October 30, 2024

TP-LIC-LET-0358
Project Number 99902100

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

Subject: Transmittal of TerraPower Plume Exposure Pathway Emergency Planning Zone Methodology Topical Report, NAT-3056 Revision 3

References:

1. Letter from TerraPower, LLC to U.S. Nuclear Regulatory Commission, "Submittal of TerraPower: Plume Exposure Pathway Emergency Planning Zone Methodology Topical Report," March 20, 2023 [ADAMS Accession No. ML23080A045].

2. Letter from TerraPower, LLC to U.S. Nuclear Regulatory Commission, "Submittal of TerraPower: Plume Exposure Pathway Emergency Planning Zone Methodology Topical Report, Revision 1," November 16, 2023 [ADAMS Accession No. ML23321A036].

3. Letter from TerraPower, LLC to U.S. Nuclear Regulatory Commission, "Transmittal of TerraPower Plume Exposure Pathway Emergency Planning Zone Methodology Topical Report, NAT-3056 Revision 2," October 29, 2024 [ADAMS Accession No. ML24303A147].

This letter transmits the TerraPower, LLC, (TerraPower) Topical Report, NAT-3056, Revision 3, *TerraPower, LLC (TerraPower) Natrium® Topical Report: Plume Exposure Pathway Emergency Planning Zone Sizing Methodology* (enclosed) for review and approval. This Topical Report supersedes Revision 1 of NAT-3056, which was submitted in Reference 2. This Topical Report describes TerraPower's methodology to be used to determine the Plume Exposure Pathway

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(PEP) Emergency Planning Zone (EPZ) for the Natrium plant[1]. This revision clarifies information discussed during the Advisory Committee on Reactor Safeguards (ACRS) subcommittee (Design-Centered Review: TerraPower) meeting held on September 19, 2024.

As provided in Reference 1, and subsequently Reference 2, the purpose of submitting this Topical Report is to provide information to the U.S. Nuclear Regulatory Commission (NRC) to facilitate efficient and timely review of the TerraPower PEP EPZ sizing methodology. TerraPower also requests, as part of this review and associated comment resolution, that the NRC provide a safety evaluation report (SER) on the PEP EPZ sizing methodology.

The submittal described in Reference 3 contains an editorial error that is corrected with this submittal. TerraPower requests the submittal described in Reference 3 be withdrawn.

This letter and enclosures make no new or revised regulatory commitments.

If you have any questions regarding this submittal, please contact Ian Gifford at igifford@terrapower.com or Nick Kellenberger or nkellenberger@terrapower.com.

Sincerely,

George Wilson

George Wilson
Vice President of Regulatory Affairs
TerraPower, LLC

Enclosure: *TerraPower, LLC (TerraPower) Natrium® Topical Report: Plume Exposure Pathway Emergency Planning Zone Sizing Methodology*, NAT-3056 Revision 2

cc: Josh Borromeo, NRC
Mallecia Sutton, NRC
Nathan Howard, DOE
Jeff Ciocco, DOE

[1] Natrium is a TerraPower and GE-Hitachi technology.

ENCLOSURE

***TerraPower, LLC (TerraPower) Natrium® Topical Report: Plume Exposure Pathway Emergency Planning Zone Sizing Methodology,* NAT-3056, Revision 3**

Controlled Document - Verify Current Revision

NATRIUM

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Document Title: TerraPower, LLC (TerraPower) Natrium® Topical Report: Plume Exposure Pathway Emergency Planning Zone Sizing Methodology				
Natrium Document No.: NAT-3056	**Rev. No.:** 3	**Page:** 1 of 37	**Effective Date:** Upon issuance	**Target Quality Level:** N/A
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Approval

Approval signatures are captured and maintained electronically; See Electronic Approval Records in EDMS.

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

REVISION HISTORY

Revision No.	Effective Date	Affected Section(s)	Description of Change(s)
A	03/02/2023	All	Initial Issue – DRAFT 2-28-23
0	03/14/2023	All	Initial Issue
1	See EDMS	All	Change addresses questions from the NRC during the PEP EPZ Audit and minor editorial changes.
2	See EDMS	All	Changed section 3.6 to account for changes suggested by ACRS subcommittee. Additionally, a minor change was made to 6.1.3 for consistency.
3	See EDMS	All	Changed to Rev. 3 in the header as it was missed for Rev. 2

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EXECUTIVE SUMMARY

This topical report provides the methodology and criteria that will be used to establish the site-specific plume exposure pathway (PEP) emergency planning zone (EPZ) size for the Natrium® reactor. The Natrium reactor is a TerraPower, LLC (TerraPower) and GE Hitachi technology.

This methodology provides a risk-informed approach for determining a PEP EPZ size based on the area within which public dose, as defined in Title 10 of the *Code of Federal Regulations*, Part 20.1003, “Definitions,” is projected to exceed 10 mSv (1 rem) total effective dose equivalent over 96 hours from the release of radioactive materials from the facility, considering accident likelihood and source term, timing of the release sequence, and meteorology.

The methodology utilizes the approach laid out in Appendix A, *General Methodology for Establishing Plume Exposure Pathway Emergency Planning Zone Size*, of proposed Regulatory Guide 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," as well as supporting information from NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants."

Release sequences (events that lead to a radiological release) to be considered in the PEP EPZ methodology will be selected based on risk-information from the design and site-specific Natrium reactor probabilistic risk assessment (PRA). The PRA will address all modes and hazards, including seismic events, using the guidance in Regulatory Guide 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors," Nuclear Energy Institute 18-04, “Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development,” and American Society of Mechanical Engineers/American Nuclear Society RA-S-1.4-2021, "Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants."

All non-seismic release sequences contributing one percent (1%) or more to the overall release frequency will be included, as well as all Design Basis Accidents. Individual events and groups with sums greater than the frequency 1E-08 per reactor year will be considered for cliff-edge effects. All non-seismic release sequences with a frequency greater than or equal to 1E-07 per reactor year and contributing 1% or more of overall release frequency will be retained for evaluation.

The seismic events evaluated for the PEP EPZ sizing will be based on the beyond design basis earthquake for the site. The seismic events sequences are based on a spectrum of seismic events and is consistent with NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants". Most of the risk due to seismic events will be captured and the release sequences will ensure that the PEP EPZ size is appropriate for the seismic event.

Once the release sequences are selected, release sequence simulations will be conducted to determine projected doses. The methodology for source term development for the PEP EPZ analysis will be consistent with overall Natrium reactor assessment and projections and will be a direct input into the radiological consequences methodology. This input will establish the specific radionuclide inventory and the quantity released for the events that will be assessed in the PEP EPZ analysis. A mechanistic source term methodology will be used for the source term calculations that provide the radioactive materials released to the environment. A meteorological file will be created by obtaining meteorological data available for a representative location for one year for the calculation submitted with the Construction Permit Application and two years that is most representative of the meteorological conditions at the site for the calculation submitted with the Operating License Application.

Projected doses will be evaluated against three dose-based criteria akin to those in NUREG-0396. During the design phase, if the PEP EPZ sizing criteria are not met, then a determination will be made if design changes or analysis refinements can be made to reduce the PEP EPZ size, or if the PEP EPZ size needs to be expanded. Accident and consequence simulations will be reperformed to address any changes made.

1 INTRODUCTION

1.1 Purpose

The purpose of this topical report (ToR) is to provide the methodology and criteria that will be used to establish the site-specific plume exposure pathway (PEP) emergency planning zone (EPZ) size for the Natrium reactor.

The ToR contains the PEP EPZ sizing methodology for which U.S. Nuclear Regulatory Commission (NRC) approval is sought. This methodology provides an approach for determining a PEP EPZ size based on the area within which public dose, as defined in Title 10 of the *Code of Federal Regulations* (10 CFR) 20.1003, “Definitions,” is projected to exceed 10 mSv (1 rem) total effective dose equivalent (TEDE) over 96 hours from the release of radioactive materials from the facility, considering accident likelihood and source term, timing of the release sequence, and meteorology. In addition, it addresses the consideration of the area in which predetermined, prompt protective measures are necessary.

1.2 Scope

The PEP EPZ methodology utilizes the approach laid out in Appendix A, *General Methodology for Establishing Plume Exposure Pathway Emergency Planning Zone Size*, of proposed Regulatory Guide (RG) 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," [1] as well as supporting information from NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants" [2].

This report is based on the following technical considerations:

- Methodology is designed to be structured and repeatable,
- Risk-informed methods are used to determine the spectrum of release sequences to be evaluated, including internal, external, and seismic events, and
- Analysis of uncertainties.

This PEP EPZ methodology is based upon numerical inputs from the Probabilistic Risk Assessment (PRA), Radiological Consequence Assessment Methodology [3] and Source Term Methodology [4], which are outside the scope of this ToR. The associated uncertainty with each input will be quantified within their own respective assessments, however, the overall uncertainty will be addressed in the PEP EPZ analysis submitted for the Operating License Application (OLA). The methodology for the uncertainty analysis within the scope of this ToR is described within this report.

1.3 Abbreviations

ACRS	Advisory Committee on Reactor Safeguards
ANS	American Nuclear Society

AOO	Anticipated Operational Occurrence
ASME	American Society of Mechanical Engineers
BDBE	Beyond Design Basis Event
CEMP	comprehensive emergency management plan
CFR	Code of Federal Regulations
CPA	Construction Permit Application
CPG	Comprehensive Preparedness Guide
DBA	Design Basis Accident
DBE	Design Basis Event
DID	defense-in-depth
DG	Draft Guide
DL	defense line
EAB	Exclusion Area Boundary
EAL	Emergency Action Level
EOP	emergency operations plan
EP	Emergency Preparedness
EPA	Environmental Protection Agency
EPZ	Emergency Planning Zone
ESP	Early Site Permit
F-C	frequency-consequence
FEMA	Federal Emergency Management Agency
GEH	GE-Hitachi Nuclear Americas, LLC
GMRS	Ground Motion Response Spectra
LBE	Licensing Basis Event
LWR	light-water reactor
MACCS	MELCOR Accident Consequence Code System
NEI	Nuclear Energy Institute
NRC	U.S. Nuclear Regulatory Commission
NSRST	non-safety-related with special treatment
NPUF	non-power production or utilization facilities
NUREG	U.S. Nuclear Regulatory Commission technical report designation

NUREG/CR	contractor prepared NUREG
OLA	Operating License Application
ONT	Other New Technology
PAG	Protective Action Guide
PEP	Plume Exposure Pathway
PGA	Peak Ground Acceleration
PIE	plant initiating event
PRA	Probabilistic Risk Assessment
rem	Roentgen equivalent man
RG	Regulatory Guide
SECY	Office of the Secretary
SMR	Small Modular Reactor
SOARCA	State-of-the-Art Reactor Consequence Analysis (NUREG-1935)
SPRA	Seismic Probabilistic Risk Assessment
SR	safety-related
SRM	staff requirements memorandum
SSC	structure, system, and component
SSE	Safe Shutdown Earthquake
TED	total effective dose
TEDE	total effective dose equivalent
TerraPower	TerraPower, LLC
ToR	Topical Report
TVA	Tennessee Valley Authority

2 REGULATORY BASIS

The purpose of this section is to discuss the regulatory basis that supports the PEP EPZ sizing methodology. It also discusses the historical background on the development of the regulatory basis of the 10-mile PEP EPZ for the light water reactor (LWR) operating nuclear plants, the regulatory basis for reducing and risk-informing the PEP EPZ size, and recent NRC rulemaking and guidance documents that address reevaluation of PEP EPZ size and planning elements for small modular reactors (SMRs) and other new technologies (ONTs). Also provided are examples where the NRC has considered and approved reduced PEP EPZ sizes.

2.1 Regulatory Requirements and Guidance Considered

The methodology described in this ToR is based upon the proposed requirements for Emergency Preparedness (EP) for SMRs and ONTs in SECY-22-0001, Rulemaking Issue (Affirmation), "Final Rule: Emergency Preparedness for Small Modular Reactors and Other New Technologies" [5][1] (herein referred to as proposed final EP SMR-ONT rule) and proposed RG 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities" [1].

The proposed final EP SMR-ONT rule provides a scalable approach for determining the size of the PEP EPZ based on both the projected off-site public doses from a spectrum of events and the need for predetermined, prompt protective measures. Proposed RG 1.242, Appendix A, *General Methodology for Establishing Plume Exposure Pathway Emergency Planning Zone Size,* provides a sample methodology acceptable to the NRC for the analysis to establish PEP EPZ size, as required under proposed final EP SMR-ONT rule, specifically 10 CFR 50.33(g)(2).

The methodology also takes into consideration the regulatory information and guidance in the following documents:

- NUREG-0396/EPA 520/1-78-016, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants" (herein referred to as NUREG-0396) [2], provides a planning basis for off-site emergency preparedness efforts considered necessary and prudent for large power reactor facilities. It also provides the technical basis for the current EPZ regulations for operating power reactors referenced in 10 CFR 50.47, *Emergency plans*, and a PEP EPZ of about 10 miles. Additionally, it provides the technical basis for the methodology in the proposed final EP SMR-ONT rule.
- EPA-400/R-17/001, "PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents" [7] (herein referred to as the EPA PAG Manual), provides radiological protection criteria for application to all incidents that would require consideration of protective actions. The Environmental Protection Agency (EPA) Protective Action Guideline (PAG) Manual, Section 1.4, *Radiological Incident Phases and Applicability of Protective Actions,* discusses the "phases" in which emergency planners divide responses to radiological incidents. The "Early Phase" of a radiological incident is defined as:

  > "The beginning of a radiological incident for which immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the radiological incident and the prognosis for worsening conditions. … This phase may last from hours to days."

  For the "Early Phase" PAGs, the established projected dose criteria range from 1 to 5 rem total effective dose (TED)[2] over four days.

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[1] On August 14, 2023, the NRC Commissioners approved the final EP SMR-ONT rule [6]
[2] The NRC staff notes that the EPA defined TED is different than the NRC defined TEDE, as it utilizes different dosimetry methodologies. As such, the NRC uses its definition of TEDE for regulatory activities under its statutory authority.

- NUREG-1855, "Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision Making," [8] provides guidance for the treatment of uncertainties in a risk-informed application. The objectives of the guidance include fostering an understanding of the uncertainties associated with PRA, their impact on the results of a PRA, and provides a pragmatic approach to addressing these uncertainties in the context of the decision-making.
- RG 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" [9] provides an integrated approach for risk-informed decision-making that considers traditional engineering and risk information and that may be based on qualitative factors as well as quantitative analyses and information. It describes the principles of risk-informed decision-making that include addressing defense-in-depth (DID) and maintaining safety margin in parallel with use of risk analysis techniques.
- RG 1.200, "Acceptability of Probabilistic Risk Assessment Results for Risk-Informed Activities" [10] describes an approach for determining the acceptability of a PRA. This RG provides guidance on the four areas that collectively determine the acceptability of a PRA (i.e., scope, technical elements, level of detail, and plant representation) that can be met using national consensus PRA standards and a peer review.

2.2 Development of the Regulatory Basis for the Plume Exposure Pathway Emergency Planning Zone

Existing EP regulations and guidance are primarily focused on large LWRs, and which have developed over time based on gained experience. 10 CFR 50, Appendix E, *Emergency Planning and Preparedness for Production and Utilization Facilities,* identifies the specific items currently required in emergency plans. Additionally, 10 CFR 50.47 provides EP requirements for nuclear power reactors, including planning standards for on-site and off-site emergency response plans. Other relevant regulations include 10 CFR 50.54, *Conditions of licenses,* paragraphs (q), (s), and (t).

In 10 CFR 50.47(a)(1), prior to issuing an Operating License, the NRC must find that the there is "reasonable assurance" that adequate protective measures can be taken in the event of a radiological emergency. The NRC's determination of "reasonable assurance" is based in part on a Federal Emergency Management Agency (FEMA) review of the adequacy of off-site plans and resulting determinations and findings that adequate off-site protective measures can be implemented, where applicable.

2.2.1 10-Mile Plume Exposure Pathway Emergency Planning Zone

The purpose of this section is to provide background on the regulatory basis for development of the 10-mile PEP EPZ for the large LWRs.

NUREG-0396 [2], which was based on NUREG-75/014 (WASH-1400), "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants" [11], provides a planning basis for off-site emergency preparedness efforts considered necessary and prudent for large power reactor facilities and also provides the technical basis for a PEP EPZ of about 10 miles (16 kilometers). The NUREG-0396 Task Force concluded that the appropriate planning distance should be determined by consideration of a spectrum of accident consequences, tempered by probability considerations, and that no single reactor accident scenario should drive determination of the EPZ size. The NUREG-0396 Task Force, also concluded that the EPZ should be the area beyond which the projected dose from Design Basis Accidents (DBAs) and less severe core damage accidents (i.e., accidents not involving large releases of radioactive material to the environment) would not likely exceed the then applicable early-phase EPA PAGs in EPA-520/1-75-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" [12].[3] Additionally, the PEP EPZ should be of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents (i.e., more severe than the design basis accidents with a release of substantial quantities of radioactive materials to the environment). For the 10-mile PEP EPZ, NUREG-0396 evaluates the projected off-site doses against the EPA guidance of 1 and 5 rem whole body for DBAs, and the significant early injury (health effect) threshold of 200 rem whole body acute dose from more severe core-melt accidents.

The NRC issued a policy statement, "Planning Basis for Emergency Responses to Nuclear Power Reactor Accidents," [13] endorsing the NUREG-0396 PEP EPZ of about 10 miles for detailed planning and early response (e.g., 30 minutes to one day after the initiation). The intent of the EPZ was to provide dose savings to the population in areas where the projected dose could be expected to exceed the then applicable EPA PAGs. The PEP EPZ was codified in 10 CFR 50.47 and 10 CFR 50, Appendix E. Both these regulations stipulate the 10-mile PEP EPZ for power reactors, but also allow for a different PEP EPZ size for reactors with a thermal power of less than 250 megawatt thermal on a case-by-case basis.

NUREG-0654/FEMA-REP-1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants" [14], which was originally published in 1980, provides guidance and evaluation criteria for the development and evaluation of operating power reactor and off-site response organization radiological emergency response plans.

2.2.2 Reduction in the Plume Exposure Pathway Emergency Planning Zone

The NRC staff has provided EPZ-related information and conducted several studies that are useful in the reconsideration of the PEP EPZ size and planning elements for SMRs and ONTs, and the associated process for regulatory change in the following documents:

- SECY-97-020, "Results of Evaluation of Emergency Planning for Evolutionary and Advanced Reactors" [15], provides the rationale upon which EP is based for current reactor designs, stating that potential consequences from a spectrum of accidents is appropriate for use as the basis for EP for evolutionary and passive advanced LWR designs, and is consistent with the Commission's DID safety philosophy.
- SECY-10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs" [16], in part, addresses the possibility of considering the appropriate PEP EPZ size and the extent of on-site and off-site emergency planning, taking into account the characteristics of SMRs (e.g., smaller size, lower power

[3] In January 2017, the EPA published an updated version of this document, EPA-400/R-17/001, "PAG Manual Protective Action Guides and Planning Guidance for Radiological Incidents," [5] which supersedes EPA-520/1-75-001.

densities, lower probability of severe accidents, slower accident progression, and smaller off-site consequences).

- SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors" [17], discusses that even though the guidance in NUREG-0396 and EPA-400 was written for large LWRs, the principle of using dose savings to determine PEP EPZ size can also be applied to SMRs. The NRC indicated that it may be appropriate for SMRs to develop reduced PEP EPZ sizes, commensurate with their accident source terms, fission product releases, and accident dose characteristics. The projected approach for PEP EPZ sizing is based on off-site dose considerations and the use of a PRA that includes dose assessments to “calculate the probability of exceeding a PAG as function of distance from the Exclusion Area Boundary (EAB) for a spectrum of accidents” and “establishing criteria for determining the point at which the probability of exceeding the PAG is acceptably low.”
- SECY-15-0077, "Options for Emergency Preparedness for Small Modular Reactors and Other New Technologies" [18], the NRC staff sought Commission approval to initiate proposed revisions to NRC regulations and guidance for a consequence-based approach, including requirements that would allow SMR and ONT license applicants to demonstrate how their proposed facilities achieve appropriate dose limits at specified PEP EPZ distances, which may be as low as the site boundary. SECY-15-0077 indicates that the regulations can be established generically without site- or design-specific information regarding source term, fission products, or projected off-site dose. Design and licensing information provided by SMR and ONT applicants would be “rigorously reviewed” by the NRC to ensure that the off-site dose consequences are commensurate with the requested PEP EPZ size and to ensure that applicable requirements for adequate protection of public health and safety, and the environment, are met. The Commission approved the NRC staff recommendation to initiate the rulemaking in staff requirements memorandum (SRM) to SECY-15-0077 [19].
- NUREG-1935, “State-of-the-Art Reactor Consequence Analysis (SOARCA) Report” [20], evaluates fission product releases, associated off-site consequences, and hypothetical evacuations in response to potential accidents in operating plants. By applying modern analysis tools and techniques, the SOARCA project developed a body of knowledge regarding the realistic outcomes of select severe nuclear reactor accidents. The study focused on providing a realistic evaluation of accident progression, source term, and off-site consequences for select scenarios for Peach Bottom Atomic Power and Surry Power Stations. By using the most current EP practices and plant capabilities, as well as the best available modeling, these analyses are more realistic than past analyses. These analyses also consider mitigative measures (e.g., emergency operating procedures, severe accident management guidelines, and 10 CFR 50.54(hh) measures), contributing to a more realistic evaluation. All SOARCA scenarios, even when unmitigated, progress more slowly and release much less radioactive material than previously indicated. As a result, the calculated risks of public health consequences from severe accidents modeled in SOARCA are very small.

2.2.3 Development of a Risk-Informed Plume Exposure Pathway Emergency Planning Zone

Recent NRC documents also reflect progress in risk-informed methods and applications as applied to emergency planning, including PEP EPZ sizing:

- SRM to SECY-98-144, "White Paper on Risk-Informed and Performance-Based Regulation" [21] defines a "risk-informed approach" to regulatory decision-making as one that "represents a philosophy whereby risk insights are considered together with other factors to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety." Additionally, it states that DID is an element of the NRC's "Safety Philosophy," which ensures that safety will not be wholly dependent on any single element of the design, construction, maintenance, or operation of a nuclear facility.
- SECY-10-0034 [16] states that the NRC staff plans to use a risk informed- and performance-based approach that employs deterministic judgment and analysis complemented by PRA information to review design and license applications for SMRs. As provided in in the enclosure to SECY-10-0034, the NRC staff will consider a different or revised set of accidents for SMRs (e.g., other than those considered for current LWRs) to provide the basis for judging the adequacy of features such as off-site emergency planning. Additionally, the enclosure to SECY-10-0034 discusses that while the Commission stated that licensing-basis event categories (i.e., abnormal occurrences, design-basis accidents, and beyond-design basis- accidents) would be established based on the expected probability of event occurrence, selection of licensing basis events within each category would be performed using deterministic engineering judgment complemented by insights from the PRA.
- SECY-11-0152 [17] states that an appropriate method for addressing PEP EPZ size would involve (1) using a PRA that includes dose assessments based on current insights in severe accident progression to calculate the probability of exceeding a PAG level as function of distance from the EAB for a spectrum of accidents, (2) establishing criteria for determining the point at which the probability of exceeding the PAG level is acceptably low, and (3) concluding that the events provide an acceptable spectrum of consequences.
- NUREG-1935 [20] the SOARCA scenarios were selected from the results of previous staff and licensee PRAs. Some of these existing PRAs model accident sequences to the point of radiological release (i.e., Level 2 PRAs); however, most of existing PRAs in the SOARCA were limited to the onset of core damage (i.e., Level 1 PRAs). Ideally the SOARCA project would have included those sequences found to be important to risk as demonstrated by a full-scope Level 3 PRA, which is an assessment of risk of off-site consequences in the event of a severe accident that causes the release of radioactive material to the environment, however, they were not available.
- SECY-15-0077 [18] states that the concept of a PEP EPZ size commensurate with the off-site radiological risk is not new to the NRC. The NRC staff anticipated that the technical basis for this EP framework would be developed also as part of rulemaking. This would include quantitative guidelines and criteria for accident selection and evaluation specific to SMRs and ONTs. As described in SECY-15-0077, "These guidelines and criteria would then be used to derive a dose-based, consequence-oriented rationale, similar to that described in SECY-11-0152 [17], which would be used

to inform the appropriate PEP EPZ size for a specific design and its site. In addition, the staff would use historical and regulatory experiences gained over the past decades and insights gained from the results of using PRAs to inform the EP rulemaking. In addition to new regulations specifically addressing EP, the staff would expect to develop guidance for applicants. There is a potential that the technical basis for the PEP EPZ size in the dose-based, consequence-oriented EP framework could result in a PEP EPZ size much smaller than the 10-mile radius currently used, as described in SECY-11-0152, including a PEP EPZ distance effectively at the site boundary."

- NUREG/CR-7154, "Risk Informing Emergency Preparedness Oversight: Evaluation of Emergency Action Levels—A Pilot Study of Peach Bottom, Surry and Sequoyah" [22], was the first effort to apply PRA to nuclear power plant Emergency Action Level (EAL) schemes. The methodology and the limited pilot applications described in the report demonstrate the feasibility of using risk-informed approaches to enhance emergency planning. The report notes that regulatory decisions for EP are complex and should not be made solely considering PRA generated risk metrics but should be substantiated by deterministic approaches along with the PRA insights.
- SECY-22-0001 [5] states that the new alternative EP requirements and implementing guidance in proposed RG 1.242 [1] adopt a performance-based, technology-inclusive, risk-informed, and consequence-oriented approach.
- Proposed RG 1.242 [1], Appendix A, Section A-3.1, *"Event Selection,"* provides that for non-LWRs, the applicant may use the technology-inclusive, risk-informed, and performance-based methodology endorsed by RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors" [23], to determine their licensing basis events. RG 1.233 endorses Nuclear Energy Institute (NEI) 18-04, "Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development" [24] as one acceptable method for non-LWR designers to use when carrying out these activities and preparing their applications. NEI 18-04 identifies that the guidance in American Society of Mechanical Engineers (ASME)/ American Nuclear Society (ANS) RA-S-1.4, "Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants," [25] provides an acceptable means to establish the scope and technical adequacy of the PRA.
- Trial RG 1.247, "Acceptability of Probabilistic Risk Assessment Results for Advanced Non-Light Water Reactor Risk-Informed Activities" [26] endorses ASME/ANS RA-S-1.4-2021 [26] with exception. This trial RG also endorses NEI 20-09, "Performance of PRA Peer Reviews Using the ASME/ANS Advanced Non-LWR PRA Standard" [28] without exception.

2.3 Proposed Emergency Preparedness Rule for Small Modular Reactors and Other New Technologies

In May 2020, the NRC published a proposed rule, "Emergency Preparedness for Small Modular Reactors and Other New Technologies" [29] and an accompanying draft RG, DG-1350[4],

[4] DG-1350 was the precursor to draft RG 1.242.

"Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," [30] for public comment. The proposed rule provides an alternative option for SMRs and ONTs to determine the PEP EPZ as the area within which the dose to an individual is projected to exceed 1 rem TEDE over an exposure time of 96 hours from the release of radioactive materials resulting from a spectrum of accidents for the facility.

In January 2022, the NRC provided the proposed final EP SMR-ONT rule to the Commission for approval in SECY-22-0001 [5]. This proposed final rule was approved by the NRC Commissioners on August 14, 2023 [6]. This proposed final rule provides for new alternative EP requirements that adopt a performance-based, technology-inclusive, risk-informed, and consequence-oriented approach as an alternative to using the existing, deterministic EP requirements in 10 CFR 50. The proposed final EP SMR-ONT recognizes advances in design and technologically, safety enhancements in evolutionary and passive systems, and the potential benefits of smaller sized non-LWRs reactors, including slower transient response times and relatively small and slow release of fission products. While it continues to provide reasonable assurance that adequate protective measures will be implemented by an SMR or ONT licensee. In developing the regulation, the NRC considered the existing regulatory framework for EP at non-power production or utilization facilities (NPUFs) since it reflects the lower potential radiological hazards associated with the operation of SMRs and ONTs compared to large LWRs. The proposed final EP SMR-ONT rule provides for a scalable approach for determining the size of the PEP EPZ. NUREG-0396 [2] remains the technical basis for the methodology for the proposed final EP SMR-ONT rule.

As mentioned above, concurrent with the proposed rulemaking described in SECY-22-001 [5], the NRC issued proposed RG 1.242 [1]. The guidance in proposed RG 1.242 addresses a performance-based, technology-inclusive, risk-informed, and consequence-oriented approach. Appendix A to proposed RG 1.242 provides a sample methodology acceptable to the NRC for the analysis to establish the PEP EPZ size, as required under 10 CFR 50.33(g)(2). The approach has been generalized from the dose assessment methodologies that informed PEP EPZ size determinations in NUREG-0396 [2].

As discussed in Section 2.1, the proposed final EP SMR-ONT rule and proposed RG 1.242 serve as the primary regulatory basis for the PEP EPZ sizing methodology described in this ToR.

2.4 Previous NRC Considerations of Reduced Emergency Planning Zone Sizes

The concept of a PEP EPZ size commensurate with off-site radiological risk is not new to the NRC. The NRC has considered and approved reduced PEP EPZ sizes in the following examples:

- The NRC reviewed and approved various PEP EPZ size-related exemption requests from reactor licensees that have permanently ceased operations and defueled based on the reduced risks from the sites. Examples include:
    - Three Mile Island Nuclear Station, Units 1 and 2 – Exemptions from Certain Emergency Planning Requirements and Related Safety Evaluation [31], and
    - Pilgrim Nuclear Power Station – Exemptions from Certain Emergency Planning Requirements and Related Safety Evaluation [32].

In their reviews, the NRC staff concluded that the postulated dose from any applicable DBA would not exceed the EPA early phase PAG levels for the public at the EAB. Additionally, the NRC concluded that for any highly unlikely Beyond Design Basis Events (BDBEs), the length of time available for the site personnel to implement pre-planned mitigation measures consistent with plant conditions and, if warranted, for off-site agencies to implement protective actions using a comprehensive emergency management plan (CEMP)[5], provided confidence that off-site measures for the public could be taken without preplanning. In NSIR/DRP-ISG-02, "Emergency Planning Exemption Requests for Decommissioning Nuclear Power Plants" [33], the staff concluded that if a minimum of 10 hours was available to initiate mitigative actions or, if needed, for off-site authorities to implement protective actions using a CEMP approach, and formal off-site radiological emergency plans, required under 10 CFR 50, were not necessary. CLI-19-10, Memorandum and Order, "Tennessee Valley Authority (Clinch River Nuclear Site Early Site Permit Application)" [34], granted an Early Site Permit (ESP) to the Tennessee Valley Authority (TVA) for the Clinch River Site. In CLI-19-10, the NRC discusses their conclusion that "TVA's methodology for establishing a 2-mile and site boundary EPZ is consistent with the methodology used to establish the 10-mile EPZs reflected in our current regulations." The Advisory Committee on Reactor Safeguards (ACRS) concluded that the NRC staff was correct in determining that TVA's EPZ-sizing methodology is "consistent with analyses that form the technical basis of the current [10-mile] PEP EPZ and maintains the same level of protection." Section C.3 of CLI-19-10 notes that the Staff does "not view TVA's proposal [of site boundary PEP EPZ] as eliminating an element of defense in depth; rather, emergency planning activities would be appropriately scaled to reflect the potential hazards posed by the facility."

- In the Safety Evaluation for NuScale Topical Report, TR-0915-17772, Revision 3, "Methodology for Establishing the Technical Basis for Plume Exposure Emergency Planning Zones at NuScale Small Modular Reactor Plant Sites'" [35] the NRC staff concluded that there is reasonable assurance that the proposed methodology in the NuScale Topical Report is adequate for assessing PEP EPZ size. The NuScale PEP EPZ methodology uses a risk-informed approach to screen appropriate release sequences to be evaluated for the determination of the PEP EPZ size. The screening includes quantitative insights from PRA, including consideration of uncertainty, as well as application of engineering insights emphasizing safety margin and DID. Based on the accident sequence screening, the risk results, including source terms and off-site dose versus distance, serve as the basis for a PEP EPZ size methodology. It includes consideration of internal events, external hazards, and all modes of operation, as well as

[5] A CEMP, in this context, also referred to as an emergency operations plan (EOP), is addressed in FEMA's Comprehensive Preparedness Guide (CPG) 101, "Developing and Maintaining Emergency Operations Plans" [36]. CPG 101 is the foundation for State, territorial, Tribal, and local EP in the United States. It promotes a common understanding of the fundamentals of risk-informed planning and decision making and helps planners at all levels of government in their efforts to develop and maintain viable, all-hazards, all-threats emergency plans. An EOP is flexible enough for use in all emergencies. It describes how people and property will be protected; details who is responsible for carrying out specific actions; identifies the personnel, equipment, facilities, supplies and other resources available; and outlines how all actions will be coordinated. A CEMP is often referred to as a synonym for "all hazards planning."

other PRA risks. The final PEP EPZ size is the smallest distance at which the dose consequences of all screened in release sequences are less than their respective dose criteria.

The NuScale methodology was informed by the 2013 NEI White Paper, "White Paper on Proposed Methodology and Criteria for Establishing the Technical Basis for Small Modular Reactor Emergency Planning Zone" [37], and incorporates concepts from NUREG-0396 [2] in that the objective goal is based on consideration of off-site dose-based consequences to distance.

The NRC imposed "Conditions of Use" related to the use of PRA in the NuScale PEP EPZ methodology, including that the PRA will be developed for all modes and hazards (at Capability Category II) and will be peer reviewed using the guidance in RG 1.200 [10]. Additionally, the identification, assessment, and dispositioning of key assumptions and sources of uncertainty should be consistent with the guidance in RG 1.200 and NUREG-1855 [8].

3 ACCIDENT SCREENING METHODOLOGY

3.1 Process Overview

Figure 3-1 provides an overview of the PEP EPZ methodology. Each step that will be implemented to determine the final PEP EPZ distance is also presented below with the corresponding ToR section number:

- Compile release sequences from the PRA for all internal and external initiators (Sections 3.4 and 3.5).
- Perform screening of non-seismic release sequences based on frequency, including uncertainty (Section 3.6).
- Perform screening of seismic release sequences with a unique set of selection criteria, including uncertainty (Section 3.7).
- Meteorological data will be collected and incorporated into the radiological consequence analysis (Section 5.1). (Outside the scope of this ToR.)
- Source term and radiological consequence analysis will be performed with projected PEP EPZ boundary and 96-hour event timing (Sections 4 and 5.3). (Outside the scope of this ToR.)
- Evaluate radiological dose consequences against the PEP EPZ dose criteria established from proposed RG 1.242 [1] (Sections 3.3 and 6.1).
    - If PEP EPZ sizing criteria are not met, then determine if design changes, or analysis refinements, can be made to improve PEP EPZ sizing considerations or if the PEP EPZ size must be expanded.
    - Repeat accident and consequence analysis to address any changes made.
- Determine the final PEP EPZ distance based on meeting the criteria described in Section 6.1.

3.2 Application of Risk-Informed Methods in Event Selection

Risk-informed methods and applications have progressed to provide an appropriate framework to determine PEP EPZ sizing. Important aspects of the regulatory progress in risk-informed methods and applications as applied to PEP EPZ are discussed in Section 2.2.3. As provided in proposed RG 1.242 [1], adequate information on licensing basis events (LBEs), radiological source terms, and PRA will be available and applied to the PEP EPZ sizing methodology described in this ToR. Event selection will be risk-informed based on the release frequency.

Risk-informed processes for any regulatory application should combine and balance insights from deterministic and probabilistic assessments. A qualitative evaluation of DID, consistent with regulatory guidance and practice, will be included in the risk-informed approach being used to confirm the existence, functionality, and capability of design features and strategies that balance accident prevention and mitigation to provide confidence in the acceptably low plant risk and demonstrate protection of the health and safety of the public. In the generic process used in NUREG-0396 [2] in the 1970s, the margins of safety provided by the EPZ were based on a combination of risk insights from NUREG-75/014 [WASH-1400], "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," [11] and "were qualitatively found adequate as a matter of judgment" as indicated in SECY-97-020, "Results of Evaluation of Emergency Planning for Evolutionary and Advanced Reactors" [15]. This qualitative, generic concept for determining the adequacy of the margins of safety can now be updated to include a more accurate risk-informed, design-specific approach with appropriate consideration given to quantitative and qualitative methods, as well as taking into consideration the inherent safety features associated with sodium-cooled fast reactors (SFRs). Since NUREG-0396 was published, the severe accident experimental knowledge base and analytical methods have advanced to the point where more accurate and realistic tools and models are available to support a risk-informed methodology for PEP EPZ sizing.

The risk-informed approach provided in this methodology follows the guidance in proposed RG 1.242, which includes: applying a dose-based framework with a consequence-based approach, event selections with an acceptable spectrum of consequences, and the use of a "spectrum of accidents" as a basis for developing emergency response plans and as the basis for PEP EPZ size.

The proposed risk-informed approach includes steps to achieve a more realistic consequence-based approach without having to resort to unrealistic assumptions or being over conservative. These elements include:

- Design and operational features that provide multiple, independent DID and very low release sequence frequencies with consideration of uncertainty.
- Use of mechanistic models to calculate source terms and doses, which greatly reduces the uncertainty compared to older quantitative methods.
- Integrated uncertainty analysis to increase confidence in the best estimate source term and consequence results as discussed in Section 6.3.
- Application of qualitative means to address uncertainties in the context of very low frequency events including:

- requirement to assess off-site dose consequences from the conservative DBA event analysis (Section 3.6.1),
- plant-level, qualitative evaluation of DID to demonstrate adequate balance between accident prevention and mitigation of potential consequences as an extension to emergency planning and NRC's existing DID philosophy and guidance, and
- development of an emergency plan that provides a base for expanding mitigation and protective action strategies, if necessary, in accordance with regulatory guidance to provide additional DID.

3.3 Dose-Based Criteria

The methodology provided in proposed RG 1.242 [1] has been generalized from the dose assessment methodologies that informed the PEP EPZ size determinations in NUREG-0396 [2]. The probabilistic dose aggregation in NUREG-0396 demonstrated that the PEP EPZ was of sufficient size such that the following conditions were met:

a. Projected doses from the traditional DBAs would not exceed PAG[6] levels outside the PEP EPZ,
b. Projected doses from most core melt sequences[7] would not exceed PAG levels outside the PEP EPZ, and
c. For the worst core melt sequences, immediate life-threatening doses would generally not occur outside the PEP EPZ.

As stated in proposed RG 1.242, "The methodologies used for event selection, identification of source terms, modeling of releases, and aggregation of potential off-site doses should provide similar confidence that appropriate off-site planning will be identified for small modular reactors, non-light-water reactors, and non-power production or utilization facilities."

The dose criteria employed in the methodology described in this ToR are:

- **Criterion A**: Projected doses from the DBAs would not exceed PAG levels outside the PEP EPZ. (Refer to Section 6.1.1 for a discussion of this criteria.)
- **Criterion B**: Projected doses from most radiological release sequences would not exceed PAG levels outside the PEP EPZ. (Refer to Section 6.1.2 for a discussion of this criteria.)
- **Criterion C**: Immediate life-threatening doses from the worst-case radiological release sequences would generally not occur outside the PEP EPZ. (Refer to Section 6.1.3 for a discussion of this criteria.)

The use of the PAGs as criteria ensure that the PEP EPZ is properly sized by meeting an approved standard public exposure to dose. The metric used in NUREG-0396 for condition C is

[6] Whenever the term "PAGs" is used, it refers only to the early phase EPA PAGs.
[7] As provided in NEI 18-04, plant damage states in non-LWR may not involve an equivalent metric to the core damage state, therefore as provided elsewhere in this ToR, radiological release frequencies are used.

200 rem whole body acute dose. Criterion C as applied in this ToR uses a red bone marrow for whole body acute dose[8], as discussed in Section 6.1.3.

The methodology for determining appropriate release sequences to be evaluated against the criteria are addressed in Sections 3.6 and 3.7, and method details for applying the dose criteria are provided in Section 6.1.

The application of these criteria is consistent with the guidance outlined within proposed RG 1.242 and provides a similar level of confidence provided by the criterion originally found in NUREG-0396.

3.4 Development of the Probabilistic Risk Assessment

The PRA being developed is design and site-specific. It will address all modes of operation and external hazards, including seismic events, using the guidance in RG 1.233 [23] and NEI 18-04 [24]. RG 1.233 endorses NEI 18-04 as one acceptable method for non-LWR designers to use when selecting licensing basis events (LBEs)[9, 10]. The PRA will be developed using the guidance in ASME/ANS RA-S-1.4-2021, "Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants" [27] and will address the full spectrum of internal events and external hazards that pose challenges to the capabilities of the plant. Before submittal of the final PEP EPZ sizing analysis, the PRA will be peer reviewed and meet the requirements within the PRA standard. The PRA will identify the facility radiological sources and events. Specific hazards may be screened or addressed in another manner and will be identified and assessed accordingly within the final PEP EPZ sizing calculation as described in Section 3.5.1.

NEI 18-04 describes a systematic process for identifying and categorizing event sequences[11] as anticipated operational occurrences (AOOs), Design Basis Events (DBEs), BDBEs for non-LWRs.[12] DBAs are derived from DBEs by assuming that only safety-related (SR) structures, systems, and components (SSCs) are available to mitigate the events. The primary determinate for categorizing events is the estimated release frequency of the event sequence.

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[8] Red bone marrow (the A-RED MARR MACCS output parameter) is an acceptable effective dose for acute whole-body dose (Reference [NUREG-0396/EPA 520/1-78-016] Section III, Subsection D).

[9] LBEs are defined in terms of event sequences comprised of an Initiating Event, the plant response to the Initiating Event (which includes a sequence of successes and failures of mitigating systems) and a well-defined end state.

[10] NEI 18-04 uses AMSE/ANS RA-S-1.4-2013 as an acceptable means for a PRA.

[11] In the PRA, an "event sequence" refers to the progression from initiating event to an end state within an event tree, with each sequence representing a unique event progression. The term “event sequence” is used in lieu of the term “release sequence” used in LWR PRA standards because the scope of the LBEs includes AOOs and initiating events with no adverse impacts on public safety.

[12] The definitions of some phrases used in NEI 18-04 are different from the same phrases used in NRC regulations and guidance developed for LWRs. The terms “AOO” and “DBE” are examples of similar terms having different definitions. The terminology used in this ToR with respect to event selection reflects the terminology in NEI 18-04.

Sequences used in the screening process are expected to be defined by an initiating event and the failures of specific SSCs representing the success or failure of mitigating systems at the system level.

All sequences are treated individually within the PEP EPZ event selection process. Use of individual sequences also removes ambiguity in performing source term and dose analyses. However, screened in sequences may be grouped into release categories to reduce the number of required source term and dose consequence simulations as discussed in Section 3.5.4. Grouping of sequences into release categories will be identified and justified in PRA documentation.

The methodology in NEI 18-04 includes plotting event sequence families on the frequency-consequence (F-C) target and assessing margins based on event frequency and estimated 30-day dose at the EAB.[13] The mean values of the frequencies are used to classify the LBEs into AOO, DBE, and BDBE categories. However, as described in NEI 18-04, Section 3.2.2, *LBE Selection Process*, when the uncertainty bands defined by the 5th percentile and 95th percentile of the frequency estimates straddles a frequency boundary, the LBE is evaluated in both LBE categories.

The PRA will be used to identify applicable event sequences to be considered in the PEP EPZ methodology. To support the identification of applicable event sequences, event sequences for all internal events and external events, as well as all operating modes, will be compiled.

A review of the assumptions and sources of uncertainty in the underlying PRA will be completed to identify and address any potential impact on the application of the PEP EPZ sizing method. The uncertainty issues that can be directly related to sizing the PEP EPZ include:

- key assumptions in the PRA,
- model uncertainty, and
- completeness uncertainty.

3.5 Hazards and Initiating Events

3.5.1 Treatment of Hazards Groups

As stated above, the evaluation of events for the determination of PEP EPZ sizing requires that initiators from screened in event sequences include a broad spectrum of events, including internal and external events. Evaluated hazards will include the hazard groups from ASME/ANS RA-S-1.4-2021 [27]:

- internal events,
- internal floods,
- internal fires,
- seismic events,

[13] For the purposes of assessing the PEP EPZ size, the doses are assessed using a 96-hour (4-day) period.

- high winds, and
- external floods.

Additional hazards will be assessed including site specific hazards and their inclusion or screening will be identified within the associated PRA documentation and within the PEP EPZ sizing calculation. Events will also be evaluated against all modes of operation including full power, low power, refueling, and shutdown.

Accident phenomena will be analyzed as part of the PRA and will be used as input to the PEP EPZ sizing methodology. The PRA will address all hazards, all modes, all sources, and events will be screened according to specific screening criteria outlined in Sections 3.6 and 3.7. Events that are screened out will be identified and justified within the documentation. The PEP EPZ sizing analysis will include the relevant accident phenomena that is found to be applicable to the Natrium reactor design.

3.5.2 Security Events

Security events are explicitly not addressed by ASME/ANS RA-S-1.4-2021. Security events will be considered for completeness for the PEP EPZ; however, accidents resulting from security events may be eliminated from detailed consideration in the PEP EPZ by meeting regulatory requirements to protect against threats. Security events are justified by meeting regulatory requirements and describing security-by-design features of the plant. A qualitative or quantitative assessment of the security events will be performed and documented in the PEP EPZ sizing calculation to ensure that these events are addressed, and their associated risks are captured within the PEP EPZ calculation.

3.5.3 Other Risk Events

Other risks that are design-specific or site-specific that may also lead to potential off-site radionuclide releases that may impact PEP EPZ sizing will be included. These other risks will be identified and evaluated to ensure an appropriate PEP EPZ size. A full scope of the radionuclide sources will be incorporated into the PRA and the associated events will be assessed against the PEP EPZ dose criteria methodology to ensure proper sizing.

3.5.4 Event Groupings

The PRA process supports the categorization and evaluation of PEP EPZ events in terms of estimated frequencies and consequences of event sequences or event families (i.e., groupings of event sequences having similar initiating events, challenges to plant safety functions, plant response, end state, and mechanistic source term). The event sequences and related estimations of frequencies and consequences include equipment malfunctions caused by internal and external hazards. The groupings will be consistent with ASME/ANS RA-S-1.4-2021 and will be identified and justified in PRA documentation. PEP EPZ events will be identified utilizing the PRA event sequences, event sequence families, and groupings. These events will be used for selection of sequences for the radiological consequence analysis.

3.5.5 Defense-in-Depth

The DID evaluation will be consistent with the process described in Section 5, *Evaluation of Defense-In-Depth*, of NEI 18-04 [24]. DID adequacy will be determined based on review of the plant and system-level SSC classification, defense levels identified in the fault list, and the programmatic adequacy. The defense line (DL) approach involves the identification of five DLs for each identified plant initiating event (PIE). The DID approach will also identify SSCs that are identified as non-safety-related with special treatment (NSRST) in addition to the SR SSCs determined by the PRA. The DID evaluation process will ensure that an appropriate mitigation strategy exists with enough independent, redundant functions to provide adequate DID for event response. Credit for the PEP EPZ is not used as a defense line but rather to inform the emergency response. The specific DID methodology will be addressed outside the scope of this PEP EPZ ToR.

3.6 Selection of Non-Seismic Release Sequences

3.6.1 Criterion

All non-seismic release sequences contributing one percent (1%) or more to overall release frequency (total release frequency of all release sequences) will be included as well as all DBAs. All non-seismic release sequences with a frequency greater than or equal to 1E-07 per reactor year and contributing 1% or more of overall release frequency will be retained for evaluation in the PEP EPZ analysis. (Seismic events will be evaluated separately and are discussed in Section 3.7.1.) Individual events and groups with sums greater than the frequency 1E-08 per reactor year will be considered for cliff-edge effects. Events and groups considered for cliff-edge effects will be included if the 95th percentile frequencies are above 1E-07 per reactor year, or minor changes to the events lead to large variations in plant response, or the risk profile of the events. PEP EPZ events are created using the event sequence families generated within the PRA.

This screening criteria is consistent with the spectrum of accidents that form the basis for the original PEP EPZ sizing in NUREG-0396 [2], capturing the range of WASH-1400 [11] release category frequencies. Additionally, identifying the spectrum of release sequences based on release frequency conservatively ignores the conditional probability of radionuclide release when compared to the quantification of WASH-1400 release category frequencies.

The sequence release frequency screening threshold of 1E-07 per reactor year is appropriate for the PEP EPZ sizing methodology and properly captures the associated risk to the facility as it is below the frequency-consequence analysis threshold within NEI 18-04 [24]. To ensure that cliff-edge effects and uncertainties are accounted for, events will be considered in the analysis down to a release frequency of 1E-08 per year.

3.6.2 Parameter Uncertainty

Parametric uncertainty in initially screened out sequences will be evaluated to ensure a complete set of source terms is retained in the spectrum of release sequences used in the PEP EPZ sizing analysis.

The treatment of uncertainties in the non-seismic sequence screening will quantify the impacts of uncertainties using quantitative uncertainty analyses supported by sensitivity analyses consistent with NUREG-1855 [8] as follows:

1. Release sequence frequencies will be calculated as mean frequencies.
2. Proximity of the mean sequence frequency to the 1E-07 per reactor year screening criteria will be identified.
3. If the mean sequence frequency is below a screening threshold, then the upper bound (95^{th} percentile) of the frequency uncertainty range is compared to the screening criteria.
4. Consider for inclusion to the PEP EPZ sizing method those sequences that challenge the screening criteria in the PEP EPZ basis.

In the specific context of the PEP EPZ sizing method, these steps take the following form: (Refer to Figure 3-2)

1. If the 95*th* percentile release frequency of the event is greater than 1E-7 per reactor year, then the event is screened into the PEP EPZ evaluation.
2. If the mean release frequency of the event is greater than 1E-8 per reactor year, then the event is considered for cliff-edge effects within the PEP EPZ evaluation.
3. If the mean release frequency of the event is below 1E-8 per reactor year, then the event is screened out of the PEP EPZ evaluation.

3.7 Selection of Seismic Release Sequences

3.7.1 Criterion

The seismic event selection criteria will utilize the insights from a site-specific scoping level seismic PRA (SPRA) to establish a limiting peak ground acceleration (PGA) for the site needed for the PEP EPZ sizing analysis. This limiting PGA value determined for the PEP EPZ analysis would be aligned to achieve at least two times the Ground Motion Response Spectrum (GMRS) to limit the range of seismic hazard under consideration within the credible range of ground motions. However, an upper bound PGA of 1.0g will be utilized to acknowledge the limitations of the PRA and uncertainties associated with availability of local and state emergency response infrastructure at large ground motions. The use of limiting PGA value assures the range of ground motion that needs consideration for emergency planning and PEP EPZ sizing is bounding for the site and will be supported by the SPRA to ensure that the value selected adequately encompasses the associated risk from credible seismic events. The limiting PGA selected will identify the specific set of events that need consideration for the bounding seismic scenario used in PEP EPZ sizing based on the site-specific characteristics and design.

This limiting PGA will be utilized in establishing the bounding seismic event that will be utilized to establish the PEP EPZ sizing calculation for the CPA. The limiting PGA will be used as the event screening threshold for the selection of PEP EPZ events for the seismic PEP EPZ sizing calculation for the OLA. The evaluation of the events against the dose criteria will be consistent between the CPA and the OLA. This limiting scenario for CPA is expected to capture the important phenomena that will challenge the required safety functions and radiological barriers after a seismic event. Site-specific seismic PEP EPZ events identified from the SPRA, using the limiting PGA as an event screening threshold, will be utilized within the PEP EPZ sizing analysis during OLA. Thus, meeting the intent of RG 1.242, Appendix A, to screen in events with low likelihood but severe consequences. Figure 3-3 shows the flow of the seismic EPZ event analysis depending on the development stage during the licensing process.

The bounding seismic scenario chosen, utilizing the insights from the SPRA, and representing the limiting PGA, will encompass most of the sequences and represent the dose consequences and seismic impacts to the facility from high consequence credible events found at the site. The proposed seismic event selection criterion is consistent with the philosophy discussed in NUREG-0396 [2]. Specifically, the seismic event to be analyzed will be determined based on a review of the full spectrum of seismic events, informed by frequency considerations, and used to establish the PEP EPZ. Additionally, this approach is consistent with the guidance in proposed RG 1.242 [1], Appendix A, in that the seismic event used for the PEP EPZ sizing determination is bounding for most radiological release sequences as well as accounts for the dose consequences and seismic impacts to the facility from high consequence credible events.

3.7.2 Parameter Uncertainty

The bounding seismic scenario accounts for the phenomena and the consequences based on uncertainty and cliff-edge effects. The proposed approach ensures all credible sequence of events are evaluated utilizing insights from the SPRA including the assessment of the 95th percentiles of frequencies, within the range of the limiting PGA. and within the limiting PGA including results from the assessment of the 95^{th} percentile frequencies. Uncertainty associated with the confidence of the site-specific seismic characteristics are addressed within the SPRA and specific seismic analyses. The SPRA, including the scoping level model, evaluates the distribution in the uncertainty quantification, see Section 6.3. The proposed method selects initiating events and event sequences by accounting for the limitations of PRA technology in the estimation of the frequency of rare events.

3.8 Release Timing

The timing of the release of radionuclides for each event is determined as part of the source term methodology and is outside of the scope of this PEP EPZ ToR. The radionuclide release timing information will be utilized in the event groupings to inform the emergency procedures and, if necessary, identify the events that require prompt protective measures (refer to Section 6.2). The timing of events is established when developing the source term analysis for each event and will be identified and documented in the PEP EPZ sizing calculation.

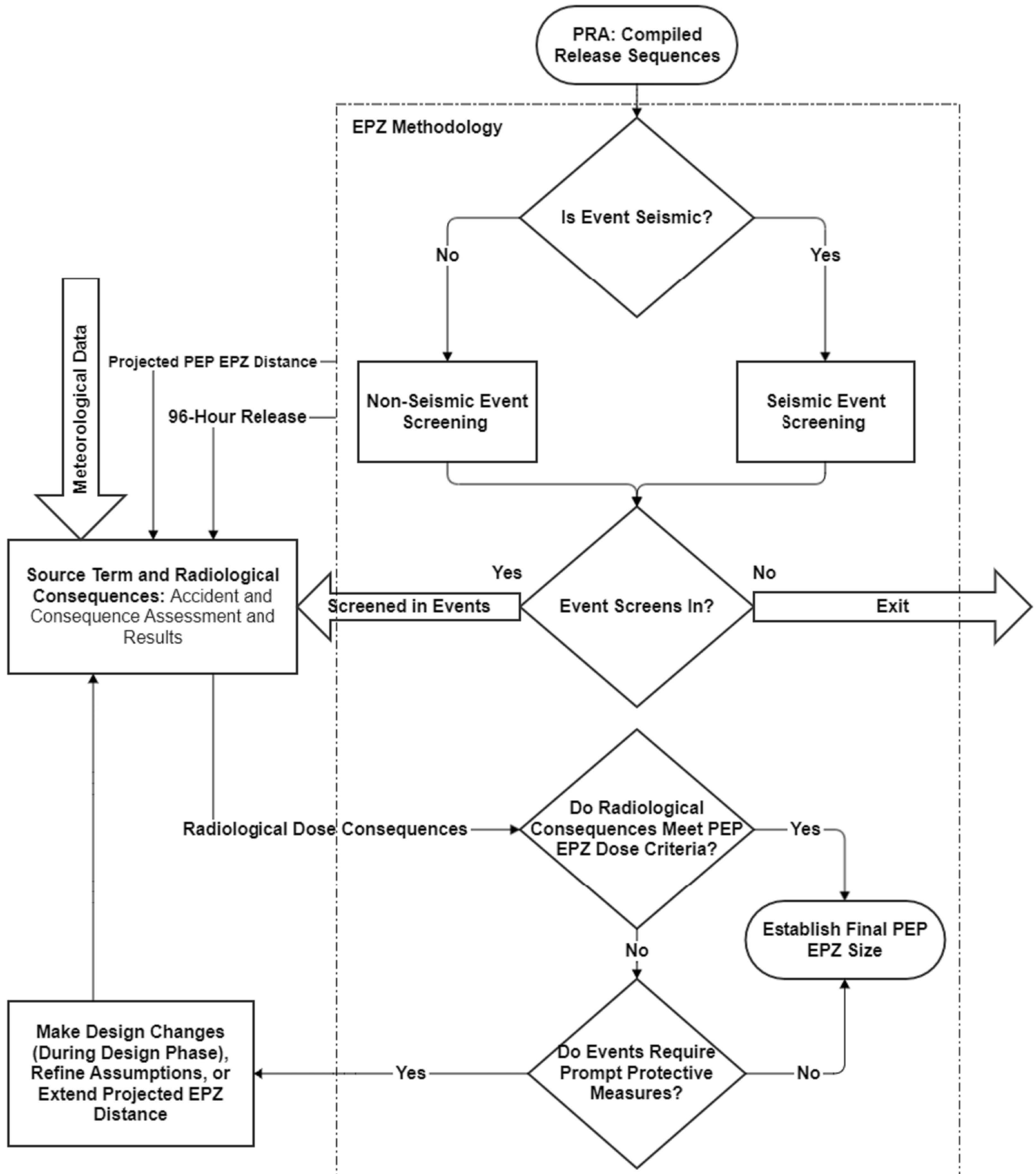

Figure 3-1: Overall Methodology to Determine PEP EPZ Distance

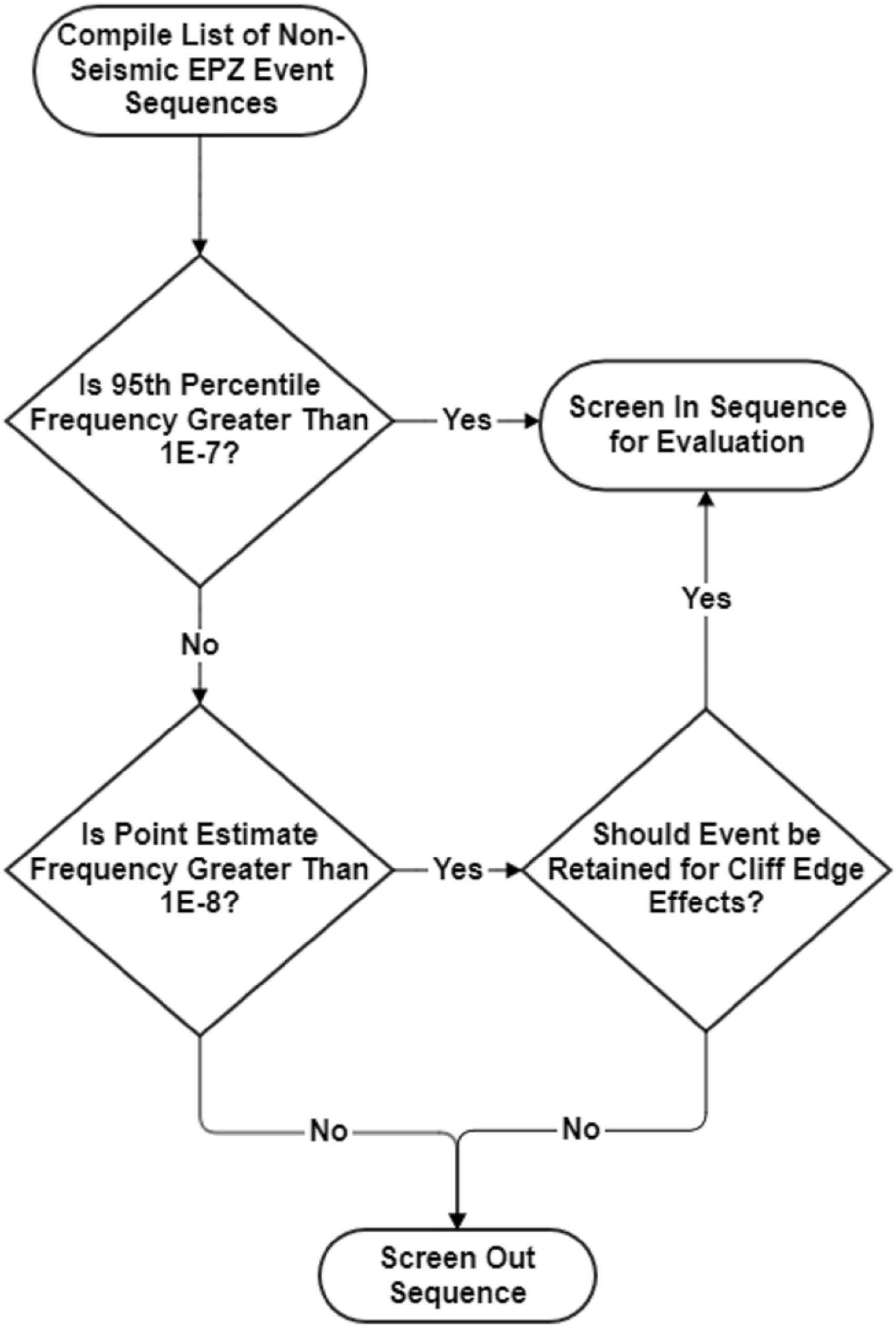

Figure 3-2: Non-seismic Release Sequence Screening

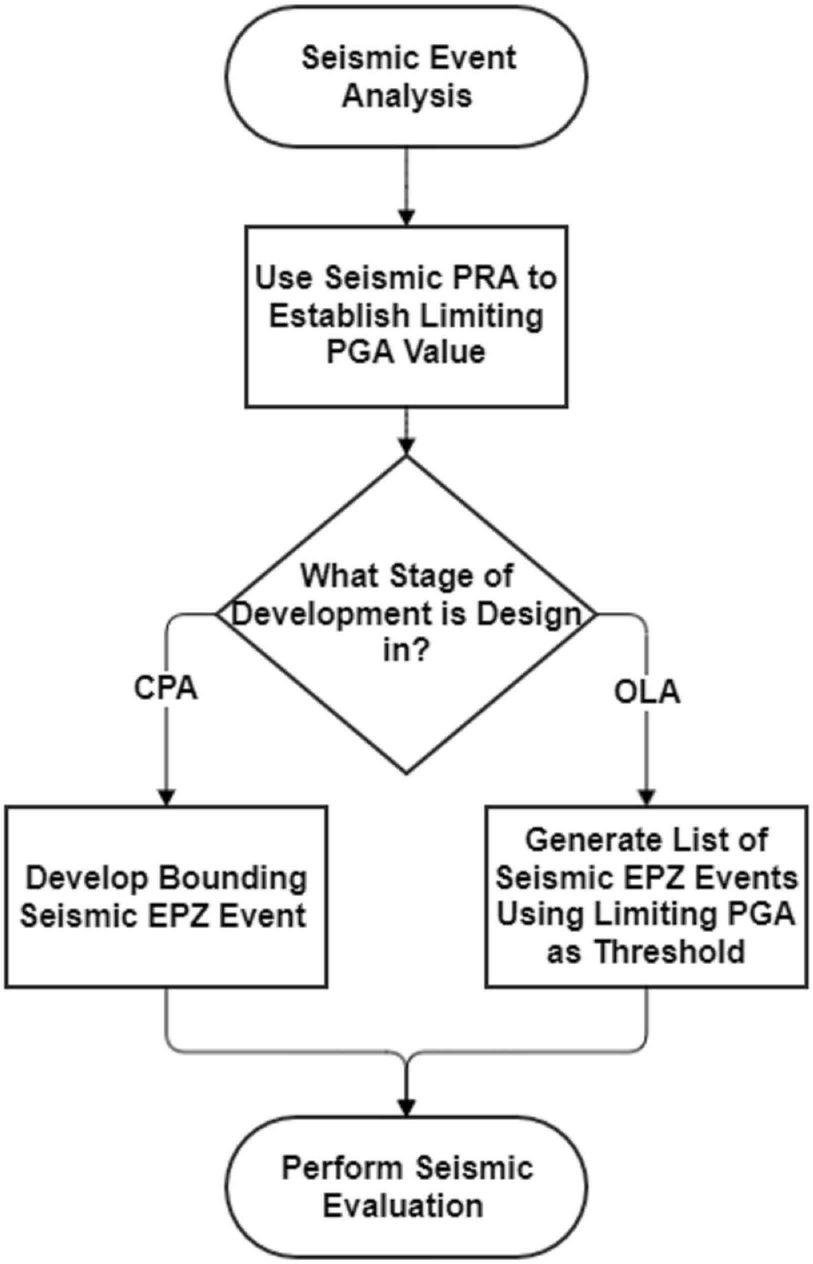

Figure 3-3: Seismic Event Analysis Flow Chart

4 SOURCE TERM METHODOLOGY

The source term methodology will be used to develop mechanistic source terms associated with the release scenarios. The mechanistic source terms are a direct input into the radiological consequences methodology. This input will establish the specific radionuclide inventory and the quantity released for the events that will be assessed in the PEP EPZ analysis. The methodology for source term development for the PEP EPZ analysis will be consistent with overall Natrium reactor assessment and projections. This methodology is addressed separately [4] and is outside the scope of this PEP EPZ ToR.

5 RADIOLOGICAL CONSEQUENCE CONSIDERATIONS

5.1 Meteorological Input

Data collection to support the data file needed to assess the radiological consequences will occur in accordance with RG 1.23, "Meteorological Monitoring for Nuclear Power Plants" [38]. The initial PEP EPZ sizing calculation will use 12 consecutive months of representative meteorological data. The final PEP EPZ sizing will use a full two-year data set collected from the site-specific meteorological data program. The methodologies associated with the collection of the meteorological data and determination of radiological consequences are out of scope for this ToR. Meteorological data will be utilized within the radiological consequence analysis to properly assess the doses at the PEP EPZ boundary.

5.2 Population Data

For the PEP EPZ analysis, a uniform population density is assumed rather than an external population data file to make the evaluation independent of site location. A population study was conducted to develop a proper population density assumption for MELCOR Accident Consequence Code System" (MACCS) evaluations; however, the specifics of the population data will be addressed separately and is outside the scope of this PEP EPZ ToR.

5.3 Radiological Consequence Analysis

The specific radiological consequence analysis methodology [4], including the use of MACCS [39] and its associated inputs and uncertainty analysis, is outside the scope of the PEP EPZ methodology ToR. The results of that analysis are a direct input into the PEP EPZ methodology ToR and will be used specifically for the dose aggregation evaluation described in Section 6.1. The radiological consequence specific to PEP EPZ methodology ToR will quantify the dose consequences to the public from the events identified for the PEP EPZ. The methodology for the radiological consequence analysis for the PEP EPZ analysis will be consistent with the LBE consequence analyses, except instead of a 30-day dose consequence calculation a 96-hour (4-day) or 24-hour dose calculation will be assessed. In addition, no protective actions are modeled including, no evacuation, relocations, or sheltering. The public is assumed to continue normal activities during the event. These requirements will be quantified in the radiological consequences ToR.

5.4 Dose Estimation for Pathway Contributors

Doses will initially be assessed against the three criteria provided in Section 3.3 using a nominal distance at the proposed site boundary to identify which events meet the PAG levels. If the calculated dose exceeds the PAG levels, then an iterative process to incorporate the risk-informed benefits to the initial design of the facility will be used to further assess the event during the design phase. This process will begin by considering design modifications that can be made to reduce the release frequency or consequence so that the dose falls below the PAG levels. If design modifications cannot be achieved, then the dose will be calculated at larger distances until the PAG levels are met.

In lieu of determining a quantity representing the total effective acute dose (i.e., whole body value), the red bone marrow effective acute dose is chosen for evaluation against the threshold for significant early injuries (Criterion C). The rationale for this assumption is based on the considerations that the red bone marrow has the lowest dose threshold value amongst the three early fatality health effects, spatially represents the entire body, is assumed to be typically the highest effective acute organ dose, and the red bone marrow dose threshold is very close to the NUREG-0396 [2] criterion of 200 rem acute whole-body dose. The use of red bone marrow dose for acute effective dose is supported by NUREG-0396.

The red-bone marrow effective dose and 96-hour public dose criteria are specific to the PEP EPZ sizing. The PEP EPZ exposure pathways include cloud shine, inhalation, resuspension, and ground shine for the red bone effective dose and the TEDE dose.

These consequences will be calculated using the MACCS peak dose on the spatial grid. The methodology for quantifying the dose and exposure pathways and the specifics of using MACCS will be addressed separately in the radiological consequences ToR [4] and is outside the scope of this PEP EPZ ToR.

6 PROBABILISTIC DOSE AGGREGATION

The following is the methodology for aggregating the doses from different source terms with consideration of their frequencies. The methodologies outlined in proposed RG 1.242 [1] and NUREG-0396 [2] illustrate the need to provide a level of confidence that the appropriate PEP EPZ size has been established. To do this the projected doses of various events derived from the PRA will be evaluated against a set of specific criteria to ensure that risk to the general public is minimized. In Sections 3.6 and 3.7 it was illustrated how the selection of the events will take place. Once the events have been identified their respective dose consequences will be evaluated to ensure that the risk to the general public is acceptable.

6.1 Criteria for Plume Exposure Pathway Emergency Planning Zone Sizing

6.1.1 <u>Design-Basis Accidents</u>

Criterion A: Projected doses from the DBAs would not exceed PAG levels outside the PEP EPZ. (Refer to Section 3.6 and 3.7 for accident selection.)

To evaluate Criterion A, a mechanistic source term will be developed for each DBA[14] and will be evaluated using the radiological consequence analysis methodology to determine if the PAG levels [7] of 1 rem mean 4-day TEDE and 5 rem 95th percentile 4-day TEDE will be met. As provided in Section 5.4, this will be initially assessed using a nominal distance at the proposed site boundary. If the calculated dose exceeds the PAG levels, then an iterative process will be used during the design phase until design modifications are made to reduce the release frequency (or radiological consequence) or the PEP EPZ distance will be moved further out until the dose consequences meet the PAG levels.

6.1.2 Most Radiological Release Sequences

Criterion B: Projected doses from most radiological release sequences would not exceed PAG levels outside the PEP EPZ. (Refer to Section 3.6 and 3.7 for accident selection.)

To evaluate Criterion B, PEP EPZ events with a mean release frequency greater than 1E-06 will be evaluated to determine if the PAG levels of 1 rem mean 4-day TEDE and 5 rems 95th percentile 4-day TEDE will be met. As provided in Section 5.4, this will be initially assessed using a nominal distance of the proposed site boundary. If the calculated dose exceeds the PAG levels, then an iterative process will be used during the design phase until design modifications are made to reduce the release frequency (or radiological consequence) or the PEP EPZ distance will be moved further out until the dose consequences meet the PAG levels.

6.1.3 Worst Radiological Release Sequences

Criterion C: Immediate life-threatening doses from the worst-case radiological release sequences would generally not occur outside the PEP EPZ. (Refer to Section 3.6 and 3.7 for accident selection.)

To evaluate Criterion C, PEP EPZ events with a mean release frequency below 1E-06 but a 95th percentile greater than 1E-07 (see Section 3.6 for specifics) will be selected for evaluation. As provided in Section 5.4, these events will be initially assessed using a nominal distance at the proposed site boundary to identify which events meet the 24-hour, 200 rem red marrow acute effective dose. If the calculated 95th percentile dose exceeds the acute dose, then an iterative process will be used during the design phase until design modifications can be made to reduce the release frequency (or radiological consequence), or the mean event frequency falls below the 1E-07 range, or the PEP EPZ distance will be moved further out until all events in this range have a dose consequence that meets the acute dose levels. Additionally, these events will be analyzed to ensure that the dose drops rapidly from the PEP EPZ boundary. To ensure that the dose drops off rapidly from the PEP EPZ boundary, additional dose quantifications will take place at various distances beyond the PEP EPZ boundary to generate a dose distance chart mapping the reduction in dose as you move away from the PEP EPZ boundary. Probability of exceedance at distances from the site boundary as well as specific dose-distance information will be collected, and the information will be evaluated and documented to ensure the dose drops rapidly from the boundary. Dose distance curves will provide information like that of the dose distance curves found within NUREG-0396.

[14] DBAs are derived from DBEs and assume that only SR SSCs are available to mitigate the events.

6.1.4 Establishment of the Plume Exposure Emergency Planning Zone

Based on the above, the PEP EPZ will be established at the furthest distance upon which all three criteria in Sections 6.1.1, 6.1.2, and 6.1.3, will be met.

6.2 Necessity of Predetermined Prompt Protective Measures

As stated in Section 3.8, timing of the release of radionuclides will be captured for analyzed events. This timing information will be utilized to identify the necessity of prompt protective measures for PEP EPZ events and inform the emergency plan and response procedures. For the purposes of the PEP EPZ ToR, the preliminary analysis will begin with the radiological consequence analysis assuming all PEP EPZ events require predetermined prompt protective measures. If the radiological consequence of the event exceeds any of the dose criteria in Section 6.1 at the PEP EPZ boundary, then the timing of the release will be considered against the guidance in proposed RG 1.242 and specific assessment on the need for prompt protective measures will be completed. The timing of each event will be assessed individually to identify whether the need for predetermined prompt protective measures is necessary, incorporating the specific event information. This evaluation will be documented into the PEP EPZ calculation. If any PEP EPZ event is identified to necessitate the need for predetermined prompt protective measures and it exceeds any of the dose criteria, then modifications to the design or an extension of the PEP EPZ boundary are considered and would follow the iterative process described in Section 6.1. The iterative evaluation process will be used to reduce the release frequency (or radiological consequence) or move the PEP EPZ distance further out until the dose consequences meet the criterion dose levels. Identified protective measures will inform the emergency response plan and procedures. This ensures that predetermined prompt protective measure will be assessed for all PEP EPZ events.

6.3 Uncertainty and Sensitivity Analysis Methodology

To ensure that the PEP EPZ events themselves are properly being assessed Monte Carlo sampling will be performed on the PRA event frequencies to ensure correct percentiles are properly captured. This ensures confidence in the specific mean and 95th percentile values. The Monte Carlo sampling is part of the PRA process (including the SPRA). The methodology to determine the uncertainties in radiological consequences, including the uncertainty in meteorological conditions is in the radiological consequence ToR [4] . Radiological consequence uncertainties are included in the results of the radiological consequence analyses. The methodology of the source term uncertainty analysis is in the source term ToR [4] . Source term uncertainties are included in the results of the source term analyses.

Finally, to ensure that event impacts are representing the appropriate level of risk, cliff-edge events will be looked at to ensure that the event risks are properly captured. Events with frequencies down to 1E-08 will be included for cliff-edge effects. The primary focus is single failures that would either dramatically change the effects (e.g., timing, plant response, source terms, or the end states) of the accident sequencies or the risk metrics (e.g., specific doses or consequences). There are no specific criteria for what is considered a “dramatic change, this is based on engineering judgement as part of the event analysis. Cliff-edge effect evaluations will be documented in the PEP EPZ sizing calculation.

7 SUMMARY AND CONCLUSIONS ON METHODOLOGY

The proposed methodology for developing the technical basis for the PEP EPZ size utilizes the guidance in proposed RG 1.242 [1]. It is based on the selection of events from a PRA developed in accordance with current regulatory guidance and industry standard. It applies risk-informed methods and applications to determine PEP EPZ sizing. This risk-informed approach includes PRA information (including SPRA), mechanistic source terms, and a qualitative evaluation of defense-in-depth. The methodology applies severe accident knowledge and analytical methods developed since the current PEP EPZ size was determined based on NUREG-0396 [2], while still maintaining the fundamental characteristics of the methodology employed in NUREG-0396 as discussed in proposed RG 1.242.

The methodology is applicable to any PEP EPZ size, including a PEP EPZ within the site boundary. The final PEP EPZ size will be the smallest distance at which the dose consequences of all screened in release sequences are less than their respective dose criteria and requiring prompt protective measures, with a minimum distance at the site boundary. Based on the results of applying the methodology, the final PEP EPZ size may be less than the current 10-mile requirement.

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