exhaust Cover Plates	2	Crimping	Unit 1 and Unit 2
Steam Generator Power Operated Relief Valve Tailpipes	8	Pipe Penetration and Crimping	Unit 1 (4) and Unit 2 (4)
Main Steam Safety Valve Tailpipes	40	Pipe Penetration	Unit 1 (20) and Unit 2 (20)
Auxiliary Building L Line Openings	2	Pipe Penetration	0A and 0B Main Control Room Turbine Building Makeup Air Intakes
Auxiliary Building L Line Openings	4	Pipe Penetration	Division 11, 12, 21 and 22, Miscellaneous Electrical Equipment Room Exhaust*
SX Discharge Pipes	2	Missile Hit	0A and 0B SX Discharge Extension Lines

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*In a limited number of cases, the exhaust path may be impacted. Therefore, manual action is relied on to restore ventilation. These manual actions entail simple activities to open doors (to provide an exhaust path) and restart supply fans.