AN APPLICATION OF THE SSHAC LEVEL 3 PROCESS TO THE PROBABILISTIC SEISMIC HAZARD ANALYSIS FOR NUCLEAR FACILITIES AT THE HANFORD SITE, EASTERN WASHINGTON, USA

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U.S. Department of Energy
Natural Phenomena Hazards Meeting
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Germantown, MD

Overview and Purpose

- To summarize the **process** followed in the nearly-complete SSHAC Level 3 PSHA for the Hanford site
  - Focus on process and lessons learned, not on Hanford-specific technical issues
  - Lessons learned may benefit other sites
- To highlight management and technical approaches that enhance a SSHAC Level 3 study and lead to successful completion and acceptance
- To note innovations and enhancements that could find general application elsewhere

Implementation of Hanford PSHA: Innovations and Lessons Learned

- PSHA updating decision process
- Multi-sponsorship: common goals but different drivers
- Project Plan: value throughout project
- QA: SSHAC Level 3 procedure
- Kick off meeting including field trip
- Focused new data collection program
- PPRP roles at workshops, working meetings, briefing
- Reference data base and report documentation handled through project website
- Diversity of technical community views expressed at workshops
- SSC and GMC models adapted to Hanford-specific conditions
  - Source types, fault characteristics, seismicity, reference baserock, subsequent usage at multiple facility sites
- Hazard calculations

SSHAC Guidelines and Guidance

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

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

ANSI/ANS-2.29-2008

American Nuclear Society

probabilistic seismic hazards analysis

an American National Standard

published by the
American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60526 USA

NUREG-2117 SSHAC Implementation Guidelines

Hanford Decision to Update PSHA

- Decision process: “10 year” update for DOE Order 420.1(b) then (c)
- Evaluation of new data, models, and methods and their hazard significance
- Use of criteria in ANS 2.29 regarding need for update, which are consistent with DOE-STD-1020-2012 and NUREG-2117
- Culmination in “Hanford Seismic Summit” with all affected groups: DOE-RL, DOE-ORP, facility managers and contractors, DNFSB, USGS, PNNL
- Subsequent partnership with Energy Northwest motivated by NRC post-Fukushima directives

DOE and NRC Criteria for Evaluating the Need for an Update to an Existing PSHA

- DOE-STD-1020-2012 *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*
- NUREG-2117 *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*

DOE-STD-1020-2012 *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*

- **9.2. Periodic Review and Update of NPH Assessments**
- 9.2.1 At a frequency not to exceed ten years, the following aspects of NPH assessments shall be reviewed for changes that would warrant updating the assessments:
  - NPH data and data collection methods;
  - NPH modeling techniques, either generic or specific to the region of interest; and
  - NPH assessment methods.
- 9.2.2 Consistent with DOE 420.1C, a preliminary estimate of whether changes to data, models, or methods are "significant" and warrant updating the assessments should be performed and consider the following criteria:
  - Are the changes to data, models, or methods likely to cause a change in the estimates of the major inputs to hazard calculations?
  - Given potential changes to the hazard inputs, by what magnitude might the calculated hazard results change, and how might the results impact current site design standards?
- 9.2.3 The preliminary estimate of how hazard results might change from new inputs will likely be imprecise. An expected significant increase in the hazard results would clearly favor completion of a new assessment. However, even if hazard results are not expected to change significantly, large changes to the input parameters may warrant a new assessment to ensure the NPH assessment continues to have a viable technical basis.
- 9.2.4 In the case of seismic hazard assessments, a determination of whether an existing assessment remains adequate for future use should consider the criteria in Section 4.1 of ANSI/ANS-2.29-2008 for the suitability of existing studies. Additional guidance on the bases for updating existing seismic assessments can be obtained from NUREG-2117, *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*.
- 9.2.5 A decision on updating an NPH assessment should consider the intended application of the assessment results.

NUREG-2117 *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*

- Chapter 6 *Updating: Replacing and Refining Probabilistic Hazard Assessments* is devoted to the updating issue
- Key parts of the updating process are:
  - Identification of new data, models, or methods that have become available
  - Evaluation of the impact of those new findings relative to hazard significance <u>and</u> to the center, body, and range of technically defensible interpretations (CBR of the TDI)
  - If needed, designing the scope and SSHAC Level for the update

Existing Study	Condition of Existing Study	Hazard Assessment Needed	Recommendation	SSHAC Level for New Study
No study, or previous studies conducted at lower SSHAC Levels (2 or 1), or non-SSHAC studies	Not adequate for nuclear/critical facilities	Regional and/or site-specific	Conduct new study	3 or 4
Regional or site-specific	Not viable**	Regional and/or site-specific	Replace existing study	3 or 4
Regional or site-specific	Viable	Site-specific	Refine regional study locally consistent with RG 1.208 and ANSI/ANS-2.27 / 2.29 2008	2, 3, or 4
Site-specific (one or more sites), no regional	Viable	Regional	Use site-specific studies to assist development of regional models	3 or 4
Site-specific (one or more sites), no regional	Not Viable	Regional	Conduct new study	3 or 4

**"Viable" is defined as: (1) based on a consideration of data, models, and methods in the larger technical community, and (2) representative of the center, body, and range of technically defensible interpretations.

NUREG-2117

July 15, 2011, Hanford Seismic Summit Meeting, ORP Summary Notes

Attendees: Twenty two people participated in the Seismic Summit from the U.S. Department of Energy (DOE), prime Hanford site contractors, United States Geological Survey (USGS), Energy Northwest, Pacific Northwest National Laboratory (PNNL), DNFSB staff (Mr. Jeff Kimball), and private consultants. Attachment 1 is a list of the attendees.

Location: The DOE Office of River Protection (ORP) office at 2440 Stevens Center Place in Richland, Washington.

Meeting format: The group was welcomed and discussions were facilitated by Paul Harrington, DOE/ORP Assistant Manager for Engineering and Nuclear Safety.

Purpose: Provide a format for discussion and advice between DOE, Hanford prime contractors, and the seismology community on issues significant at Hanford related to ensuring that a technically defensible seismic design basis is maintained for all existing and planned facilities on the Hanford Site that meets the requirements of DOE O 420.1B.

Format of Notes: No attempt is being made to document the detail of the discussion that occurred. These notes are an attempt to summarize the major points of discussion and document topics of general consensus.

USNRC Letter 50.54(f)

Issued one year after the Tohuku earthquake in Japan that led to the nuclear accident at the Fukushima Daiichi, the US Nuclear Regulatory Commission issued a letter requiring a re-assessment of the seismic safety at all existing nuclear plants in the USA

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

March 12, 2012

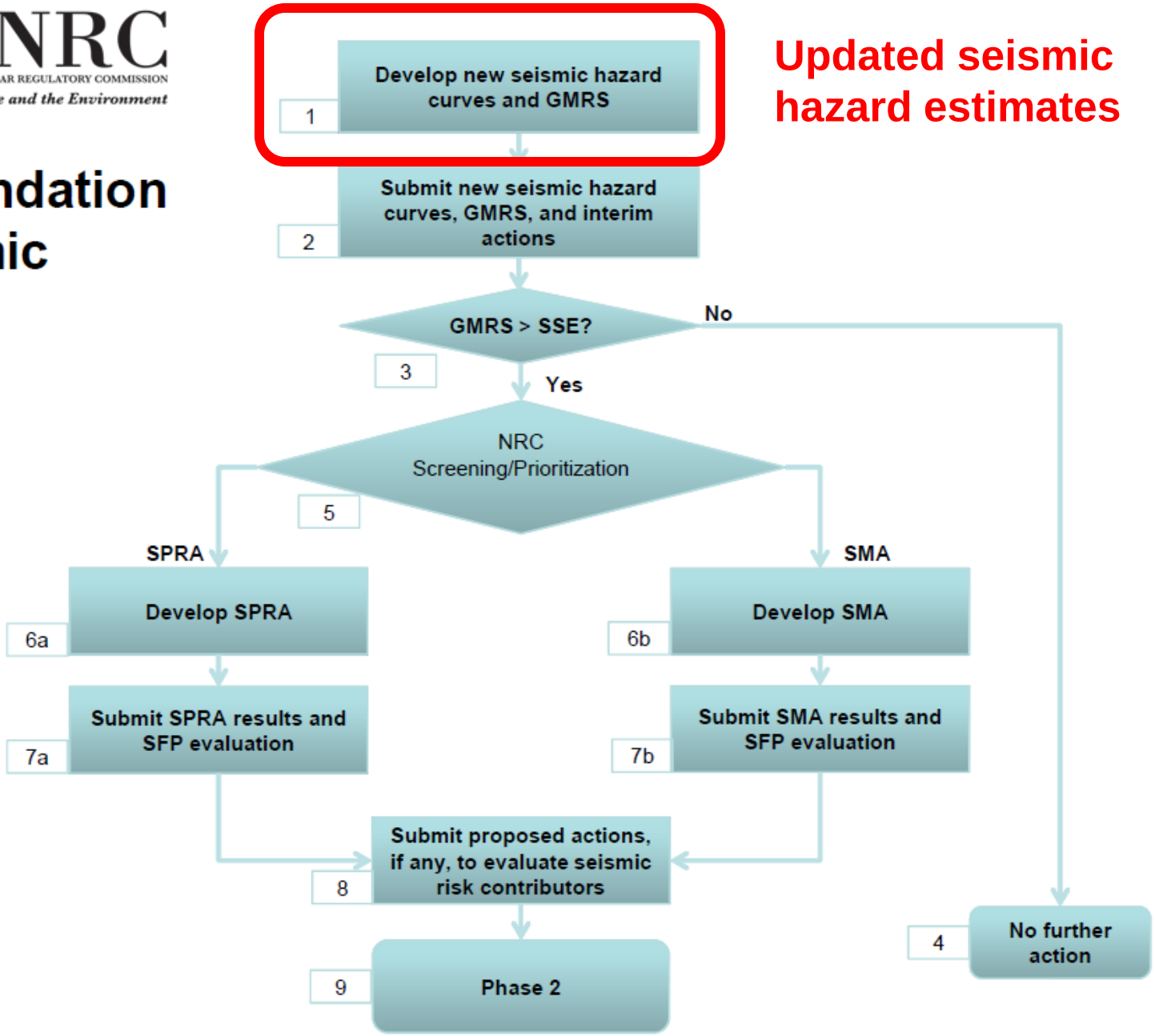
All Power Reactor Licensees and
Holders of Construction Permits in
Active or Deferred Status

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

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Recommendation 2.1: Seismic

Updated seismic hazard estimates



Step 1. Addressees should develop site-specific base rock and control point elevation hazard curves (i.e., corresponding to fractile levels of 0.05, 0.16, 0.50, 0.84, and 0.95 and the mean) over a range of spectral frequencies (0.5 Hz, 1 Hz, 2.5 Hz, 5 Hz, 10 Hz, and 25 Hz and peak ground acceleration - PGA) and annual exceedance frequencies (1×10^{-6} and higher) determined from a probabilistic seismic hazard analysis (PSHA) as follows:

CEUS

Addressees of plants located in the Central and Eastern United States (CEUS) are expected to use the CEUS Seismic Source Characterization (CEUS-SSC) model (NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities") and the appropriate Electric Power Research Institute (2004, 2006) ground motion prediction equations. Regional and local refinements of the CEUS-SSC are not necessary for this evaluation.

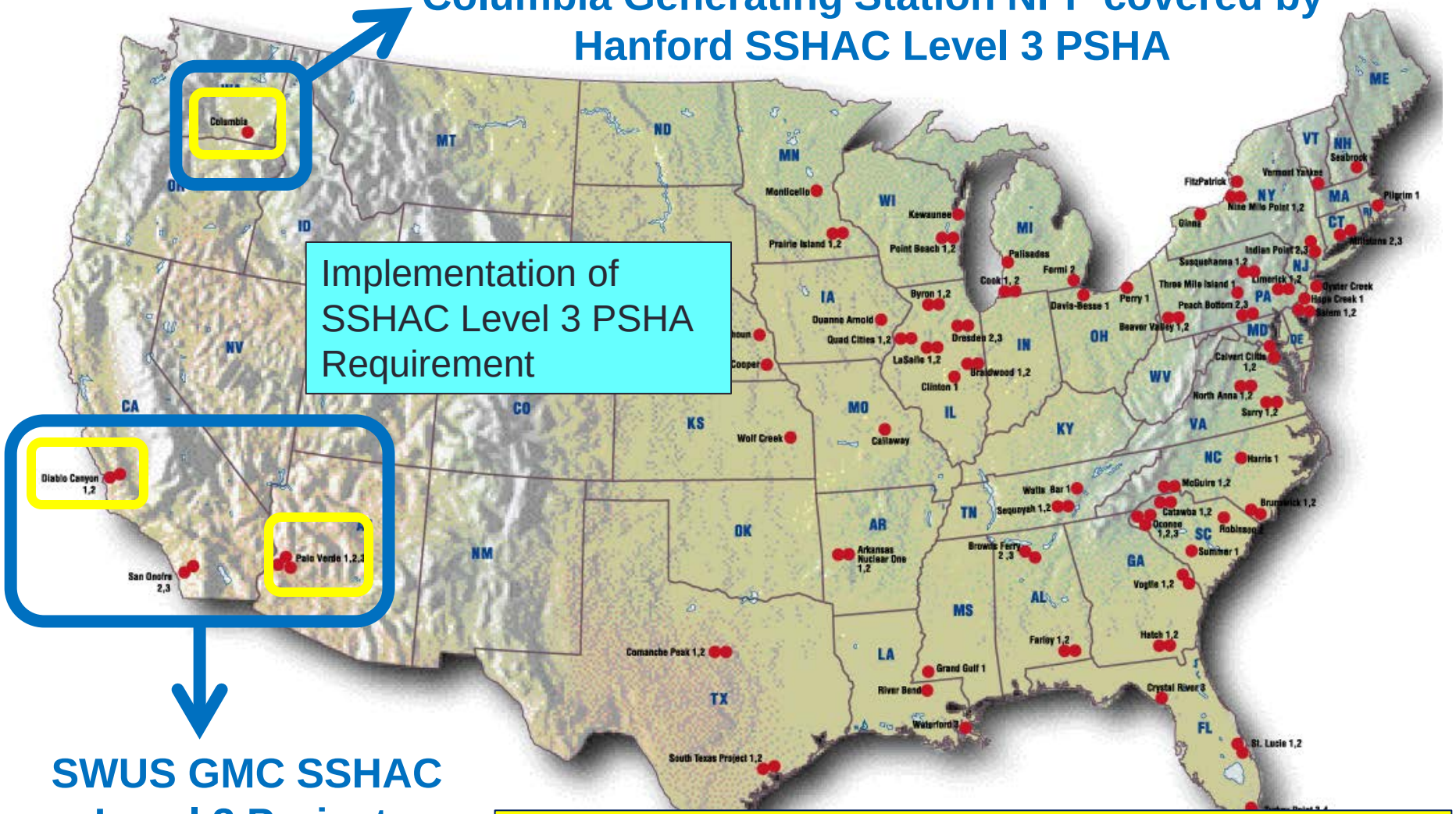
WUS

Addressees of plants located in the Western United States (Columbia, Diablo Canyon, Palo Verde, and San Onofre) should develop an updated, site-specific PSHA. Any new or updated seismic hazard assessment should consider all relevant data, models, and methods in the evaluation of seismic sources and ground motion models. Consistent with Regulatory Guide (RG) 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," addressees should use a Senior Seismic Hazard Analysis Committee (SSHAC) study, as described in NUREG/CR-6372, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts." Consistent with current practice, as described in NUREG-2117, "Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies," a SSHAC Level 3 study should be performed.

- To remove non-damaging lower-magnitude earthquakes, addressees should either use a lower bound magnitude cutoff of moment magnitude (M_w) 5 or the cumulative absolute velocity (CAV) filter for the PSHA. The CAV filter should be limited to M_w less than or equal to 5.5.

- Addressees should use site response methods 2 or 3, as described in NUREG/CR-6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines." The dynamic site response should be determined through analyses based on either time history or random vibration theory. The subsurface site response model, for both soil and rock sites, should extend to sufficient depth to reach the generic rock conditions as defined in the ground motion models used in the PSHA. In addition, a randomization procedure should be used that appropriately represents the amount of subsurface information at a

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, to be used for PSHA at plants east of the Rockies

Goal of a SSHAC Process

"The fundamental goal of a SSHAC process is to properly carry out and completely document the activities of evaluation and integration, defined as:

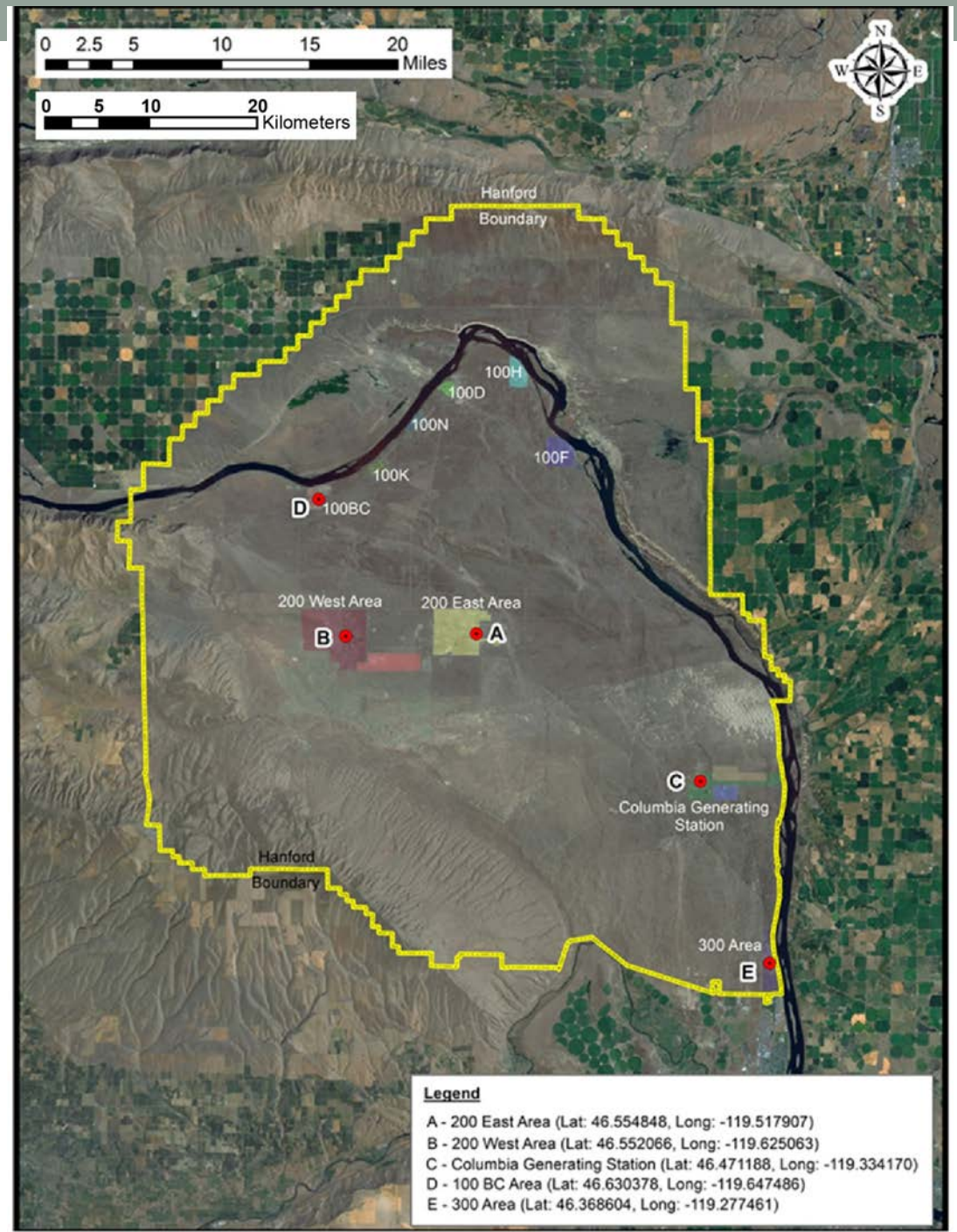
- Evaluation: The consideration of the complete set of data, models, and methods proposed by the larger technical community that are relevant to the hazard analysis.
- Integration: Representing the center, body, and range of technically defensible interpretations in light of the evaluation process (i.e., informed by the assessment of existing data, models, and methods)."

NUREG-2117

Hanford Site-Wide SSHAC Level 3 PSHA

- Purpose of Study: to develop a technically defensible PSHA that can be used for design and safety evaluations at the Hanford Site, Washington
  - PSHA must enjoy high levels of regulatory assurance, as indicated by a SSHAC Level 3 process
  - Must provide outputs that allow use at multiple facility sites within the Hanford Site, including the commercial nuclear power plant Columbia Generating Station (CGS)
  - Outputs must be compatible in format with site response analyses for site-specific facility input motions
  - Compliant with NRC requirements, per 50.54(f) letter, and regulatory guidance
  - Compliant with DOE Order 420.1B (later 420.1C) regarding 10-year update and expectations of DNFSB

Hazard Calculation Sites



Project Plan for SSHAC Level 3 PSHA

- Project Plan specifies:
  - Project organization
  - Participant roles and responsibilities
  - Scope
  - Schedule
  - Deliverables and instructions for usage
- Provides a basis for all project planning and contracting
- Ongoing information for participants and reviewers
- Recommended elements given in NUREG-2117
- Hanford PSHA Enhancements
  - New data collection activities
  - PPRP participation

Kick-off Meeting and Field Trip

New Data Collection and Analyses

- Focused studies and analyses designed to reduce uncertainties in key SSC and GMC issues, within the project schedule and budget
- GMC-related
  - Velocities at recording sites
  - Analyses of kappa
  - Analyses of basin effects
- SSC-related
  - Structural analyses of Yakima folds
  - Quaternary geologic studies
  - High-resolution earthquake relocation analyses

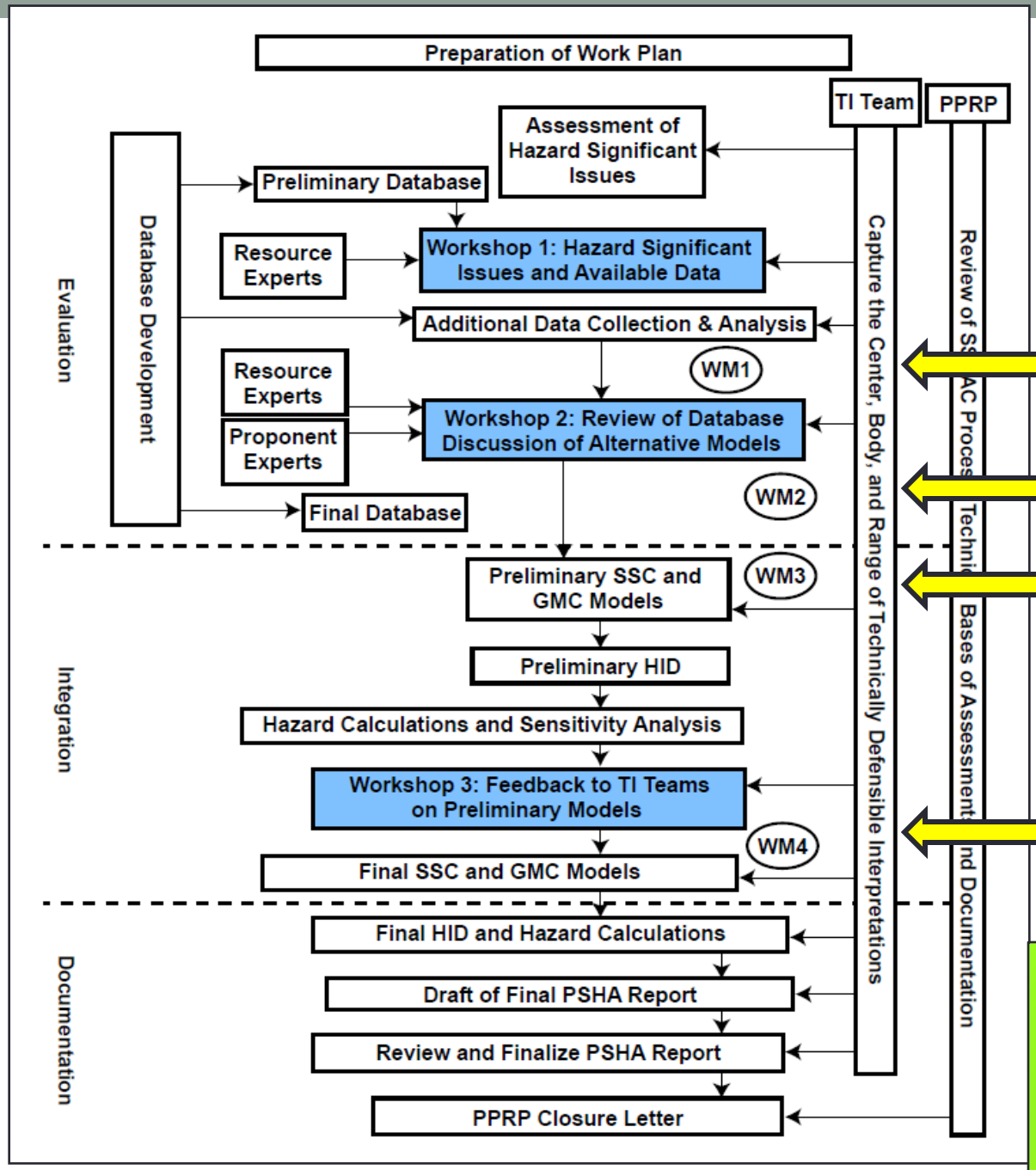
Velocity Profiles at Recording Sites

Quaternary Geologic Studies

Provided data on locations, amounts, and timing of fault deformation

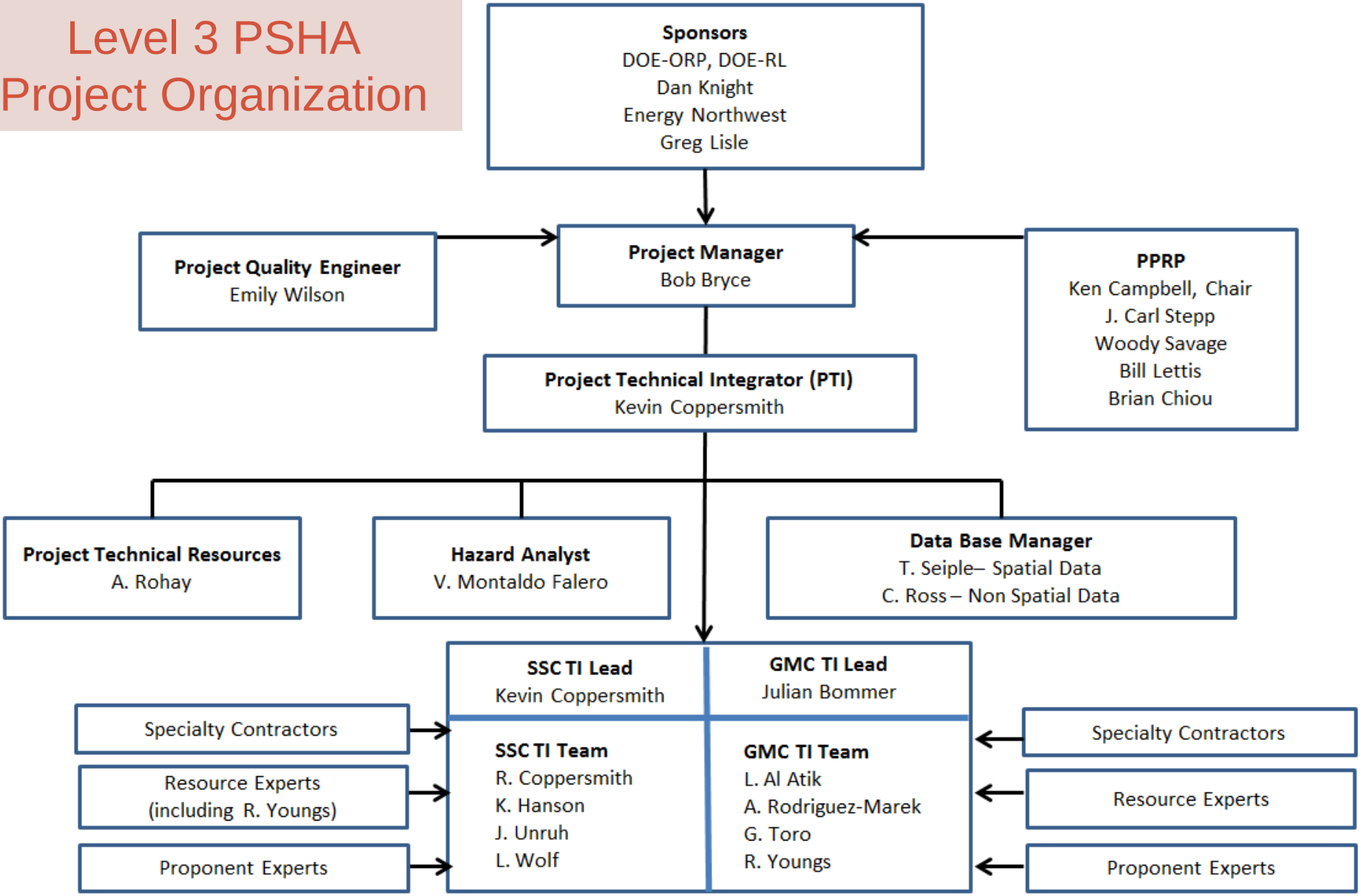
- Reduced uncertainty in recurrence rates, Mmax, and fault source geometries

TI Team Working Meetings (WM)



- 3-4 days duration
- All team members
- Conference room with GIS support
- PPRP observers

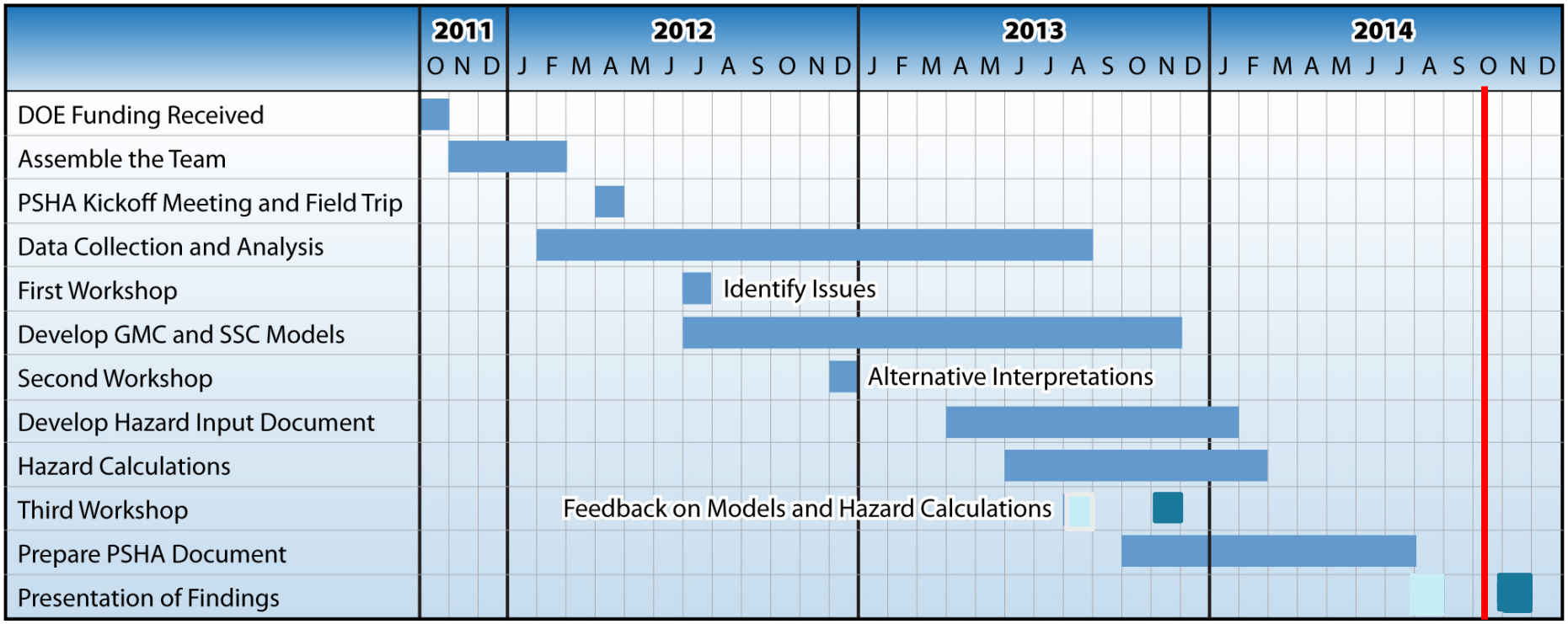
Hanford SSHAC Level 3 PSHA Project Organization



GMC Technical Integration Team

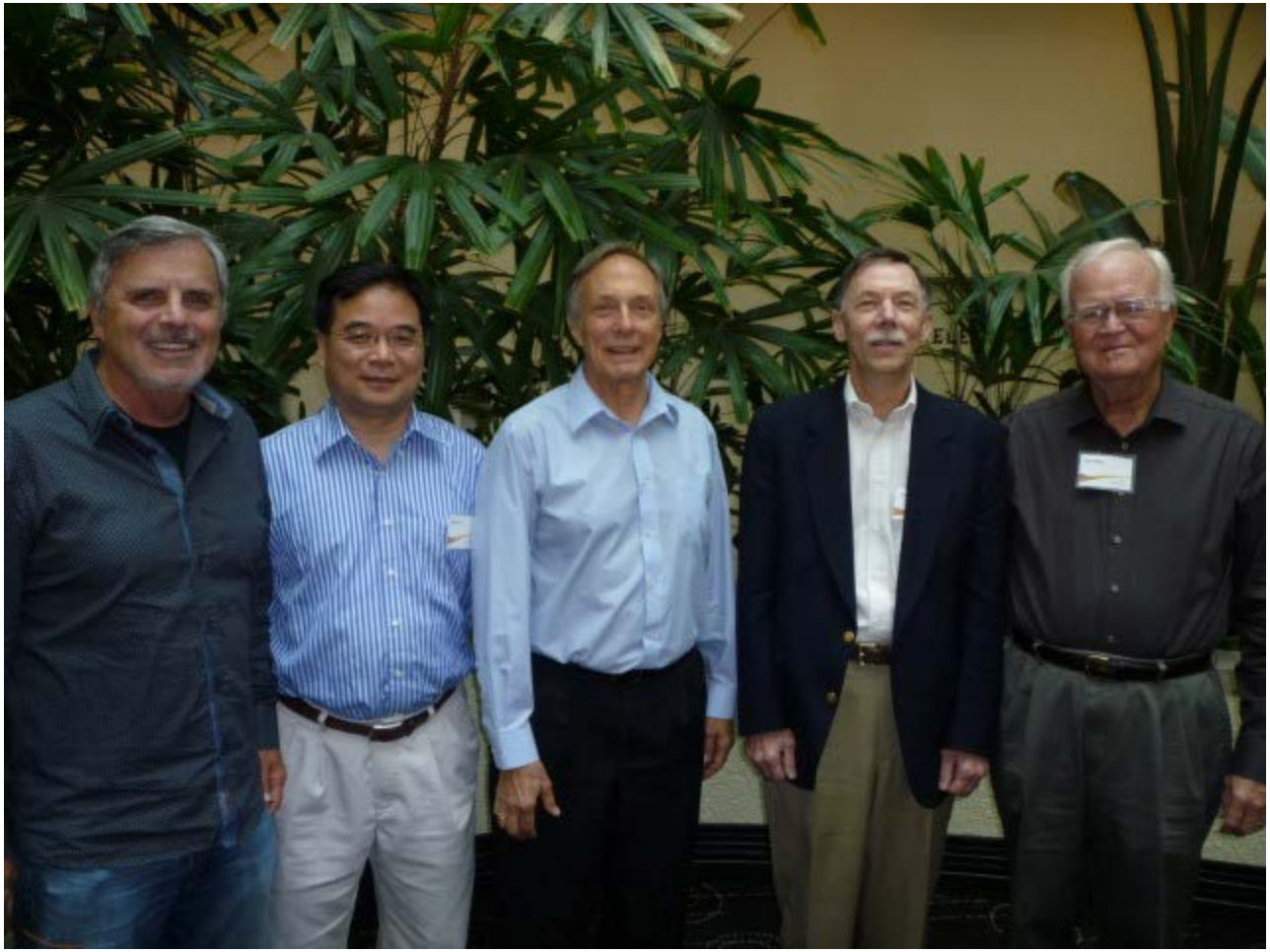
SSC Technical Integration Team

Hanford PSHA Schedule



A driver of the HPSHA schedule is Energy Northwest's submittal to NRC in March 2015

Participatory Peer Review Panel



Requirements for SSHAC Level 3 PPRP

<u>PPRP Roles and Responsibilities</u>

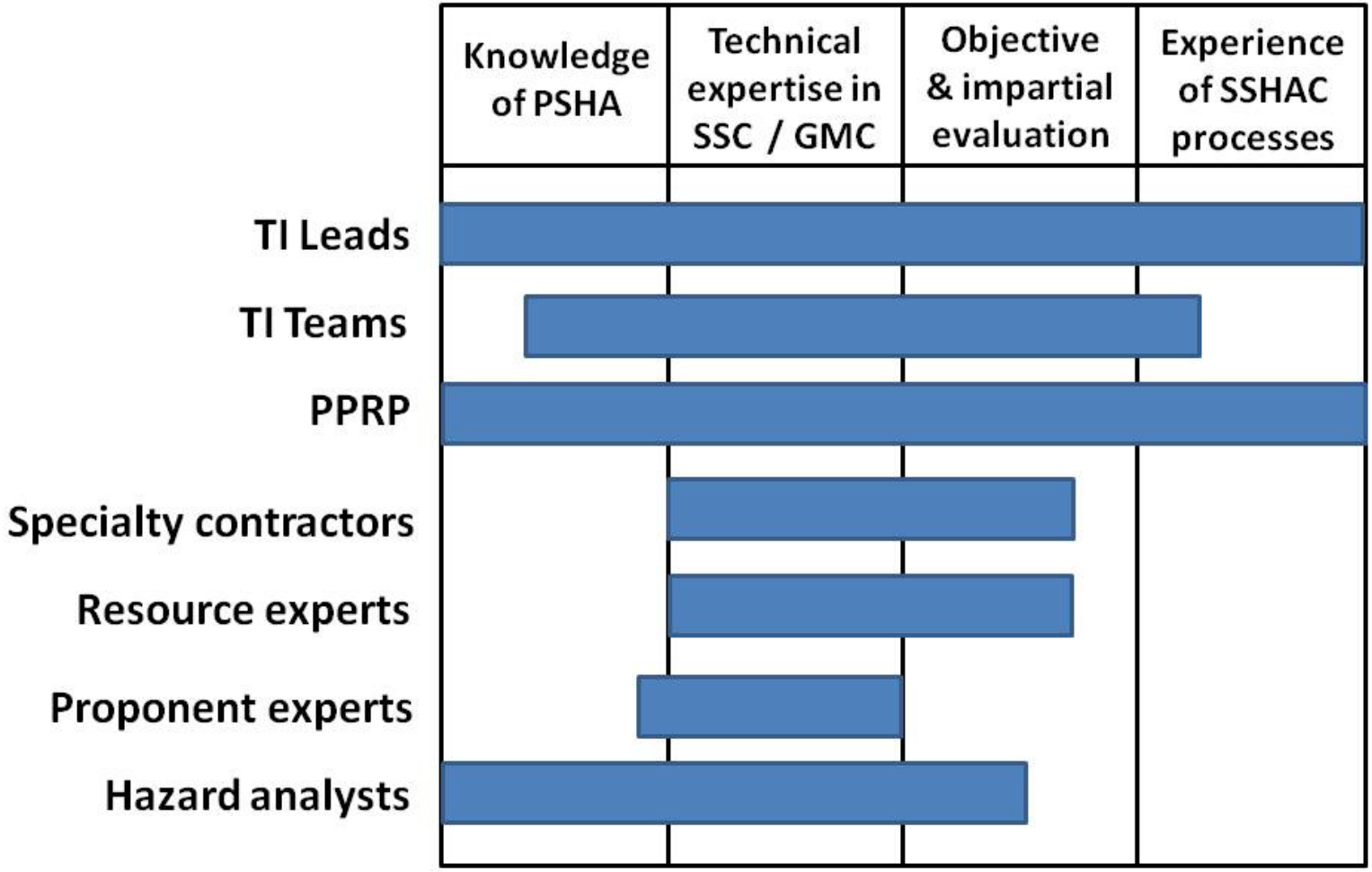
- PPRP reports to Project Manager
- *Technical* review: ensure that the full range of data, models, and methods have been duly considered in the assessment and all technical decisions are adequately justified and documented
- *Process* review: ensure that the project conforms to the requirements of the selected SSHAC level
- Provide timely perspectives and advice regarding the manner in which ongoing activities can be improved or carried out more effectively
- Be present at all the formal workshops as observers and subsequently submit a consensus report containing comments, questions, and suggestions
- Provide one or more representatives of the PPRP to attend as observers the working meetings of the evaluator experts

Requirements for SSHAC Level 3 PPRP (continued)

PPRP Roles and Responsibilities (continued)

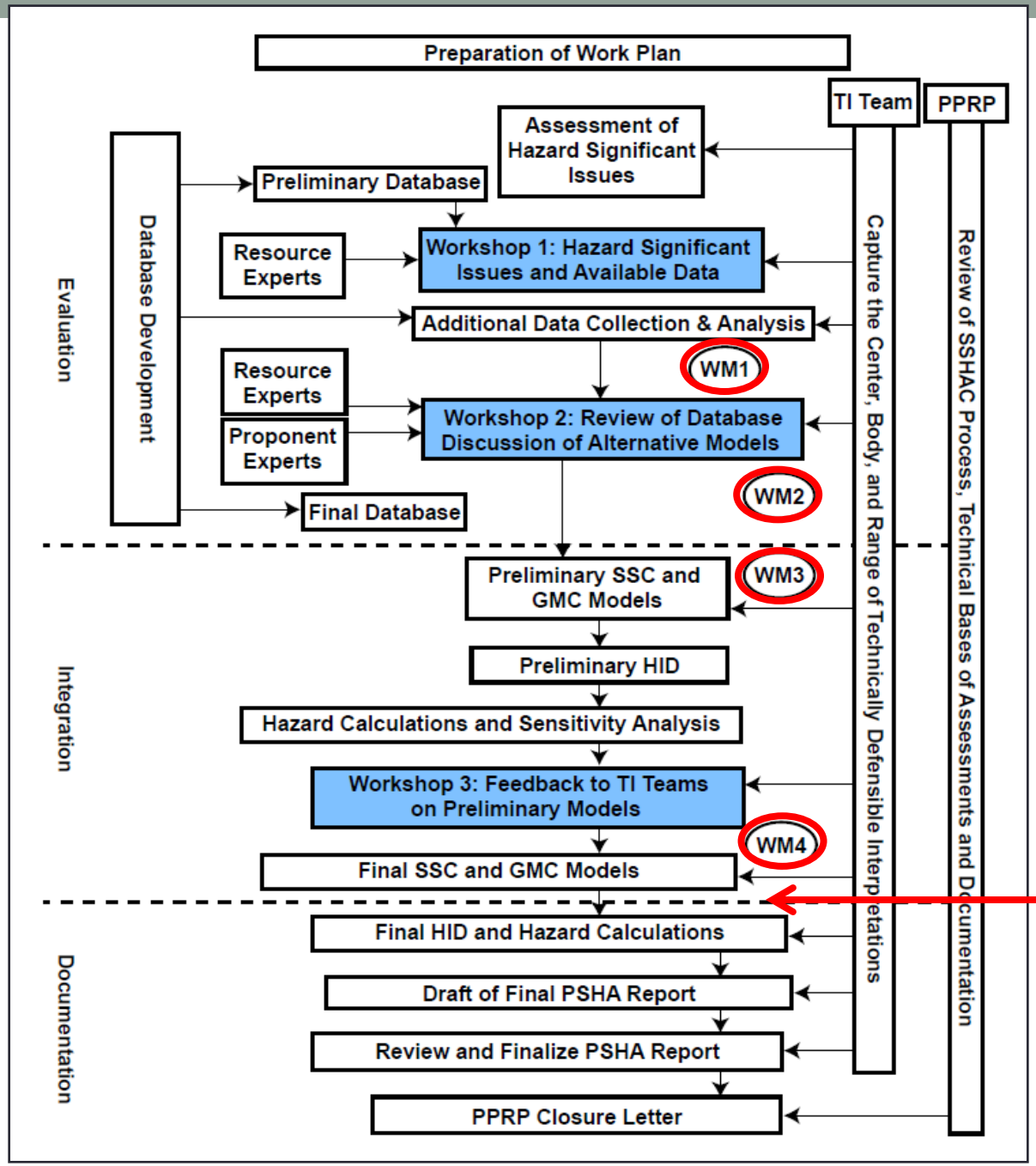
- Perform detailed review of all project documentation and provide written comments to ensure complete technical justification of integrated distribution
- Prepare PPRP Closure Letter providing final technical and process review

Selection Criteria for SSHAC Participants



Kammerer et al., 2013, SMiRT-22, *Lessons Learned from Application of the NUREG-2117 Guidelines for SSHAC Level 3 Probabilistic Seismic Hazard Studies for Nuclear Sites*

Hanford PPRP Major Activities



Full PPRP present as observers at all 3 Workshops

PPRP representative as observers at all 4 Working Meetings

PPRP allowed to interrogate TI Teams on their models at WS3

PPRP Briefing to review Final SSC and GMC models

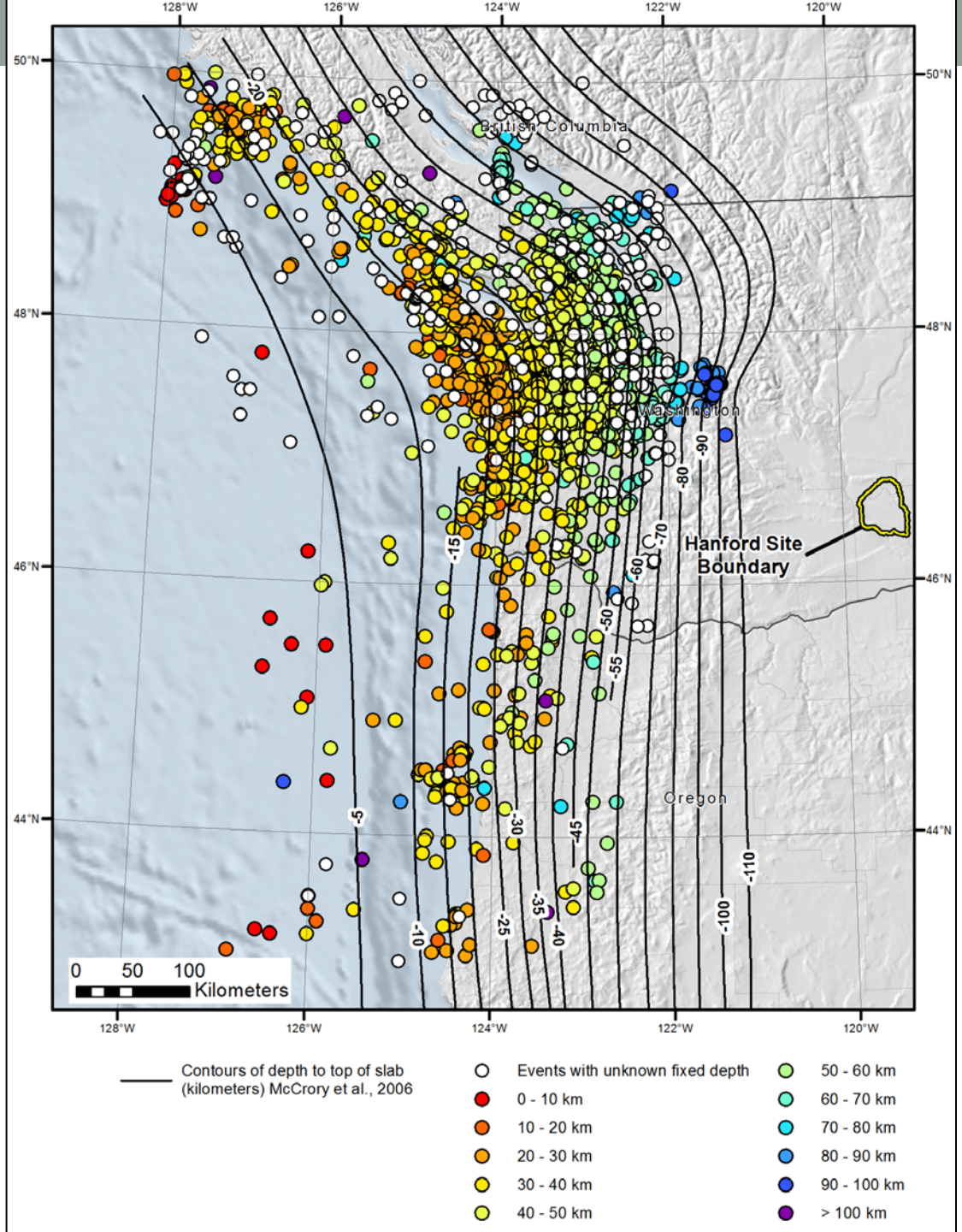
Review of Draft Report

Preparation of PPRP Closure Letter

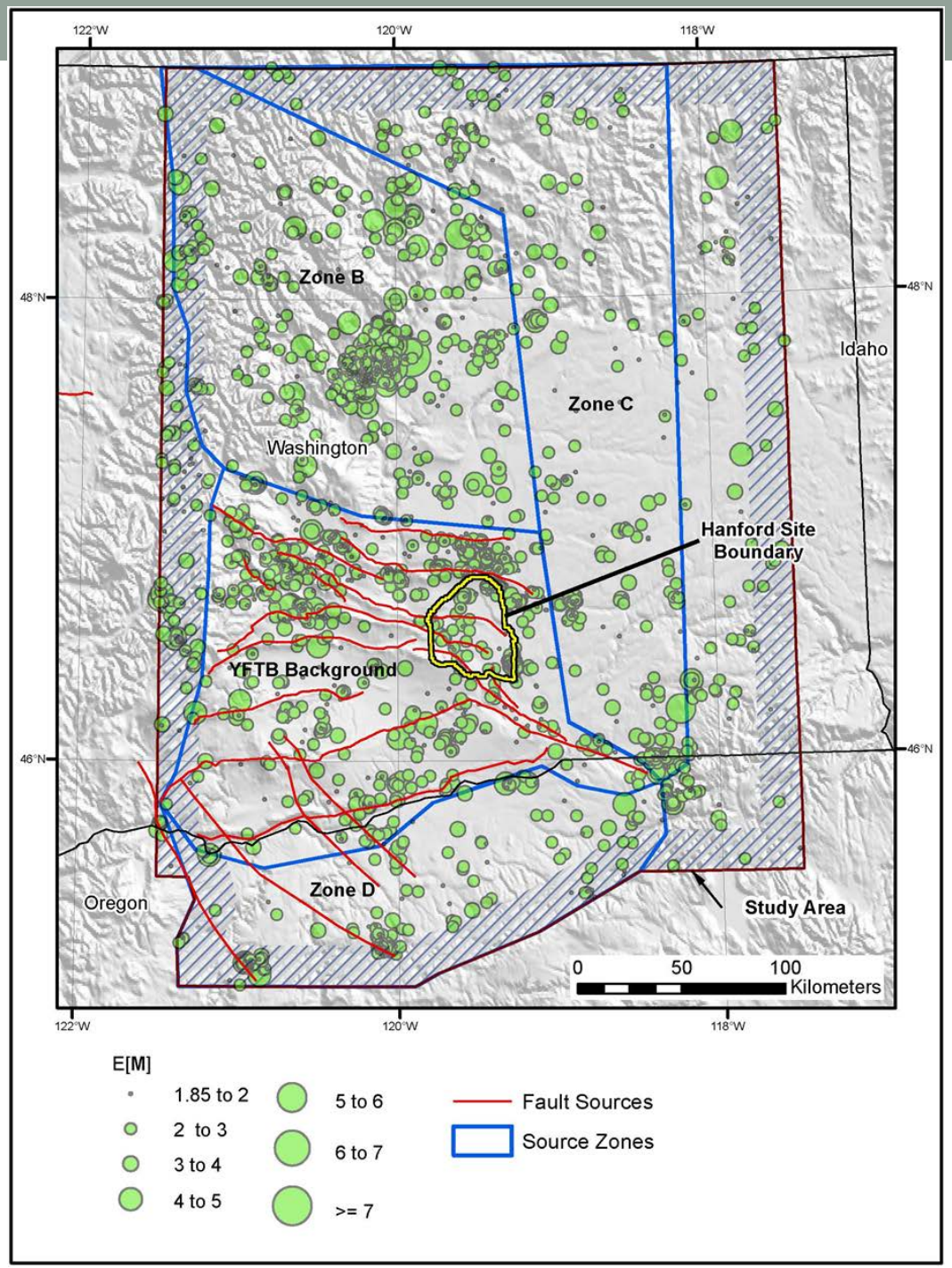
Seismic Sources in SSC Model

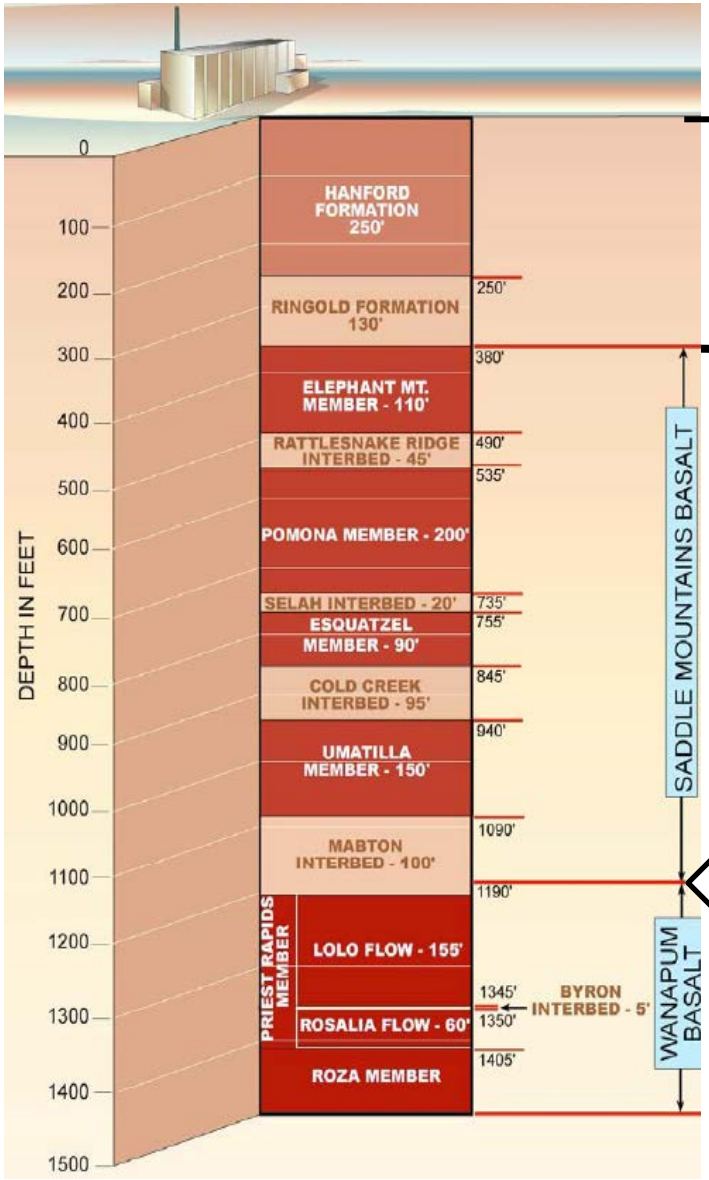
- Cascadia Subduction Zone sources
  - Plate interface
  - Intraslab source
- Seismic source zones
  - YFTB zone: serves as a “background” zone to fault sources
  - Zones B, C, and D
- Fault sources within Yakima Fold and Thrust Belt (YFTB)
  - 19 faults characterized
  - More distant faults are implicitly included in source zones

Cascadia Subduction Zone Sources in SSC Model



Crustal Seismic Sources in SSC Model





V/H ratios applicable to surface spectra

Recommendation of Approach 3 to convolve baserock hazard with AFs

Dynamic model for SMB column (including uncertainties)

- **h, Vs, ρ**
- **G/Gmax, damping curve**

Recommendations for site response analyses (including randomizations) to obtain site amplification factors, AF

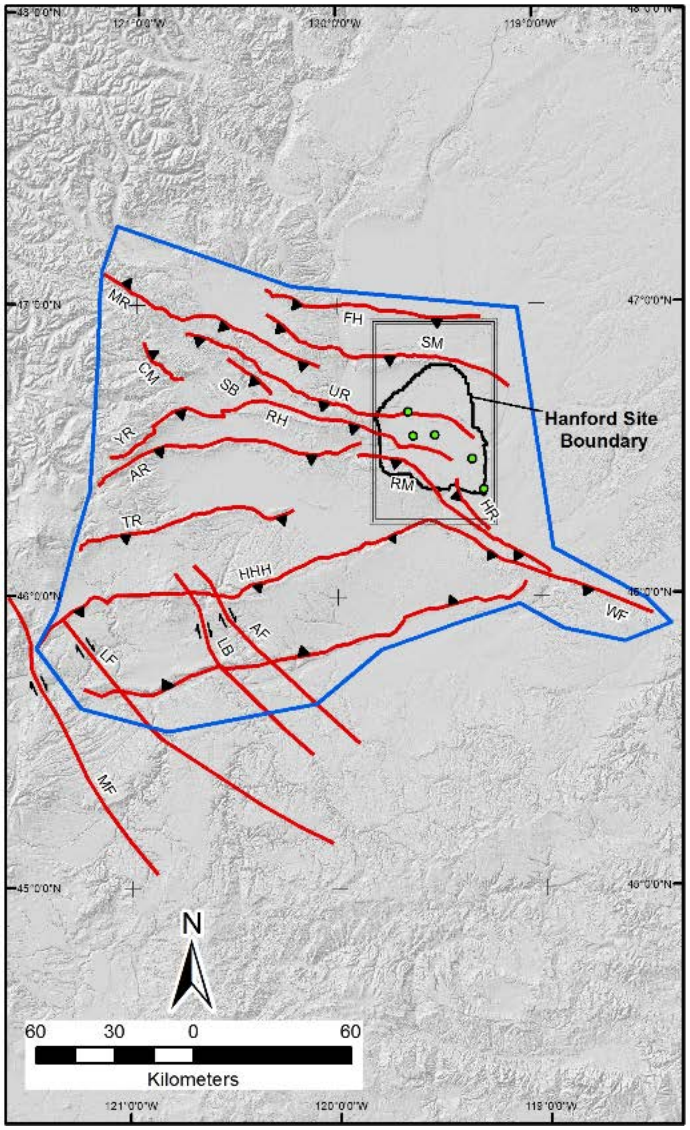
Reference horizon for GMC model and baserock PSHA

Hazard results at reference rock horizon (PSHA calculations group)

- **Hazard curves**
- **Deaggregation of hazard**
- **Deaggregated spectra**

Hazard Calculations

- All hazard calculations are controlled by QA procedures that implement ASME NQA-1 requirements
- Calculations conducted using PNNL computer cluster to shorten calculation times
- Estimated calculation time of six weeks; actual time twelve weeks
- Causes of additional calculation time:
  - Complex SSC model (subduction sources, 19 faults, four source zones, moment rate balancing, recurrence modeling)
  - Complex GMC model (source types, tectonic environment between CA and SCR, adjustments to GMPE backbone)
  - Five sites, 20 structural periods, AFE range 10^{-2} to 10^{-8}
  - Program stores files for use in deaggregation and sensitivity analyses; nearly 1,000,000,000 files stored causing cluster storage devices to crash
  - Required the file storage structure to be revised


MR
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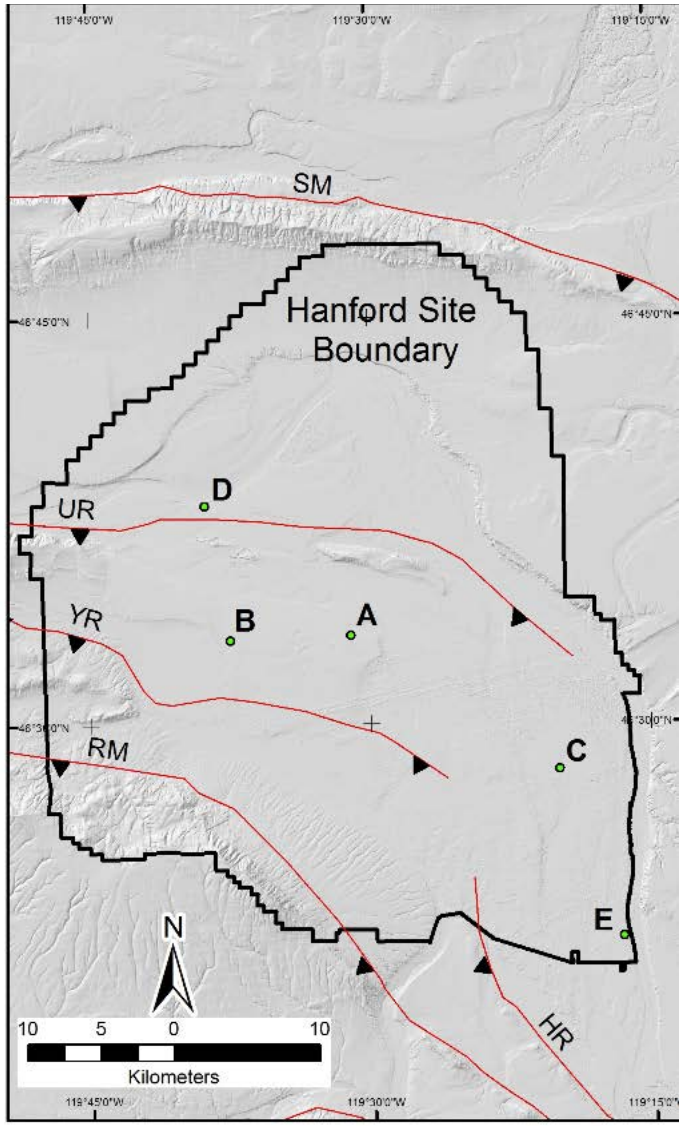
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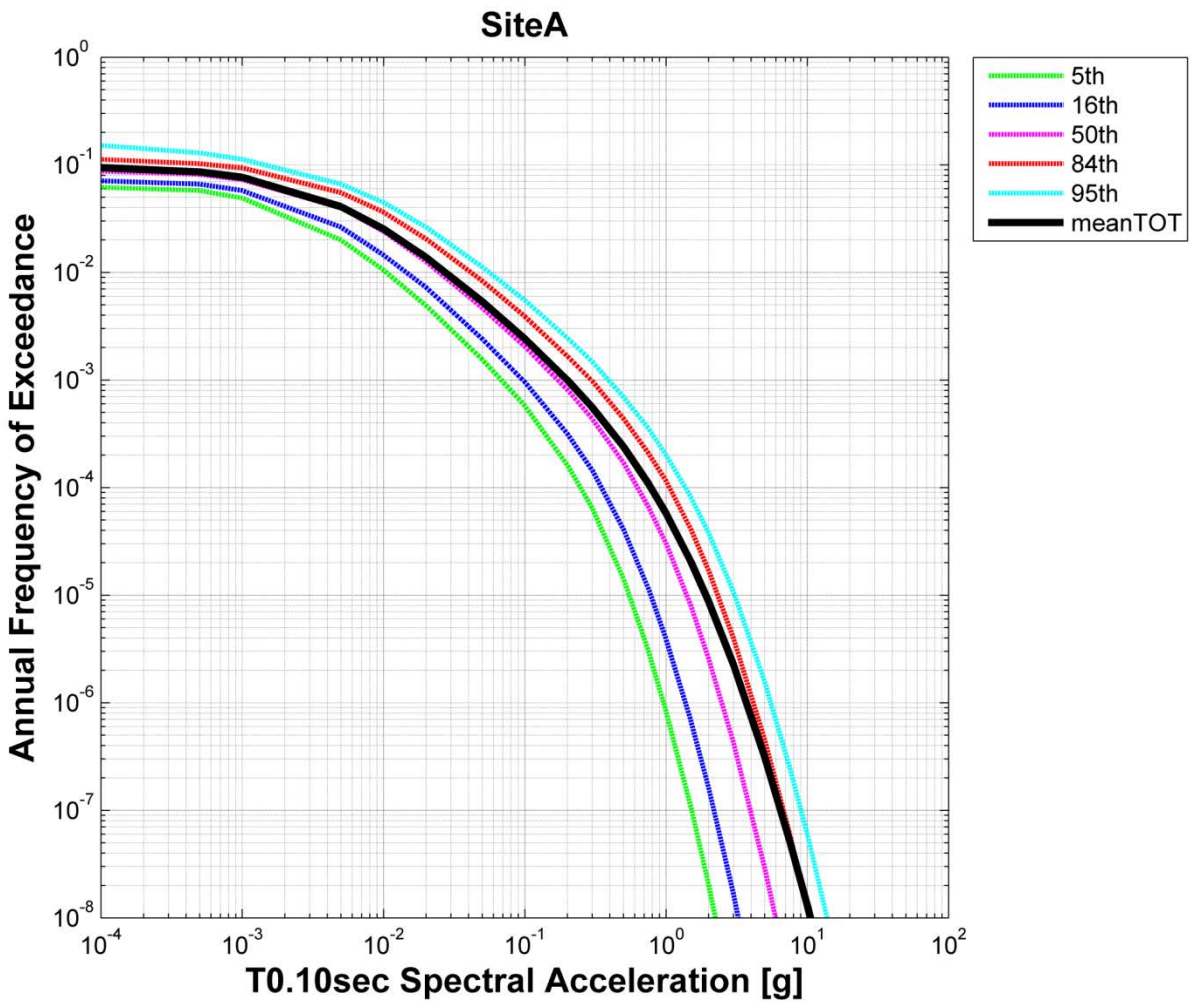
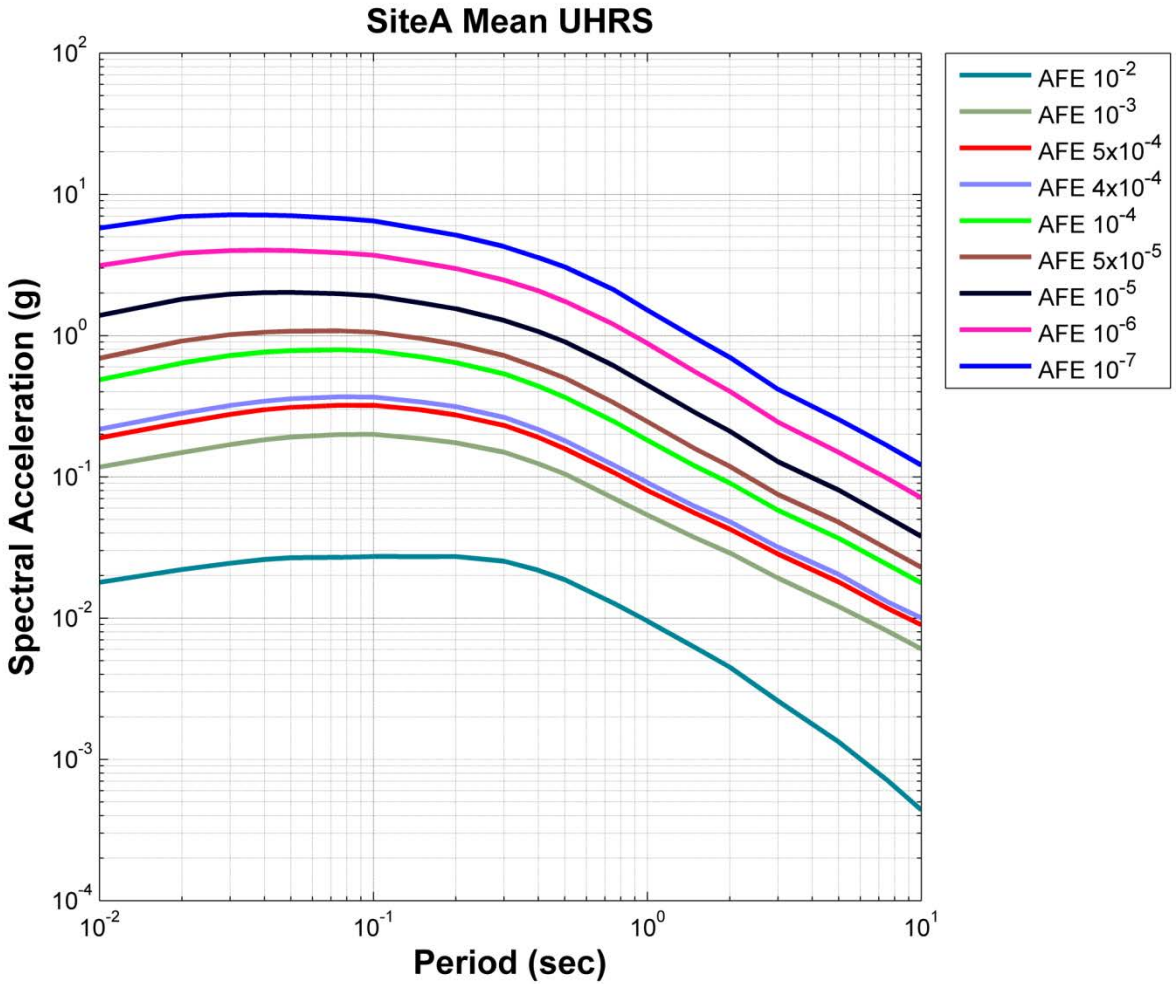
Kilometers

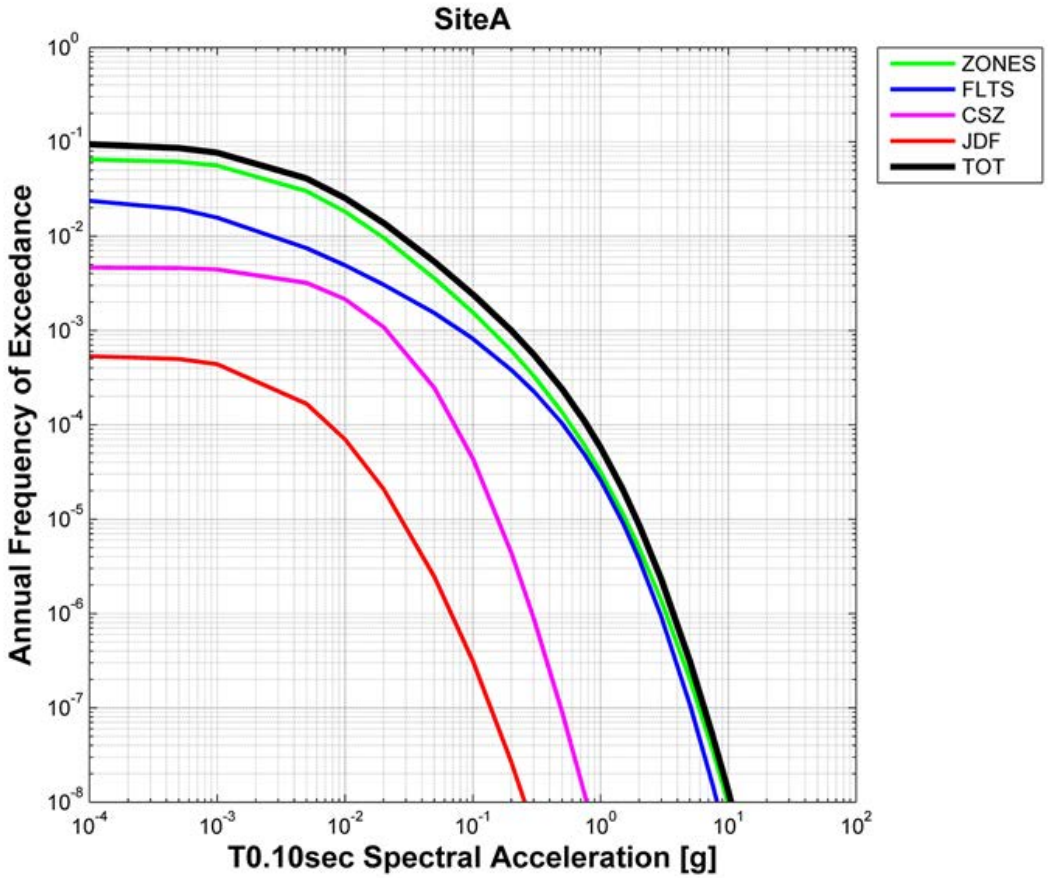
Top of Lolo Total Hazard Curves



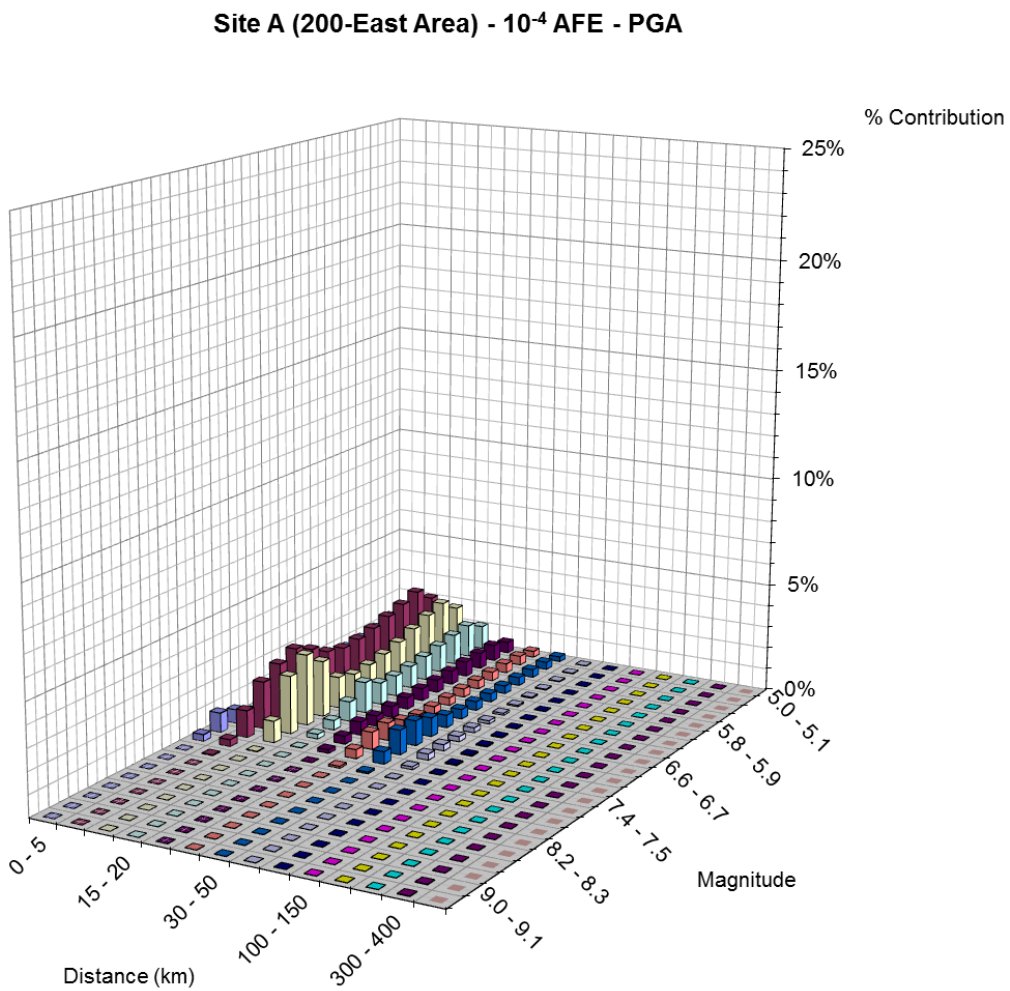
Top of Lolo UHRS



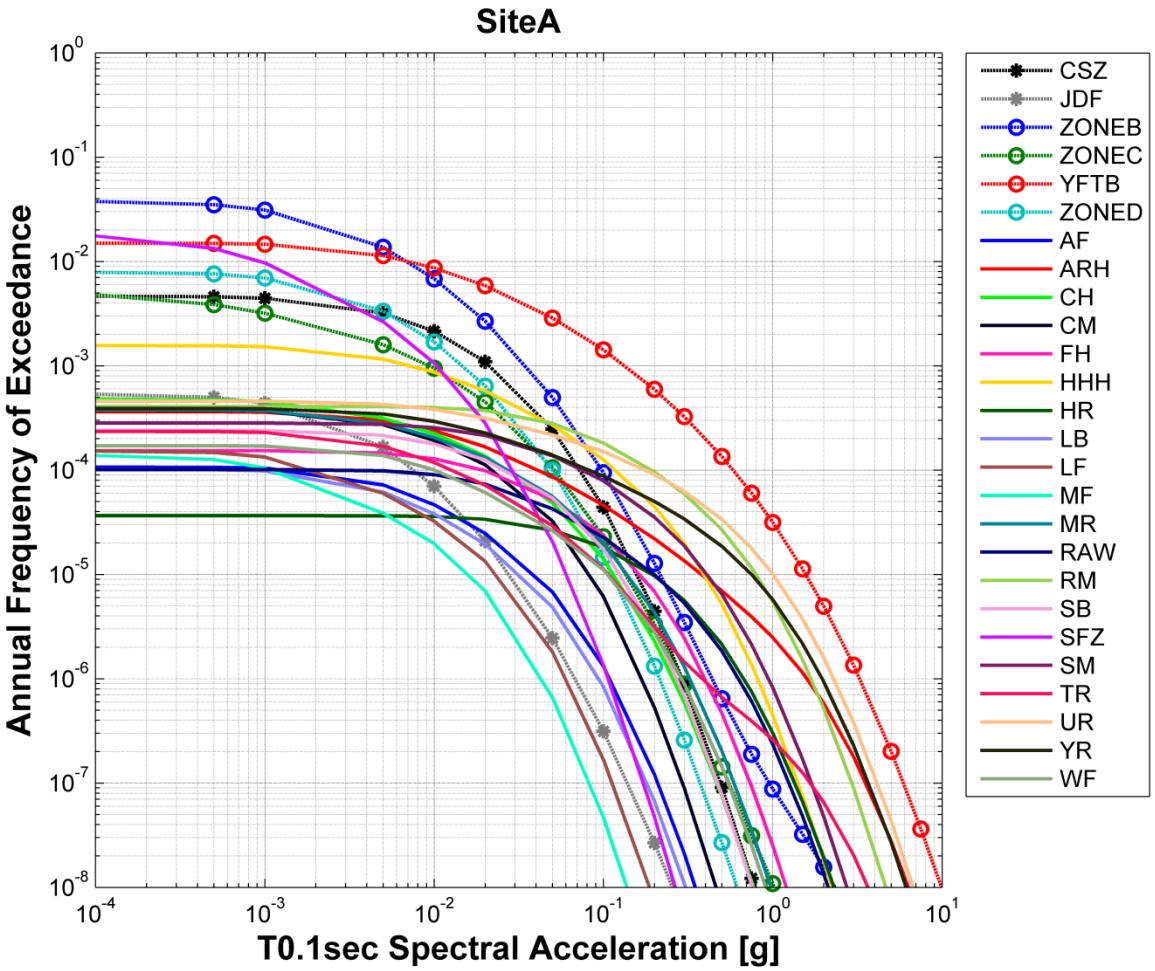
Source-type Contributions at $T_{0.1sec}$



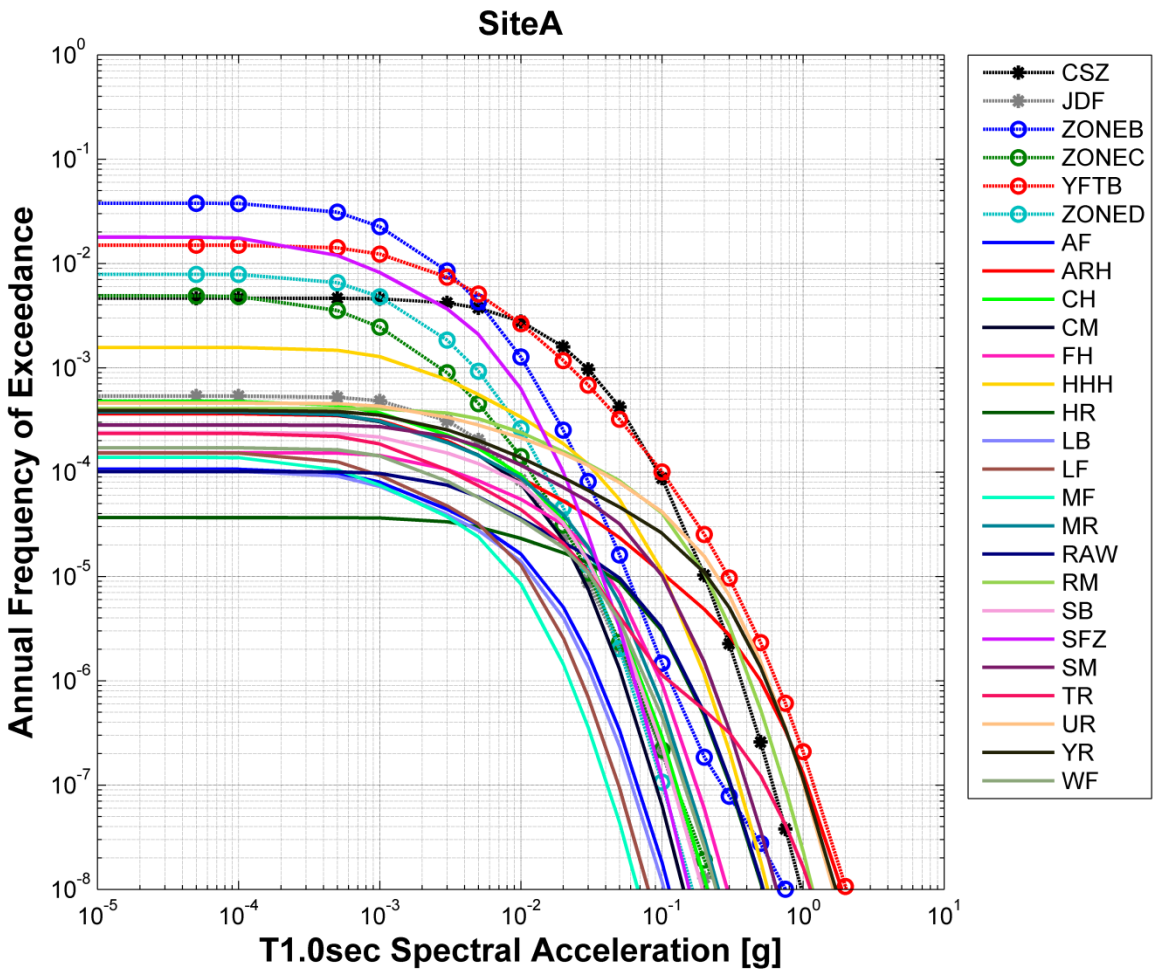
Deaggregation



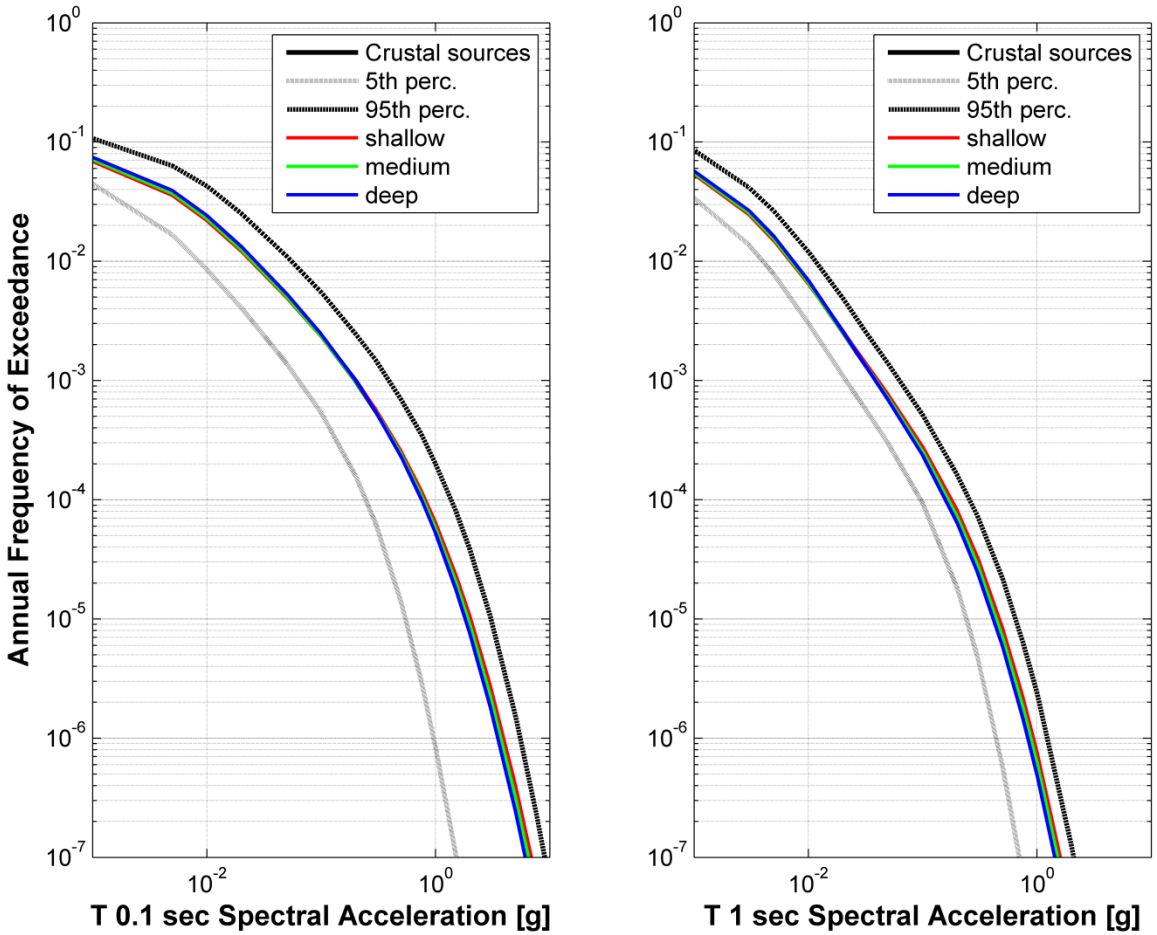
Seismic Source Contributions $T_{0.1sec}$



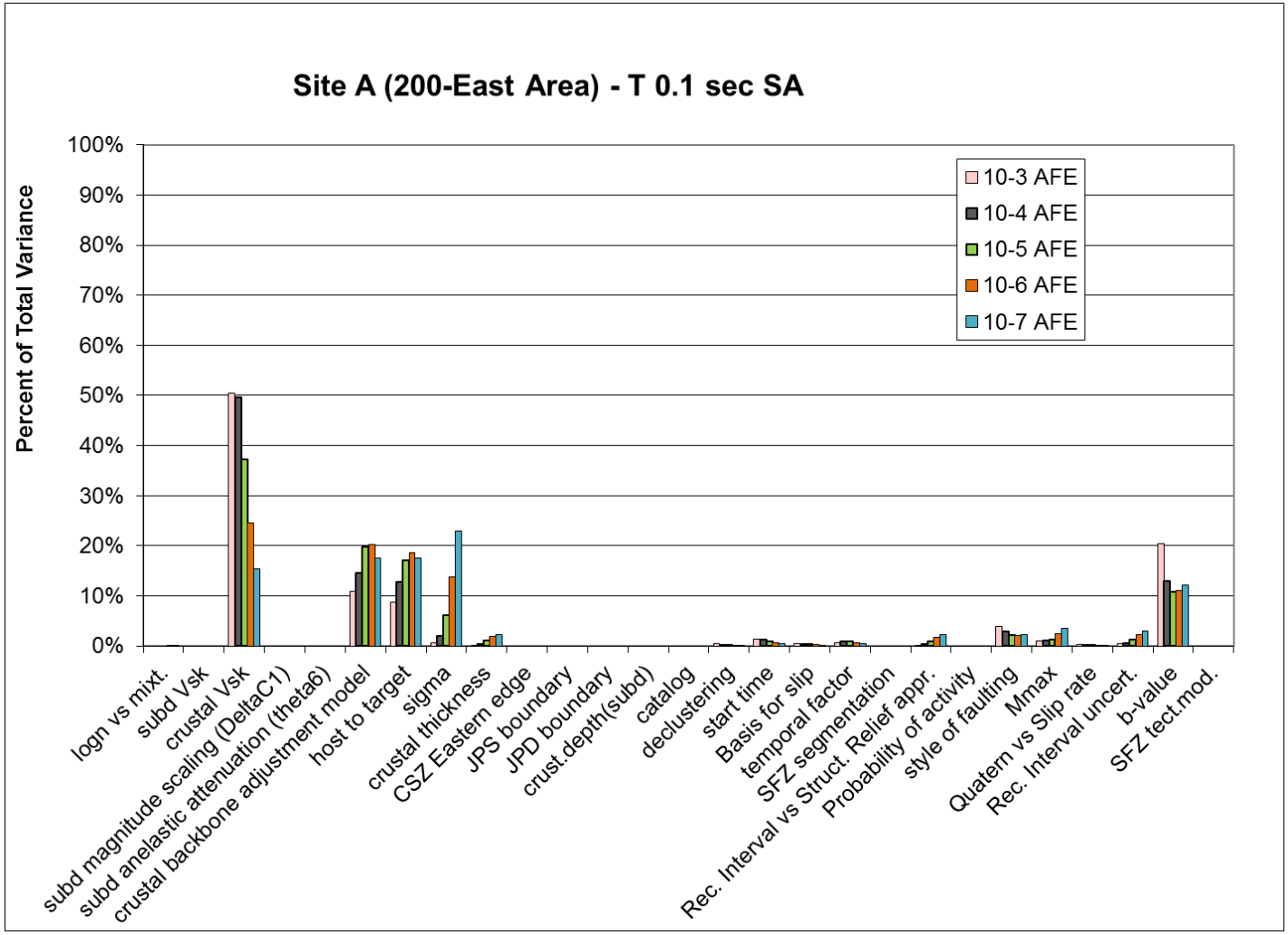
Seismic Source Contributions $T_{1.0sec}$



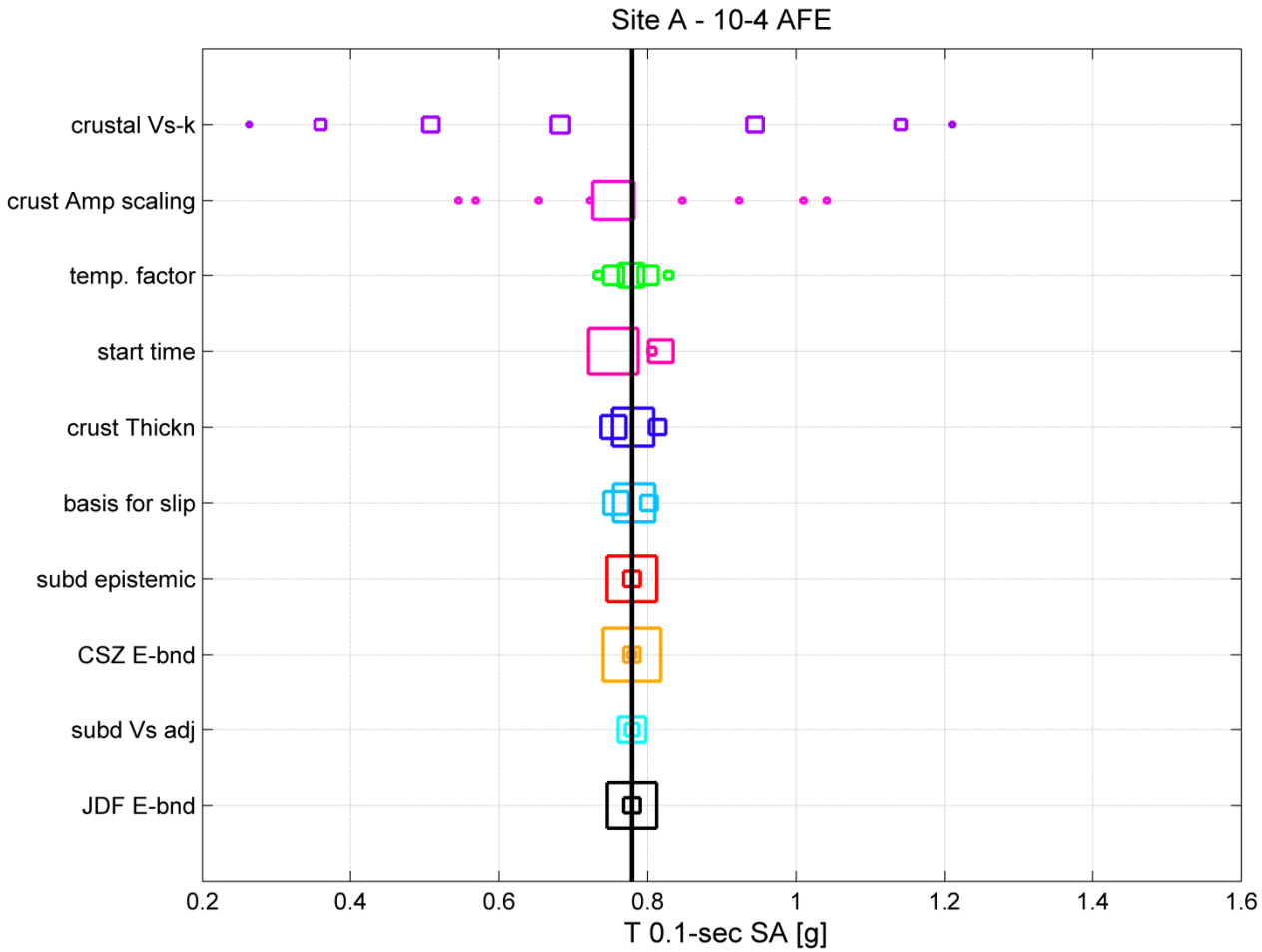
One-off Sensitivity Analyses



Contributions to Variance



Tornado Diagram 10^{-4} AFE



Conclusions: Implications to Other PSHA Updates

- Criteria for evaluating need for update are available and explicit
- SSHAC Level 3 process is appropriate for nuclear facilities, high uncertainty and hazard significance, need for regulatory assurance
- Important: Careful project planning, participant commitment, roles and responsibilities, adherence to regulatory guidance
- Engagement of PPRP is valuable
- Site-specific innovations should be encouraged, provided that essential steps are followed
- Processes of evaluation and integration by TI Teams are now well-defined
- Technical and project management must be prepared for mid-course corrections