Overview of SSHAC Process

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Coastal Flooding SHAC-F Research Webinar
March 2, 2020

Overview

- History of SSHAC and basic elements
- Implementation guidance in NUREG-2117 and NUREG-2213
- SSHAC Levels, organization, and workflow
- Standards and regulatory guidance for PFHA

What is a SSHAC process?

A structured framework and procedure for conducting multiple-expert assessments that capture uncertainties in the inputs to hazard analyses

NUREG/CR–6372
UCRL–ID–122160
Vol. 1

Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts

Main Report

Prepared by
Senior Seismic Hazard Analysis Committee (SSHAC)
R. J. Budnitz (Chairman), G. Apostolakis, D. M. Boore, L. S. Cluff, K. J. Coppersmith, C. A. Cornell, P. A. Morris

Lawrence Livermore National Laboratory

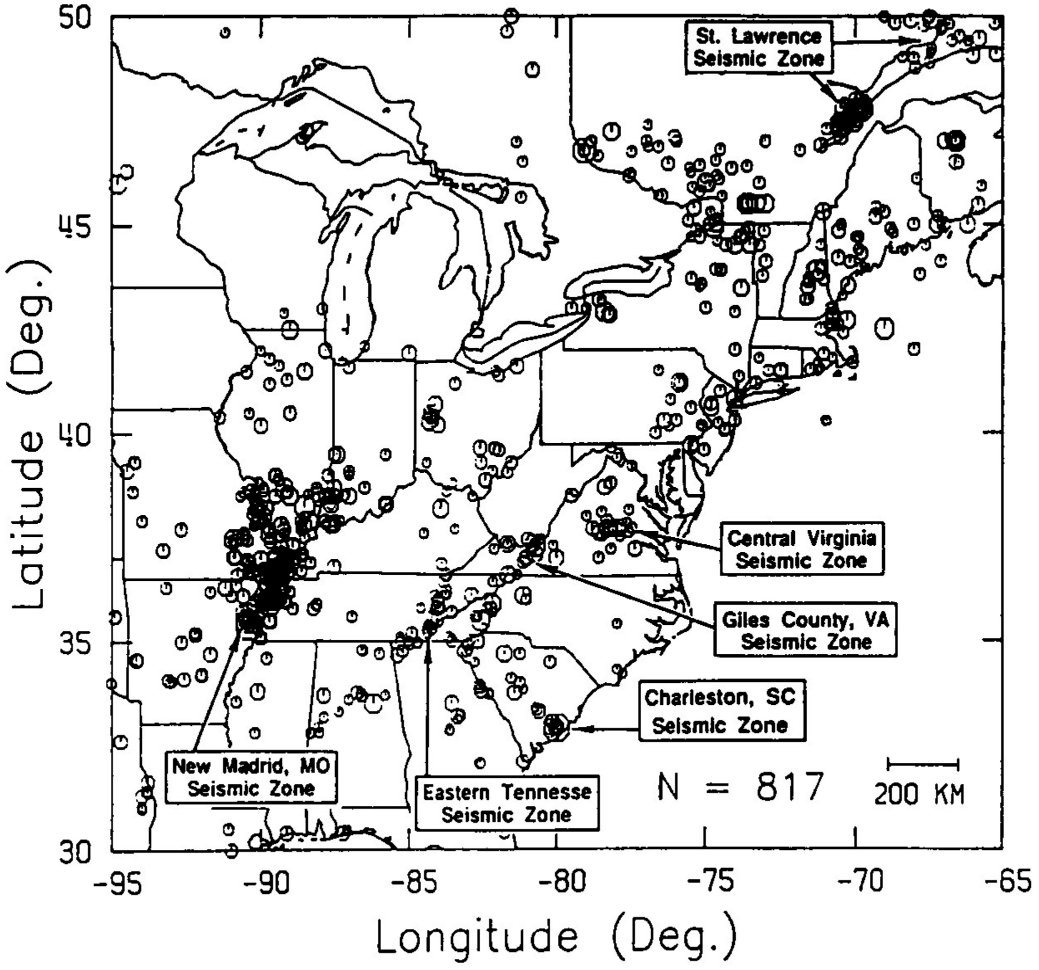
Procedures defined by the Senior Seismic Hazard Analysis Committee (SSHAC)

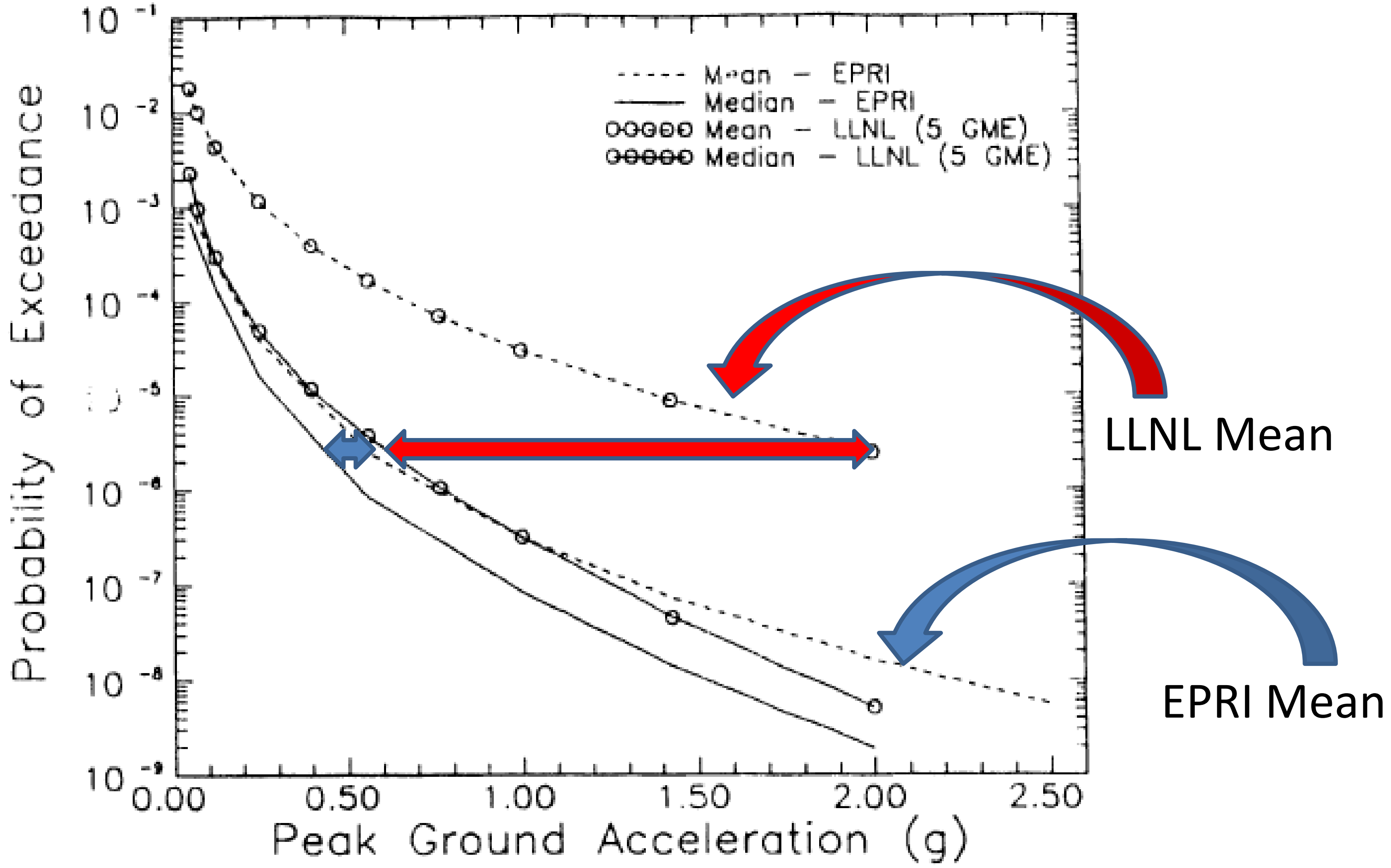
Prepared for
U.S. Nuclear Regulatory Commission
U.S. Department of Energy
Electric Power Research Institute

Why was SSHAC formed?

In the 1980s, two major PSHA studies were conducted (by LLNL and EPRI) for nuclear power plant sites in Central and Eastern USA

Because of the high degree of uncertainty regarding seismicity and ground motions in CEUS both projects employed multiple experts





Very different results, in terms of mean hazard and associated uncertainty, from the two studies for a single NPP site

Legacy of Deterministic Assessments of SSEs

- All SSEs defined deterministically
- Probabilistic seismic hazard carried out post-facto
- Annual probability of exceeding SSE varies by nearly two orders of magnitude
- Difficult to claim uniform risk across inventory of plants

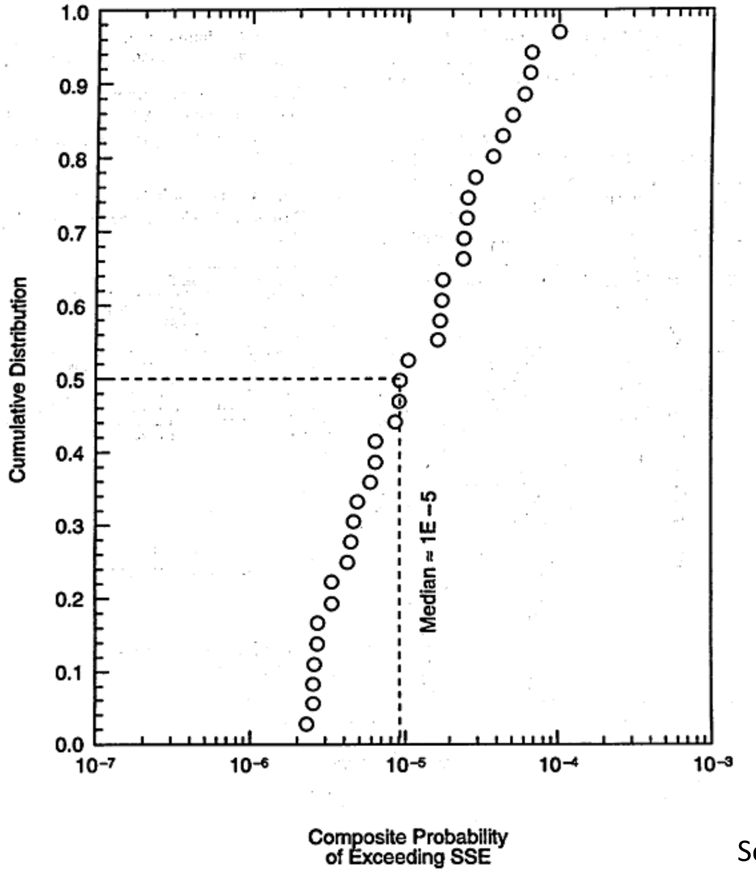


Figure B.2 Probability of Exceeding SSE
Using Median LLNL Hazard Estimates

Source: USNRC
Reg Guide 1.165

The NRC, DOE, and EPRI formed the SSHAC to review how these studies has been conducted and to propose improved procedures

"In the course of our review, we concluded that many of the major potential pitfalls in executing a successful PSHA are <u>procedural</u> rather than technical in character. ….. This conclusion, in turn, explains our heavy emphasis on procedural guidance."

NUREG/CR-6372 (1997)

Motivation for SSHAC

- Problems identified from past studies
  - Overly diffused responsibility
  - Insufficient face-to-face interaction
  - Inflexible aggregation schemes
  - Imprecise or overly narrow objectives
  - Outlier experts
  - Insufficient feedback

REGULATORY ASSURANCE

Confidence that the hazard assessment has fully taken account of all knowledge and

UNCERTAINTIES

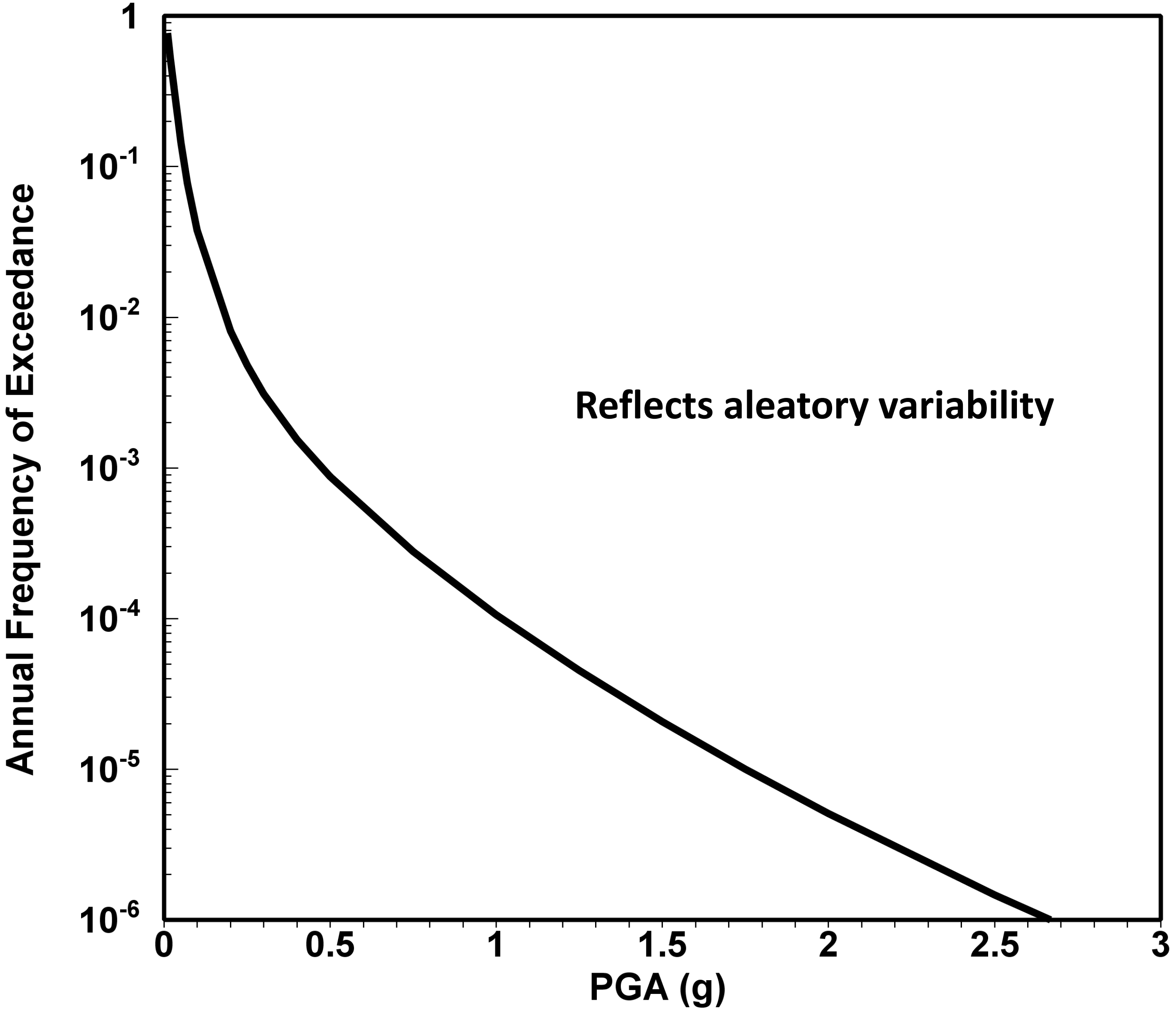
ALEATORY

- Random variability
- Characterized by probability distributions
- Theoretically irreducible with new data
- Integrated in PSHA

EPISTEMIC

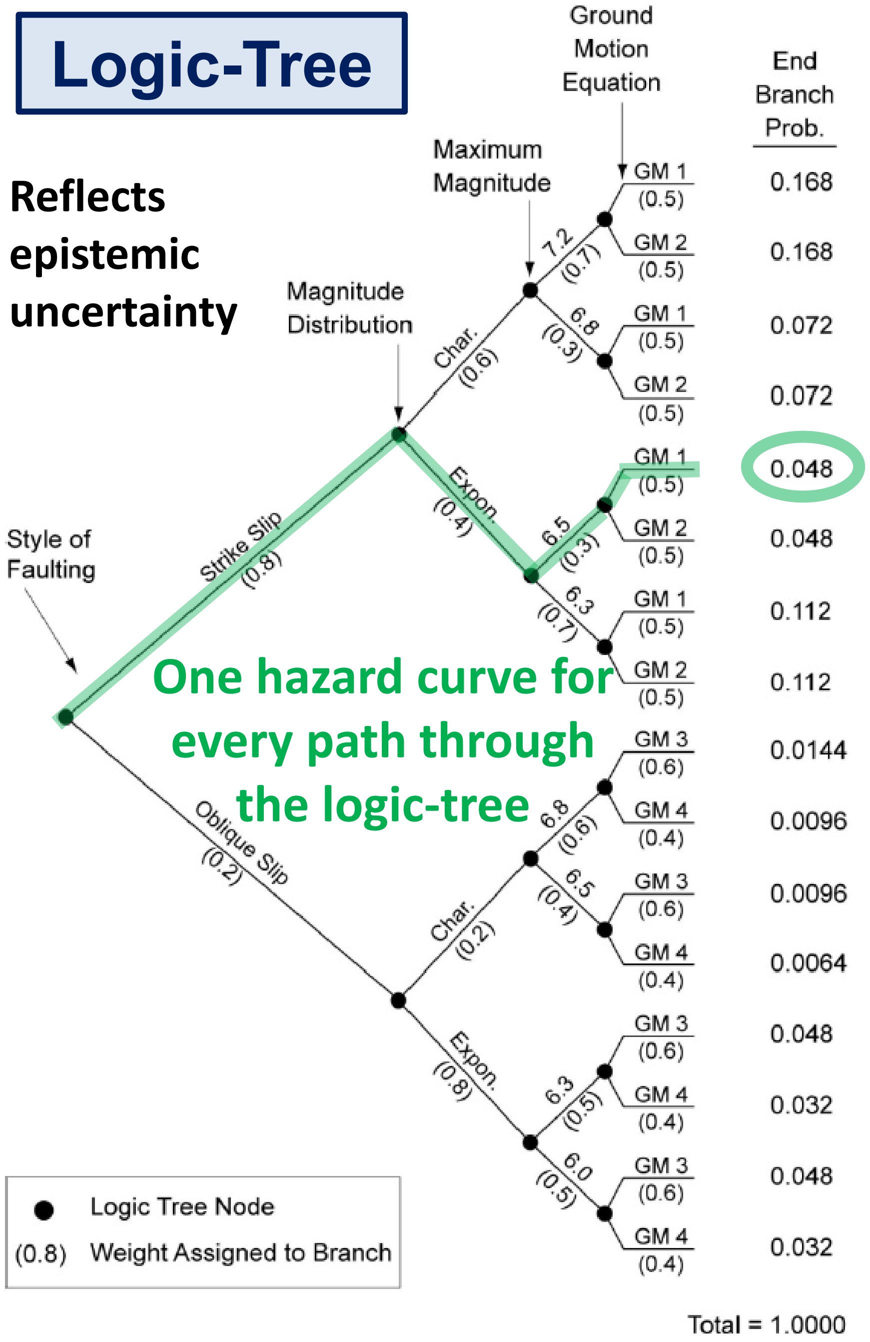
- Lack of knowledge
- Expert judgments
- Reducible with new data
- Logic trees

Seismic Hazard Curve



Logic-Tree

Reflects epistemic uncertainty

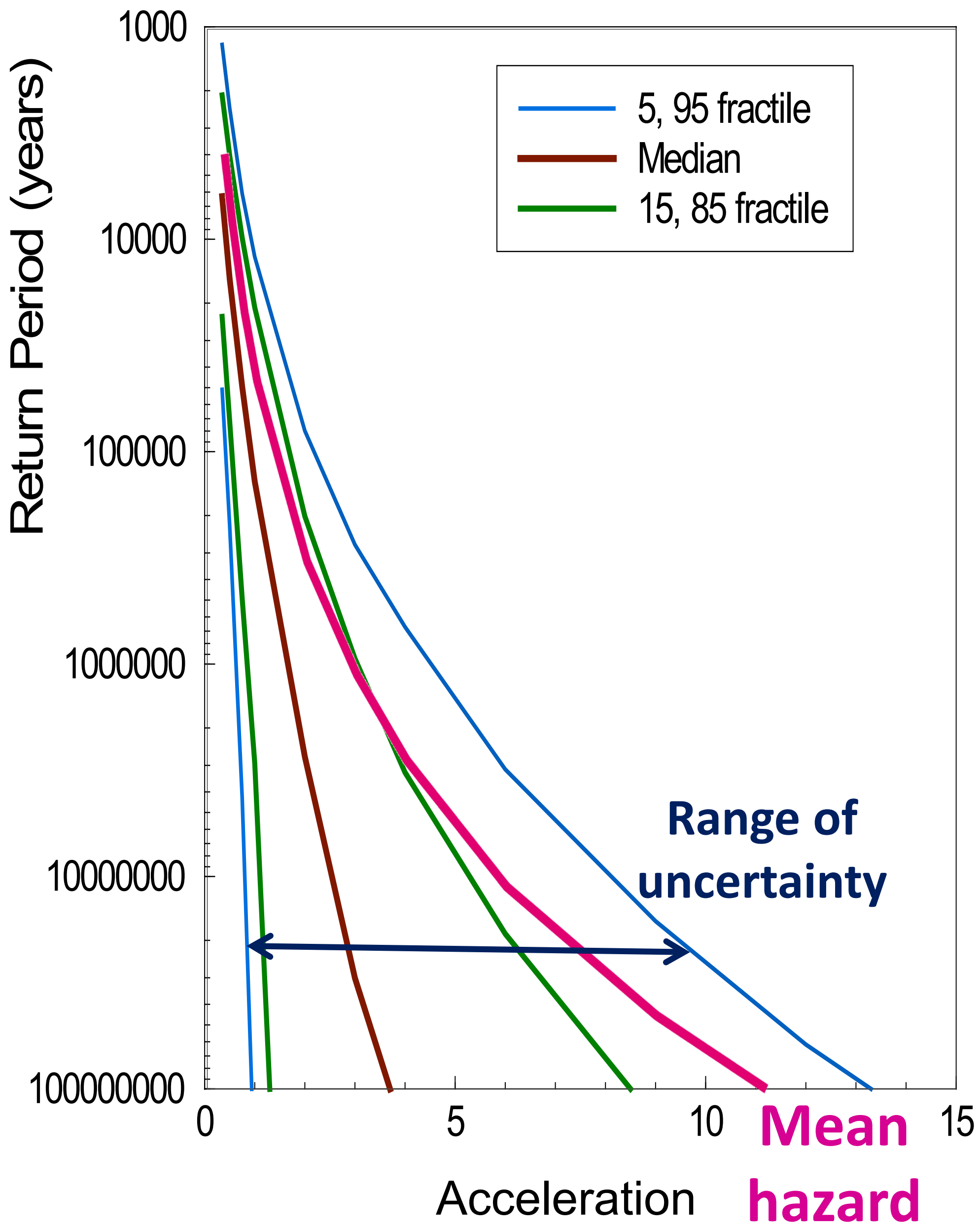


For each input to the PSHA calculations (node), the branches of the logic tree represent alternative models or parameter values

Weights are assigned to each branch (summing to unity at each node) that reflect the relative confidence of the analyst in each model being the most appropriate

Logic tree leads to multiple PSHA calculations and thus multiple hazard curves, each with an associated total weight or probability

Hazard distribution formally incorporates both aleatory and epistemic uncertainty, as required for probabilistic risk analysis



SSHAC Guidelines and Guidance

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probabilistic seismic hazards analysis

an American National Standa

published by the
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U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-2117

Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies

Office Nuclear Regulatory Research

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG–2213

Updated Implementation Guidelines for SSHAC Hazard Studies

gulatory Research

NUREG-2117 SSHAC Implementation Guidelines 2012

NUREG-2213 Updated Implementation Guidelines 2018

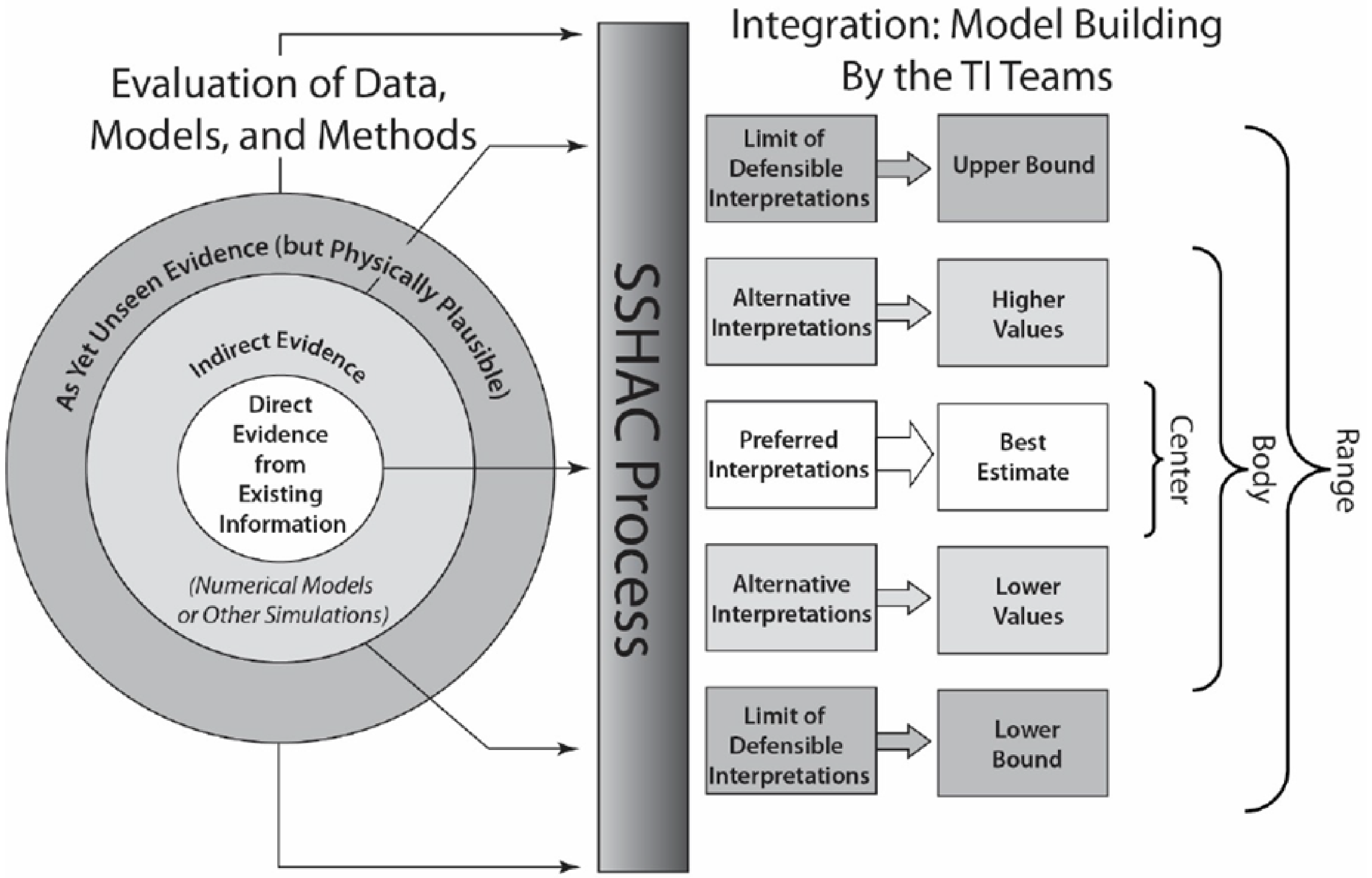
SSHAC Implementation Guidance

- Multiple applications of SSHAC led to the need for more detailed implementation guidance based on lessons learned
- NUREG-2117 (2012)
  - Defined goals of a SSHAC process: Evaluation, Integration, Documentation
  - Defined roles and responsibilities of all participants
  - Specified essential steps in Level 3 and 4 studies
- NUREG-2213 (2018)
  - Standalone replacement to NUREG-2117; overt effort to gauge experiences of practitioners over past 25 yrs
  - Further specified structure and activities of all four SSHAC Levels, especially Level 1 and 2
  - Defined five essential attributes of SSHAC study
  - Provided guidance on evaluating the need for updating existing studies

Goals of a SSHAC Process

The fundamental activities of a SSHAC process are defined as:

- Evaluation: The consideration of the complete set of data, models, and methods from the technical community
- Integration: Representing the center, body, and range of technically defensible interpretations (CBR of TDI)
- Documentation: Thorough documentation of the project databases, the evaluation process, and the technical bases for the final integrated distributions


Evaluation of Data, Models, and Methods
As Yet Unseen Evidence (but Physically Plausible)
Indirect Evidence
Direct Evidence from Existing Information
(Numerical Models or Other Simulations)
SSHAC Process
Integration: Model Building By the TI Teams
Limit of Defensible Interpretations
Upper Bound
Alternative Interpretations
Higher Values
Preferred Interpretations
Best Estimate
Alternative Interpretations
Lower Values
Limit of Defensible Interpretations
Lower Bound
Center
Body
Range

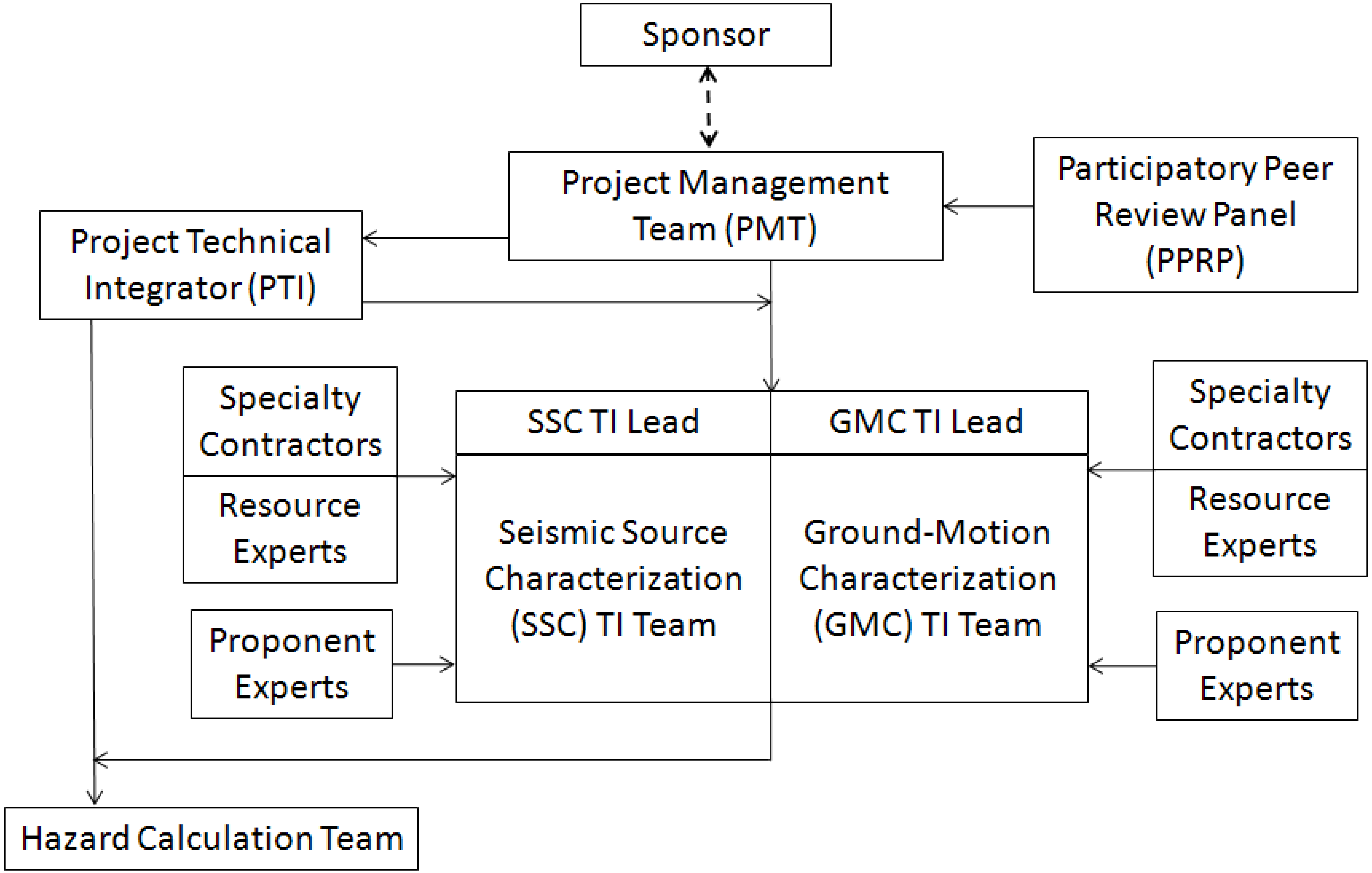
NUREG-2213

Roles in a SSHAC Level 3 Process

TI Team

EVALUATOR EXPERT (TI Team)	Impartial and objective assessor of potentially applicable data, models, and methods
INTEGRATOR (TI Team)	Builds models that capture the CBR of the TDI
RESOURCE EXPERT	Has particular knowledge of a relevant data set, method or models
PROPONENT EXPERT	Advocates a particular hypothesis or technical position; will often promote a model that they have developed
SPECIALTY CONTRACTOR	Retrieves new data or undertakes new analyses to inform evaluators
PARTICIPATORY REVIEWER	Provides procedural and technical review; ensures capture of full range of views and robust technical justifications of logic-tree

SSHAC Level 3 Project Structure



NUREG-2117

Ikata NPP Japan SSHAC Project

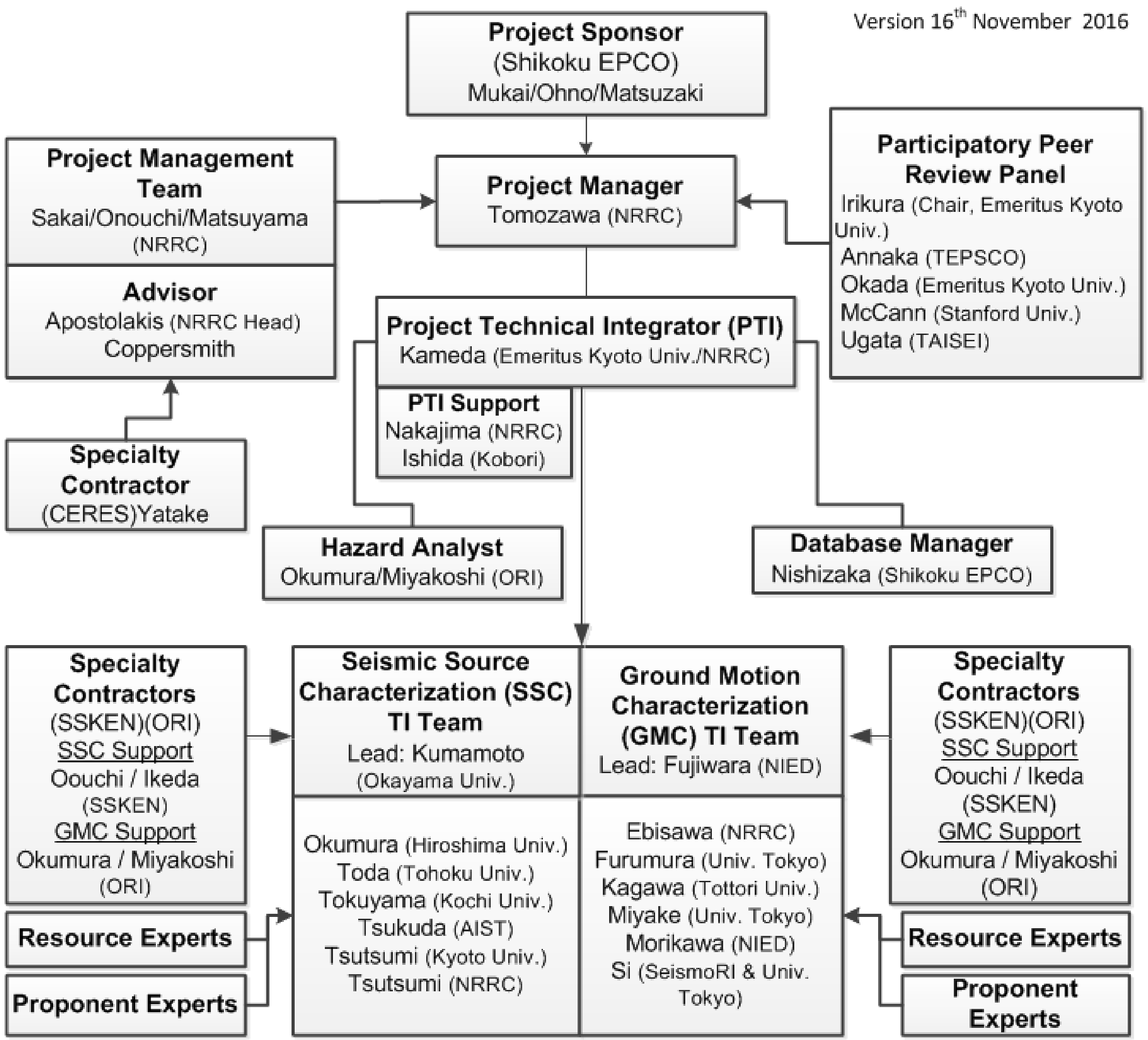


Table 4-1. Summary of Essential Steps in SSHAC Level 3 and 4 Studies

Essential Step	Discussion
1. Select SSHAC Level	• Document decision criteria and process
2. Develop Project Plan	• Includes project organization and all technical and process activities
3. Select project participants	• Includes all management, technical, and peer review participants
4. Develop project database	• Includes compilation of existing, available data • Can include focused new data collection • Data dissemination to all evaluator experts (Level 4) or TI Team members (Level 3)
5. Hold workshops (minimum of three)	Workshop topics: • Hazard-significant issues and available data • Alternative interpretations • Feedback
6. Develop preliminary model(s) and Hazard Input Document (HID)	• Preliminary models developed prior to Feedback workshop • HID provides input to hazard calculations

Table 4-1. Summary of Essential Steps in SSHAC Level 3 and 4 Studies

7. Perform preliminary hazard calculations and sensitivity analyses	• Intermediate calculations should display the impact of elements of the expert models • Hazard calculations should show the significance of all elements of the models • Sensitivity analyses should include the contributions to uncertainties
8. Finalize models in light of feedback	• Feedback provides a basis for prioritizing and focusing the finalization process • Implement expert combination process across all evaluator experts in SSHAC Level 4
9. Perform final hazard calculations and sensitivity analyses	• Should be conducted to develop the required deliverables for subsequent use of the hazard results
10. Develop draft and final project report	• Fundamental documentation of SSHAC process, technical bases, and results
11. Participatory peer review of entire process	• Periodic written reviews of key products and activities • Review of draft report • Final written review of technical evaluations and process used

NTTF Recommendations

Recommendation 2

The Task Force recommends that the NRC require licensees to reevaluate and upgrade as necessary the design-basis seismic and flooding protection of SSCs for each operating reactor.

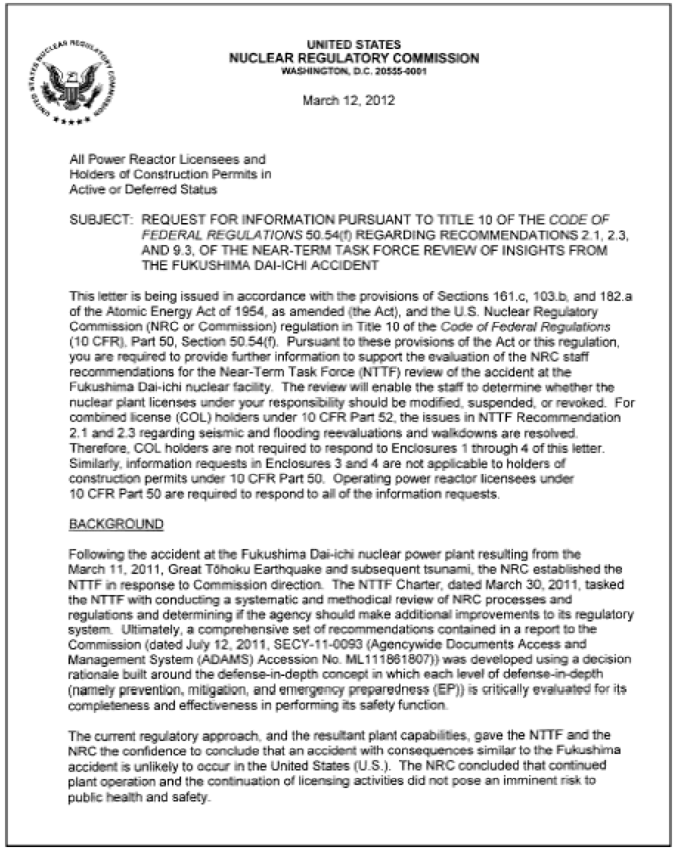
The Task Force recommends that the Commission direct the following actions to ensure adequate protection from natural phenomena, consistent with the current state of knowledge and analytical methods. These should be undertaken to prevent fuel damage and to ensure containment and spent fuel pool integrity:

2.1 *Order licensees to reevaluate the seismic and flooding hazards at their sites against current NRC requirements and guidance, and if necessary, update the design basis and SSCs important to safety to protect against the updated hazards.*

2.2 *Initiate rulemaking to require licensees to confirm seismic hazards and flooding hazards every 10 years and address any new and significant information. If necessary, update the design basis for SSCs important to safety to protect against the updated hazards.*

2.3 *Order licensees to perform seismic and flood protection walkdowns to identify and address plant-specific vulnerabilities and verify the adequacy of monitoring and maintenance for protection features such as watertight barriers and seals in the interim period until longer term actions are completed to update the design basis for external events.*

NRC 50.54(f) activities to address NTTF Seismic Recommendations



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

March 12, 2012

All Power Reactor Licensees and
Holders of Construction Permits in
Active or Deferred Status

SUBJECT: REQUEST FOR INFORMATION PURSUANT TO TITLE 10 OF THE *CODE OF FEDERAL REGULATIONS* 50.54(f) REGARDING RECOMMENDATIONS 2.1, 2.3, AND 9.3, OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT

This letter is being issued in accordance with the provisions of Sections 161.c, 103.b, and 182.a of the Atomic Energy Act of 1954, as amended (the Act), and the U.S. Nuclear Regulatory Commission (NRC or Commission) regulation in Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Section 50.54(f). Pursuant to these provisions of the Act or this regulation, you are required to provide further information to support the evaluation of the NRC staff recommendations for the Near-Term Task Force (NTTF) review of the accident at the Fukushima Dai-ichi nuclear facility. The review will enable the staff to determine whether the nuclear plant licenses under your responsibility should be modified, suspended, or revoked. For combined license (COL) holders under 10 CFR Part 52, the issues in NTTF Recommendation 2.1 and 2.3 regarding seismic and flooding reevaluations and walkdowns are resolved. Therefore, COL holders are not required to respond to Enclosures 1 through 4 of this letter. Similarly, information requests in Enclosures 3 and 4 are not applicable to holders of construction permits under 10 CFR Part 50. Operating power reactor licensees under 10 CFR Part 50 are required to respond to all of the information requests.

BACKGROUND

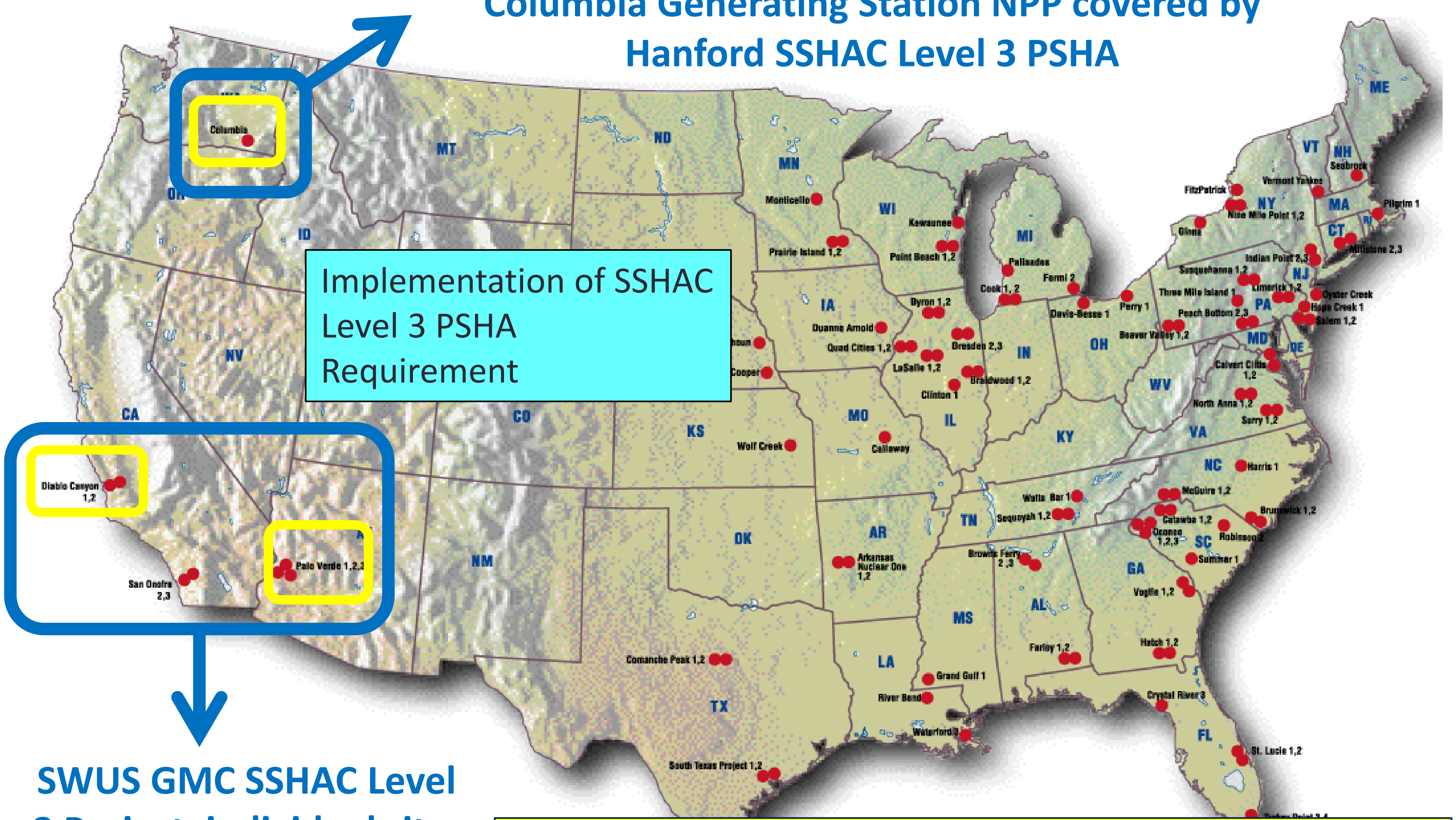
Following the accident at the Fukushima Dai-ichi nuclear power plant resulting from the March 11, 2011, Great Tōhoku Earthquake and subsequent tsunami, the NRC established the NTTF in response to Commission direction. The NTTF Charter, dated March 30, 2011, tasked the NTTF with conducting a systematic and methodical review of NRC processes and regulations and determining if the agency should make additional improvements to its regulatory system. Ultimately, a comprehensive set of recommendations contained in a report to the Commission (dated July 12, 2011, SECY-11-0093 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML111861807)) was developed using a decision rationale built around the defense-in-depth concept in which each level of defense-in-depth (namely prevention, mitigation, and emergency preparedness (EP)) is critically evaluated for its completeness and effectiveness in performing its safety function.

The current regulatory approach, and the resultant plant capabilities, gave the NTTF and the NRC the confidence to conclude that an accident with consequences similar to the Fukushima accident is unlikely to occur in the United States (U.S.). The NRC concluded that continued plant operation and the continuation of licensing activities did not pose an imminent risk to public health and safety.

50.54(f) Request for Information Letter issued March 12, 2012

- Enclosure 1 (or R2.1): Seismic hazard and risk reevaluation
- Enclosure 3 (or R2.3): Seismic Walkdowns
- Other enclosures addressed flooding and emergency response

Columbia Generating Station NPP covered by Hanford SSHAC Level 3 PSHA



SWUS GMC SSHAC Level 3 Project, individual site-specific SSC projects

The CEUS SSC model and EPRI 2013, from regional SSHAC Level 3 studies, used for PSHA at plants east of the Rockies

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RECENTLY COMPLETED OR ONGOING SSHAC LEVEL 3 HAZARD STUDIES			
Study	**Completion Year**	**Significance**	**Reference**
BC Hydro PSHA, British Columbia, Canada	2012	Major regional study for BC Hydro service area in British Columbia, Canada. Used for dam safety evaluation. Both SSC and GMC.	BC Hydro (2012)
CEUS-SSC	2012	Regional SSC study for central and eastern United States nuclear facilities; co-sponsored by NRC, DOE, and utilities	NUREG-2115
Thyspunt, South Africa PSHA	2013	Site-specific PSHA for a proposed nuclear power plant. Includes SSC, GMC, and SRA.	Bommer et al. (2015)
Hanford PSHA	2014	Site-specific study for existing nuclear facilities. Includes SSC, GMC, integration with SRA.	PNNL (2014)
Diablo Canyon SSC	2015	Site-specific SSC study. Used for existing nuclear facility.	PG&E (2015)
Palo Verde SSC	2015	Site-specific SSC study. Used for existing nuclear facility.	APS (2015)
SWUS-GMC	2015	Regional GMC study. Includes regionally specific ground motion models and adjustments for Diablo Canyon and Palo Verde plant sites.	GeoPentech (2015)
NGA-East GMC	2018	Major phased regional GMC study.	Goulet et al. (2018)
Ikata PSHA, Japan	2020	Site-specific including SSC and GMC. To be used for risk analysis of existing nuclear facility.	(In progress)
Taiwan	2021	Site-specific PSHA for four NPP sites. Includes SSC and GMC; integration with SRA.	(In progress)
Wanapum Dam, WA	2020	Seismic fragility evaluation of embankment dam for risk analysis	(in progress)
Spain PSHA for NPP Sites	2020	Integrated regional study for SSC, GMC and SRA. For multiple nuclear facilities.	(In progress)
INL Site-wide PSHA	2022	Site-specific study for existing and proposed nuclear facilities. Includes SSC, GMC, integration with SRA.	(In progress)

SRA: site response analysis

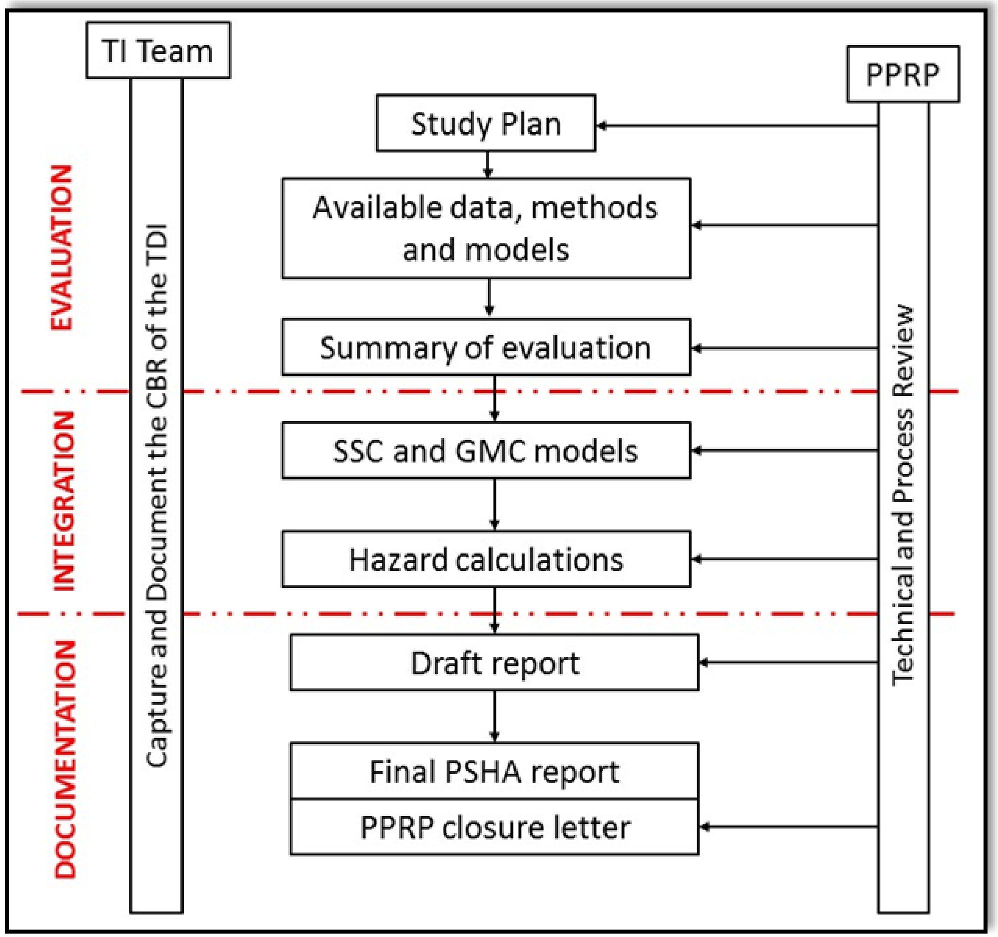
The five essential attributes of a SSHAC study (NUREG-2213)

Fundamentally, there are five essential features required for any study to be considered a SSHAC study:

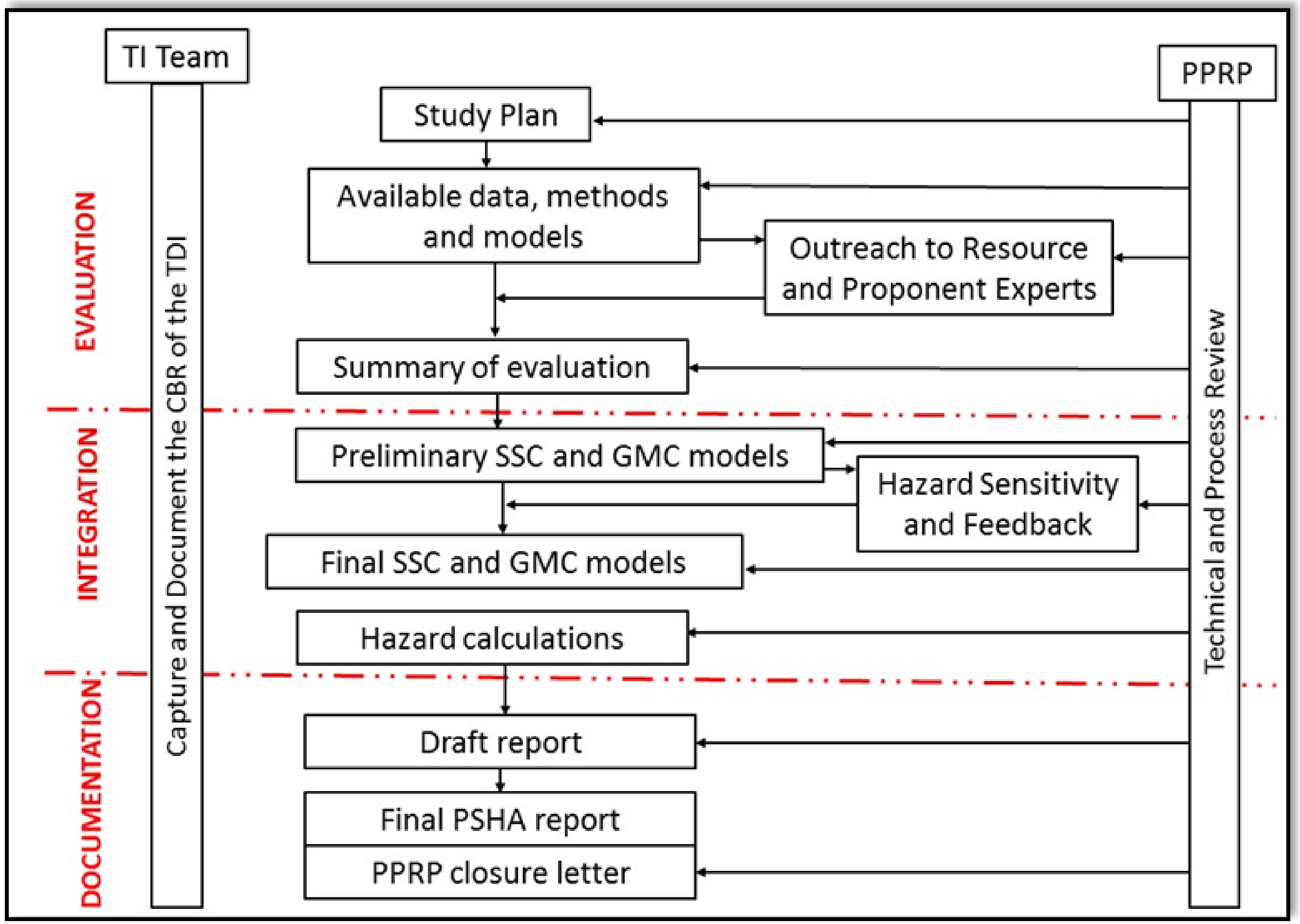
- **Clearly defined roles for all participants**, including the responsibilities and attributes associated with each role (Section 2.6).
- **Objective evaluation of all available data, models, and methods** that could be relevant to the characterization of the hazard at the site (Section 2.3). This will often include additional new data collected specifically for the hazard analysis. This process includes identifying the limits of the existing data, gaps in the existing data, and the resolution and uncertainties in the available data.
- **Integration of the outcome of the evaluation process into models** that reflect both the best estimate of each element of the hazard input with the current state of knowledge and the associated uncertainty (Section 2.3). This distribution is referred to as the center, body, and range of technically defensible interpretations (CBR of TDI) (Section 2.2). This will generally involve the construction of hazard input models for seismic source characterization (SSC) and ground motion characterization (GMC) that address both aleatory variability and epistemic uncertainties.
- **Documentation** must provide a complete and transparent record of the evaluation and integration process. Specifically, the documentation must identify all of the data, models, and methods considered in the evaluation, and justify in sufficient detail the technical interpretations that support the hazard input models (Section 2.3). In addition, the documentation must be sufficiently detailed to allow the hazard analyses to be reproduced by an external reviewer.
- **Independent participatory peer review** is required to confirm that the evaluation considered relevant data, models, and methods, and that the evaluation was conducted objectively and without cognitive bias (Section 2.4). The peer review is also required to confirm that the SSC and GMC models captured the center, body, and range of technically defensible interpretations, and that the technical bases for all elements of the models are documented adequately. The participatory peer review panel must provide a closure letter to the Sponsor for the peer review process to be considered complete (Section 2.6.9).

Project Workflow

SSHAC Level 1

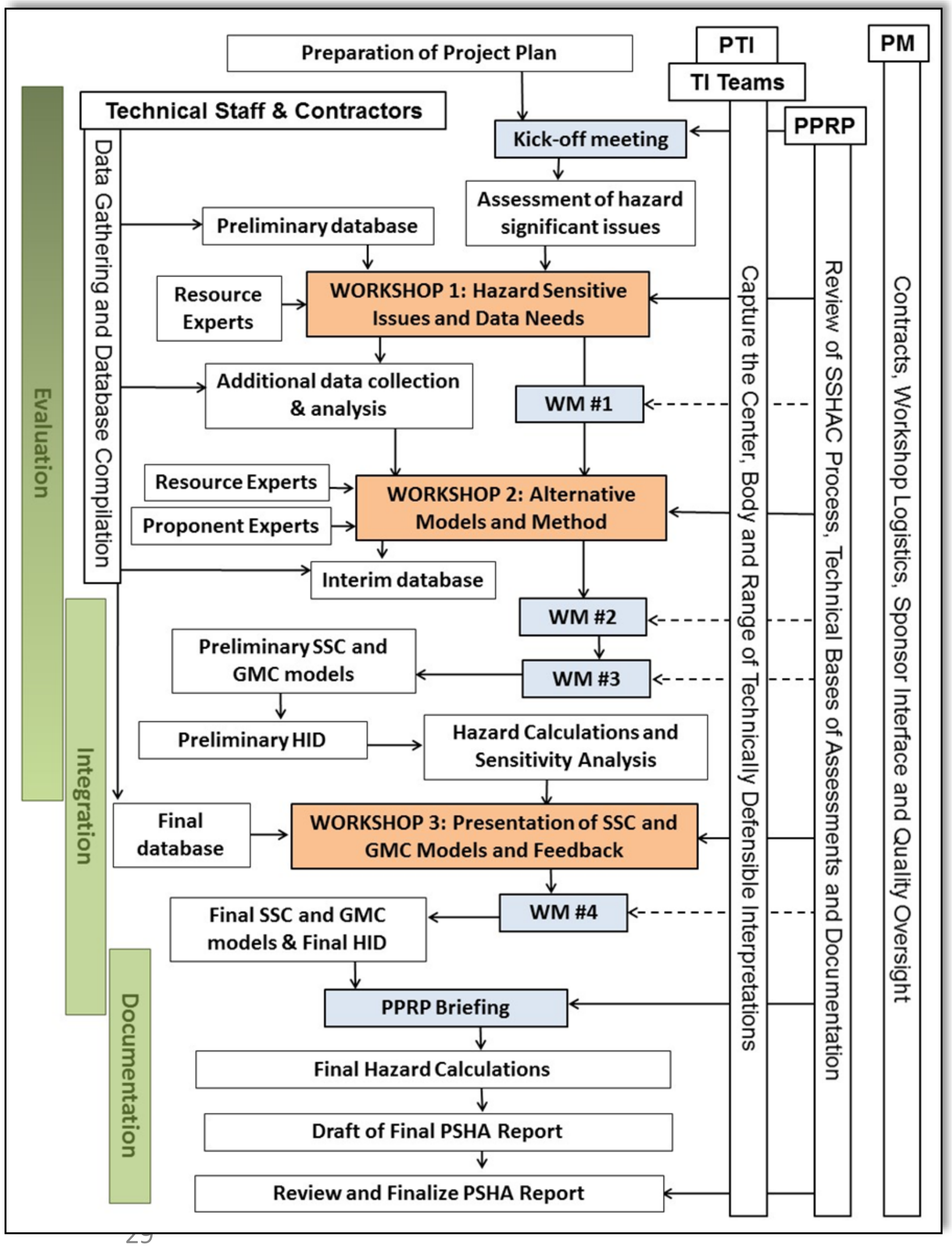


SSHAC Level 2



NUREG-2213

SSHAC Level 3 Project Workflow



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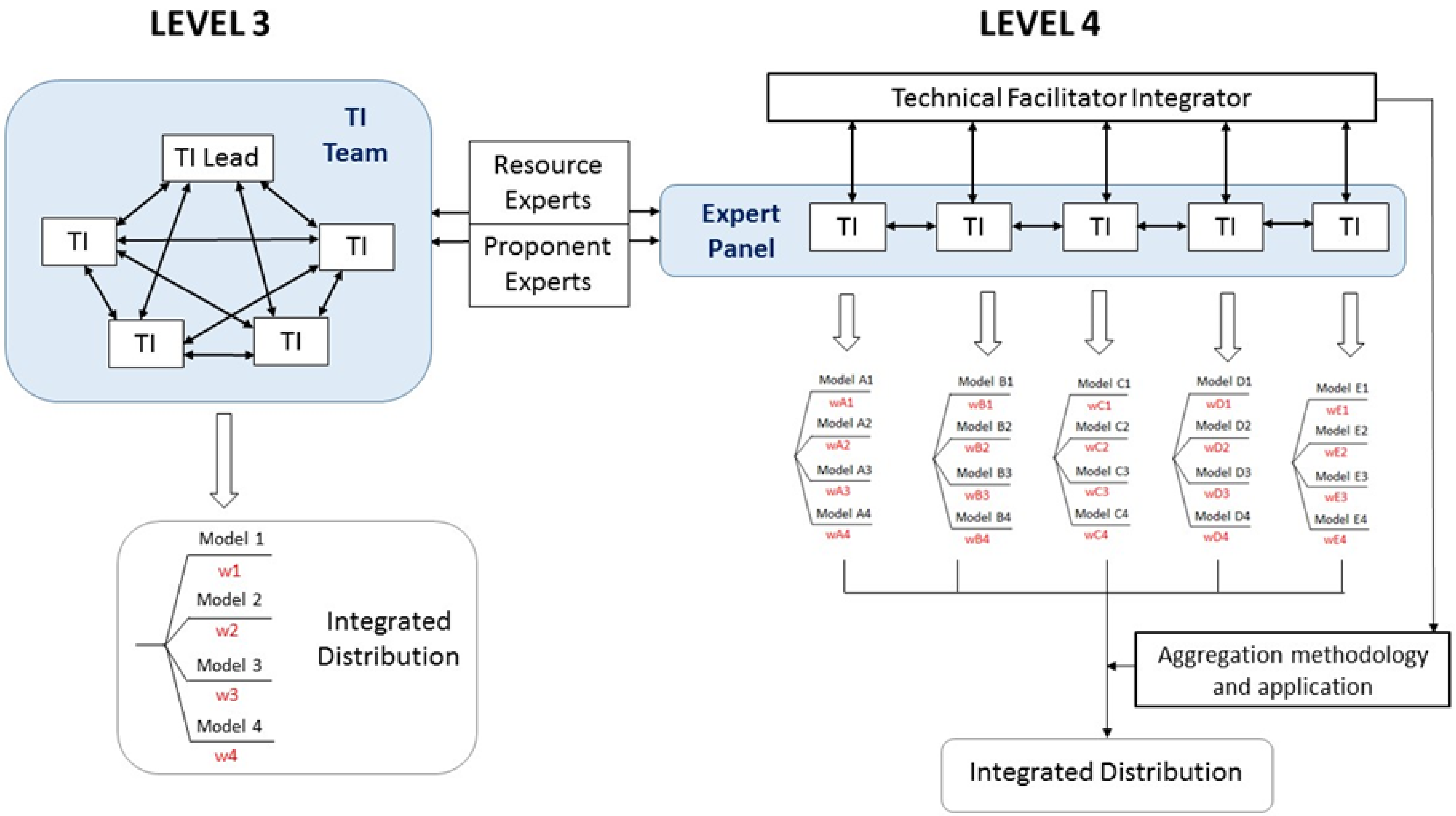

LEVEL 3
LEVEL 4
TI Team
TI Lead
TI
TI
TI
TI
Resource Experts
Proponent Experts
Model 1
w1
Model 2
w2
Model 3
w3
Model 4
w4
Integrated Distribution
Technical Facilitator Integrator
Expert Panel
TI
TI
TI
TI
TI
Model A1
wA1
Model A2
wA2
Model A3
wA3
Model A4
wA4
Model B1
wB1
Model B2
wB2
Model B3
wB3
Model B4
wB4
Model C1
wC1
Model C2
wC2
Model C3
wC3
Model C4
wC4
Model D1
wD1
Model D2
wD2
Model D3
wD3
Model D4
wD4
Model E1
wE1
Model E2
wE2
Model E3
wE3
Model E4
wE4
Aggregation methodology and application
Integrated Distribution

NUREG-2213

Table 3-3 Features of various SSHAC levels

SSHAC Level	Level 1	Level 2	Level 3	Level 4
Number of participants	• Project Manager • Small TI Team (~2) • PPRP (~2) • Hazard Analyst	• Project Manager • Small TI Team (>2) • PPRP (>2) • Resource Experts • Proponent Experts • Database Manager • Hazard Analyst	• Project Manager • Project TI • SSC & GMC TI Teams (greater than 5) members in each) • PPRP (~4-7) • Resource Experts • Proponent Experts • Database Manager • Hazard Analyst	• Project Manager • Project TI • TFI for SSC, GMC • SSC & GMC 5-10 Experts in each or 4-6 small expert teams • PPRP(4-7) • Resource Experts • Proponent Experts • Database Manager • Hazard Analyst
Interaction	• Limited, if any, contact with Proponent and Resource experts	• Proponent and resource experts contacted individually	• Proponent and resource Experts interact with TI Team in facilitated workshops • PPRP interacts with TI Team at WS3	• Proponent and Resource Experts interact with evaluator experts in facilitated workshops • PPRP interacts with Experts at WS3
Peer review	• Participatory	• Participatory	• Participatory	• Participatory
Ownership	• TI Team	• TI Lead • TI Team	• PTI • TI Lead • TI Team	• PTI • TFI • Experts
Transparency	• Dependent on documentation	• Dependent on documentation	• Interested parties can view interactions at workshops • Participatory peer reviewers observe workshops, participate in Workshop #3 • Documentation	• Interested parties can view interactions at workshops • Participatory peer reviewers observe workshops, participate in Workshop #3 • Documentation
Regulatory assurance	• Limited or no interaction with proponent and resource experts reduces confidence • Depends on TI Team and PPRP adherence to SSHAC guidelines and quality and completeness of documentation.	• Documented. Individual interaction with proponent and resource experts increases confidence over Level 1 • Depends on TI Team and PPRP adherence to SSHAC guidelines and quality and completeness of documentation	• Interaction among proponent, resource, and evaluator experts in facilitated workshops greatly increases confidence over Level 2 • Multiple feedbacks from PPRP enhances probability that SSHAC process is compliant with SSHAC guidelines • Documentation of evaluation and integration process by TI Team key to high levels of confidence	• Interaction among proponent, resource, and evaluator experts in facilitated workshops greatly increases confidence over Level 2 • Multiple feedbacks from PPRP enhances probability that SSHAC process is compliant with SSHAC guidelines • Documentation of evaluation and integration process by TI Team key to high levels of confidence

"As noted in NUREG–2117, the NRC makes no distinction between SSHAC Level 3 and 4 studies in terms of the regulatory assurance afforded by either level. As a result, in order to achieve the high levels of regulatory assurance needed for nuclear facilities (see Section 2.5) and to avoid some of the additional burdens associated with Level 4 studies (see Section 3.1), SSHAC Level 3 has gained considerable favor as the approach to conducting PSHA for nuclear facilities in the U.S. and in several other countries. Nevertheless, there may be situations in which a SSHAC Level 4 study is the most appropriate method to address the unique requirements or circumstances of a project."

-NUREG-2213

NUREG-2213

Table 3-3 Features of various SSHAC levels (Continued)

SSHAC Level	Level 1	Level 2	Level 3	Level 4
Cost	• Lowest because of limited number of participants	• Somewhat greater than Level 1 because of time required for interaction with proponent and resource experts	• Significantly greater than Level 2 because of larger number of participants and use of facilitated workshops • Greater likelihood that TI Team members are physically dispersed, leading to travel costs and costs for systems to remotely access data and information • Labor and travel costs associated with multiple TI Team working meetings	• Comparable to Level 3 in terms of use of facilitated workshops, numbers of participants, systems to remotely access data and information • Somewhat greater costs than Level 3 for working meetings because of need for TFI to interact individually with each expert or expert team
Duration	• Shortest because of limited or no interaction with proponent and resource experts	• Slightly greater than Level 1 because of time required for interaction with proponent and resource experts	• Significantly greater than Level 2 because of workshops, working meetings, briefings, multiple rounds of hazard calculations, and difficulties in synchronizing schedules with all participants	• Similar to Level 3 or longer because of workshops, working meetings, briefings, multiple rounds of hazard calculations, and difficulties in synchronizing schedules with all participants
Management challenge	• Least because of fewer participants and activities,	• Somewhat greater than Level 1 because of larger TI Team and the need to interact individually with proponent and resource experts whose schedules cannot be controlled	• Significantly greater than Level 2 because of increased number of participants and the need to issue contracts for each, logistics of organizing workshops and working meetings, and maintaining schedules over the duration of the project	• Comparable to Level 3 in terms of number of participants and the need to issue contracts for each, logistics of organizing workshops, and maintaining schedules over the duration of the project • Somewhat higher challenge due to the need to hold and schedule separate working meetings with each expert or expert team

SHAC-F Levels – Riverine Flood Hazard Assessment

Riverine Floods	SHAC-F Level 1	SHAC-F Level 2	SHAC-F Level 3
Potential purpose	Screening (e.g., binning flood hazards in high or low risk categories) Significance Determination	Replace screening analysis or update/refine existing Level 3 Significance Determination	Support design PRA for licensing new and built plants
Expected Outcome	Family of Discharge/Elevation Hazard Curves relevant to the system you are analyzing (need to revisit)	Family of Hazard Curves plus associated effects	Family of Hazard Curves plus associated effects
Data	• Stage/Discharge Data • (systematic at site data including historic information) • Regional and Paleo data if available • (flood frequency) • Use what you have	• Discharge Data • Regional Data • Historic and Paleo data • (flood frequency) • Use what you have • More extensive effort to find and assemble existing data • Contact resource experts for simulation model data	• Discharge Data • Regional Data • Historic and Paleo data • (flood frequency) • Use what you have • More extensive effort to find and assemble existing data • Contact resource experts for simulation model data
Models	• Screening flood frequency model • Conceptual Model • ACM – L1 • Statistical Models • Process understanding influencing data • Single population • Regionalization • Nonstationarity	• ACM – L2 • Consider spatial variation • Simulation models	• Conceptual Model • ACM – L3 • Statistical plus simulation • Spatiotemporal resolution of model predictions to support PRA • Locations of SSCs
Principal Sources of aleatory variability	Streamflow	Streamflow (possibly precipitation, basin initial conditions)	Streamflow, precipitation, basin initial conditions,
Principal sources of epistemic uncertainty	Measurement uncertainty in discharge data, alternative statistical models, parameter uncertainty	Measurement uncertainty in discharge data, alternative statistical models, parameter uncertainty in simulation model parameters	Measurement uncertainty in discharge data, alternative statistical models, parameter uncertainty in simulation model parameters

SHAC-F Levels – Riverine Flood Hazard Assessment (cont'd.)

Riverine Floods	SHAC-F Level 1	SHAC-F Level 2	SHAC-F Level 3
TI Team Makeup	Small TI Team (e.g., two-one in flood frequency modeling, one in regional hydrologic modeling)	Small TI Team; possibly multiple teams (e.g., probabilistic modeler, precipitation frequency analyst, and runoff/hydraulic modeler)	Larger TI Team members (alternative models may require additional TI team members, e.g., probabilistic modeler, precipitation frequency analyst, and runoff/hydraulic modeler)
PPRP	Small PPRP Team (e.g., two-one for flood frequency modeling review and one for regional hydrologic modeling review)	Two or more reviewers (e.g., one/more for flood frequency, one/more for simulation modeling, one/more for regional hydrologic modeling); Feedback on preliminary models; Communication with PPRP during evaluation and integration	Larger team of reviewers (e.g, precipitation and runoff experts, experts in use of potential runoff/hydraulic models, PRA expert); Feedback on preliminary models; Engagement during evaluation and integration process; PPRP briefing of final model

Standards and Regulatory Guidance for Seismic Design of Nuclear Facilities

DOE

Variety of nuclear facilities

- **DOE Order (O) 420.1C,** *Facility Safety*
- **DOE-STD-1020:** *NPH Analysis and Design Criteria*
- **ANSI/ANS-2.26**, *Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design.*
- **ANSI/ANS-2.27**, *Criteria for Investigation of Nuclear Facility Sites for Seismic Hazard Assessment*
- **ANSI/ANS-2.29**, *Probabilistic Seismic Hazards Analysis*

NRC

Nuclear power plants

- **10 CFR 100.23** *Geologic and Seismic Siting Criteria*
- **10 CFR Part 50**, App. S, *Design Bases for Protection Against Natural Phenomena*
- **RG 1.208** *A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion*
- **NUREG/CR-6728:** *Risk Consistent Design Spectra*
- **NUREG/CR-6372**: *PSHA: Guidance on Uncertainty and Use of Experts*
- **NUREG-2213:** *Updated Implementation Guidelines for SSHAC Hazard Studies*

ASCE/SEI Standard-43-19

Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities

DOE-STD-1020-2016

DOE Natural Phenomena Hazard (NPH) Requirements

NOT MEASUREMENT SENSITIVE

DOE-STD-1020-2016
December 2016
Superseding
DOE-STD-1020-2012

DOE STANDARD
Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities

U.S. Department of Energy
Washington, D.C. 20585

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Section 2.3
NPH Design Category

Table 2-1: Design Categories in NPH Event

Category	Unmitigated Consequence Thresholds[1]	
	Co-located Worker[2]	Public
NDC-1	< 5 rem TED Or ≥ PAC-1[3]	Not applicable[4]
NDC-2	5 - 100 rem TED Or ≥ PAC-2	5 - 25 rem TED Or ≥ PAC-1
NDC-3	> 100 rem TED Or > PAC-3	> 25 rem TED Or > PAC-2

- Design categories determined from safety 'hazard evaluation' analysis per DOE-STD-3009-2014.
- Methodology determines unmitigated consequences of SSC failure for radiological and chemical releases to co-located workers & public

Risk-Informed Approach to Flood Hazard Design Criteria

- Endorses development of PFHA and use of SSHAC approach

Table 5-1: Flood-Related Hazards

Flood-Related Hazards	Cause
River Flooding	Precipitation, rapid sedimentation, volcano, rapid snow melt, ice jams
Dam, Levee or Dike Failure	Earthquake, flood, static failure, upstream dam failure, landslide, volcano
Storm Surge	Hurricane
Tsunami	Earthquake
Seiche	Earthquake, wind
Wave	Tsunami, wind
Landslide	Earthquake, precipitation, volcano
Volcano-Created Flood	Volcano
Stormwater Runoff	Precipitation, ponding, inadequate drainage capacity
Change in Ground Water Level	Precipitation, ponding, flooding, drought and over pumping
Mudflow	Volcano, earthquake, precipitation
Water-Borne Debris	Damage to upstream objects or landscape that produce debris
Subsidence-Induced Flooding	Supercritical Fluid Extraction

Table 5-2: Return Period (Years) for Safety SSCs Exposed to Submersion

SSC Category	FDC-1	FDC-2	FDC-3	FDC-4	FDC-5
Return Period	500	2,000	10,000	25,000	*

Table 5-3: Return Period (Years) for Safety SSCs Not Exposed to Submersion

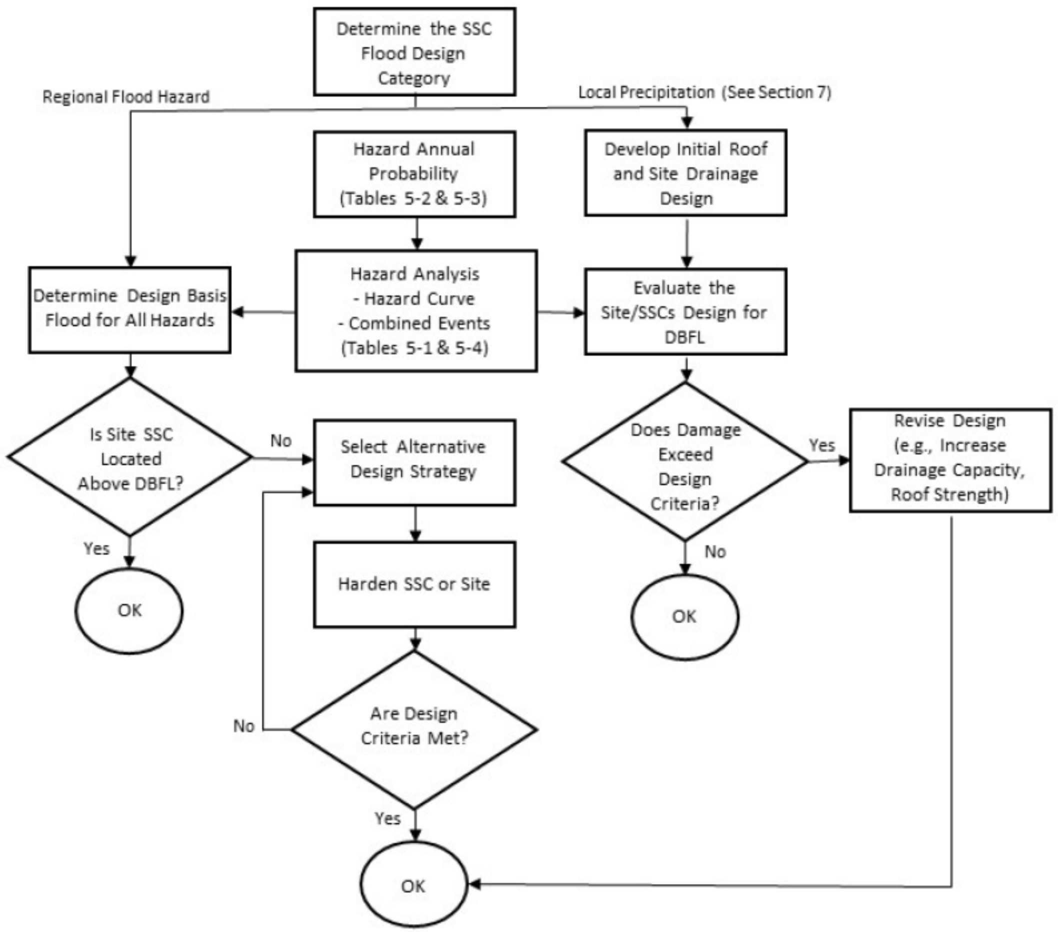
SSC Category	FDC-1	FDC-2	FDC-3	FDC-4	FDC-5
Return Period	100	200	2,500	6,250	*

Design Requirements DOE-STD-1020-2016

Table 5-4: Design Basis Flood Event Combinations

Primary Hazard	Case No.	Event Combinations*
Stream, Extreme Local Precipitation, and River Flooding	1	Peak flood elevation due to all flooding contributors with the exception of upstream dam failure. The hazard analysis for river flooding should include all contributors to flooding, including releases from upstream dams, and ice jams. Flooding associated with upstream dam failure is included in the dam failure category.
	2	Wind-waves corresponding, as a minimum, to the 2-year wind acting in the most favorable direction coincident with the peak flood (i.e., Case 1, above) or as determined in a probabilistic analysis that considers the joint occurrence of river flooding and wind-generated waves.
	3	Ice or debris forces (i.e., static and dynamic) and Case 1.
	4	Peak and ground water level and Case 1. Evaluate the potential for erosion and debris due to the primary hazard.
Dam, Levee, or Dike Failure	1	Peak flood elevation due to all modes of levee or dam failure: overtopping, structural failure, upstream dam failure, failure due to ice or debris forces.
	2	Wind-waves corresponding, as a minimum, to the 2-year wind acting in the most favorable direction coincident with the peak flood (i.e., Case 1, above) or as determined in a probabilistic analysis that considers the joint occurrence of river flooding and wind-generated waves.
	3	Evaluate the potential for erosion and debris due to the primary hazard. Should be evaluated as part of the hazard analysis if overtopping and/or failure occur.
	4	Peak and ground water level and Case 1. Evaluate the potential for erosion and, debris due to the primary hazard.

Figure 5-1: Flood Evaluation Process



DOE Handbook 1220-2017

DOE-STD-1020 commentary/guidance/good practices

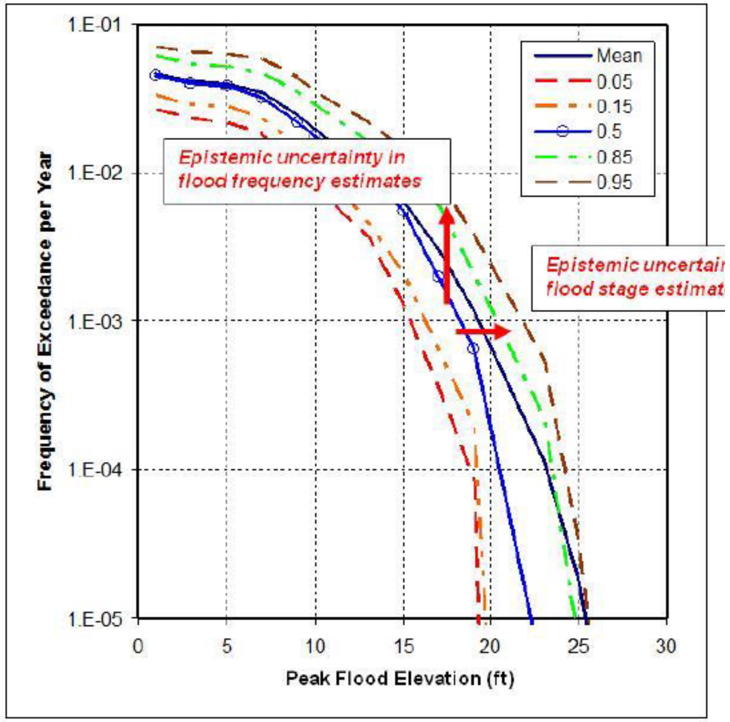


Figure B-1. Flood Hazard Results for a Riverine Flood Site

NOT MEASUREMENT SENSITIVE

DOE-HDBK-1220-2017

DOE HANDBOOK

NATURAL PHENOMENA HAZARDS ANALYSIS AND DESIGN HANDBOOK FOR DOE FACILITIES

U.S. Department of Energy
Washington, D.C. 20585

B.2 Probabilistic Framework

B.2.1 Overview

Floods are temporally- and spatially-variant stochastic events whose occurrence and magnitude (amount of precipitation or peak discharge) are defined in terms of their frequency, return period, or probability of occurrence. As with other NPH phenomena, the ability to accurately estimate the frequency or probability of future occurrences is subject to uncertainties in the historic record, data limitations, an incomplete understanding of the physical phenomena, and modeling uncertainties (For further information, see NUREG/CP-0302, 72017, *Proceedings of the Workshop on Probabilistic Flood Hazard Assessment* (PFHA). In spite of these challenges, technical developments in the past 20-30 years have established a reasonable framework for performing probabilistic assessments of extreme natural phenomena events. Such assessments can be used to support regulatory decision-making and to determine design basis loads (For further information, NUREG-2117, 2011, *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*). Once design basis loads are established, engineered controls can be effectively designed and constructed, and administrative controls can be implemented to provide additional safeguards.

The probabilistic framework for developing PFHAs built on the following components:

- A probabilistic uncertainty model that describes the stochastic nature of random flood events and hazards, termed an "aleatory uncertainty model";
- A probabilistic uncertainty model that accounts for parametric knowledge-based uncertainties on the frequency and magnitude of flood events and hazards, termed "epistemic uncertainty model";
- Utilization of all current, relevant and applicable information on both recent floods and floods evidenced in the geologic record (e.g., paleofloods);
- Use of computational modeling capabilities; and
- Explicit modeling of epistemic uncertainties.

The last of the listed factors includes the formal, structured elicitation of expert interpretations, evaluation and integration of sources of uncertainty, and participatory peer review that validates the

ANS-2.8 Standard

Probabilistic Evaluation of External Flood Hazard for Nuclear Facilities

Objective

- Develop ANSI/ANS voluntary consensus standard for determining a full range of external flood hazards
- Serve as a reference for siting nuclear facilities, SSC design, and evaluation of flood protection features
  - Deterministic methods screening process
  - Deterministic methods focus on bounding flood hazards (when possible and desirable)
  - Probabilistic risk informed methods for treating frequency-based hazard requirements and understanding hazard uncertainties
- Identify "best practices" and technologies for performing the above assessments using new flood data and technical knowledge gained over past 20 years

Scope

- Riverine flooding
  - Rainfall, snowmelt
  - Controlled and uncontrolled releases from upstream dams
- Upstream dam failure
  - Hydrologic
  - Non-hydrologic (seismic, intrinsic, other)
- Hurricane-induced storm surge
- Wind- and earthquake-generated seiche
- Tsunami
  - Seismically-initiated
  - Landslide-initiated

Probabilistic Approach - example

- Riverine Flood
  - √ Riverine Probabilistic Flood Hazard Analysis (PFHA)
  - √ Probabilistic Aleatory Modeling
  - √ Probabilistic Epistemic Uncertainty Modeling

Projects at Ballot or Resolving Ballot Comments

Projects at ballot have completed drafts that have been issued for subcommittee or consensus committee ballot/concurrent public review. Before proceeding, all comments must be considered. Multiple ballots may be needed before a draft is approved. The following draft standards are in the process of approval/comment resolution:

ANS-2.8-201x, "Probabilistic Evaluation of External Flood Hazards for Nuclear Facilities" [new standard/supersedes ANS-2.8-1992 (W2002)]

Calls for structured approach to addressing uncertainties in PFHA

Conclusions

- Original SSHAC was a response to the need for procedural guidance to be used by NRC, nuclear utilities, and DOE
- SSHAC process is a formal, structured approach to identifying, incorporating, and documenting knowledge and uncertainties in hazard analyses
- Based on implementation experience in US and worldwide, SSHAC process is now well-defined in standards and guidance documents
- SSHAC process can be scaled to three SSHAC Levels, depending on the application
- Research into the application of the process to PFHA for nuclear facilities is appropriate and supported in standards and regulatory guidance