Mid-Columbia Approach to Seismic Hazard

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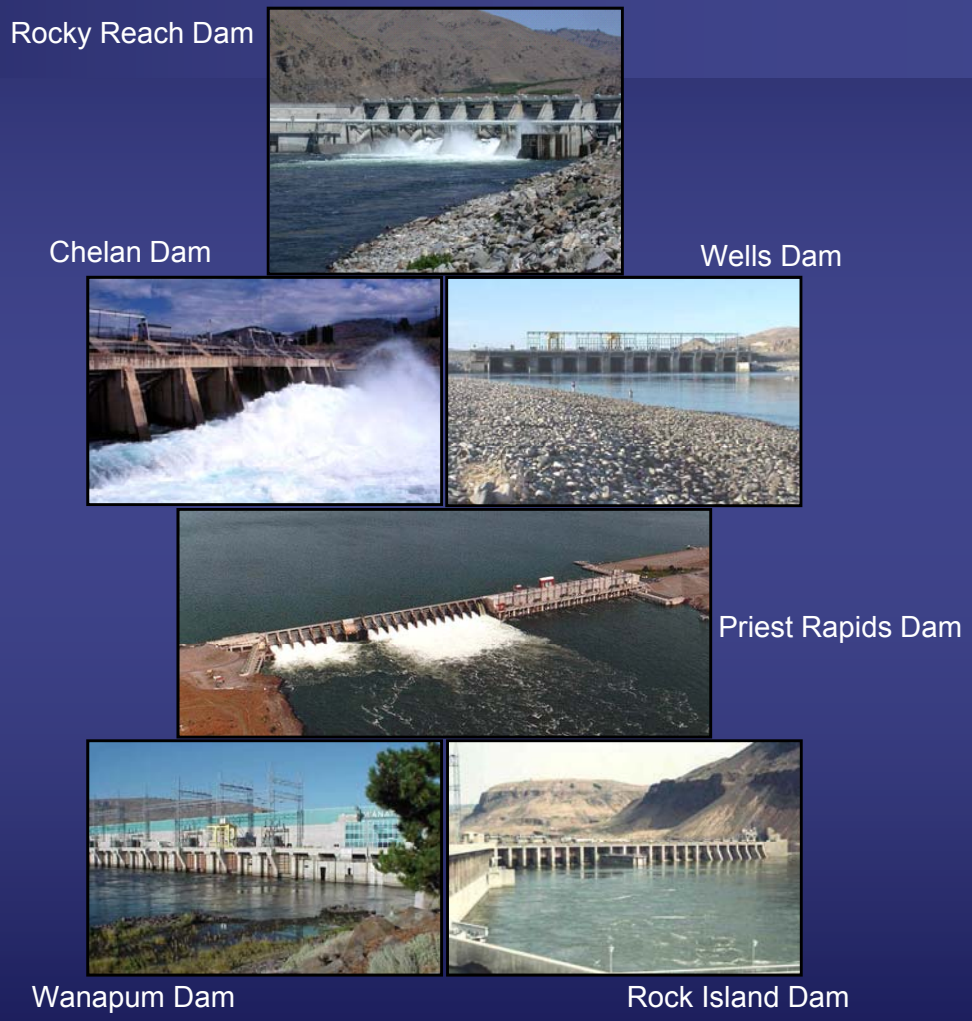
NW Hydropower Operators Meeting

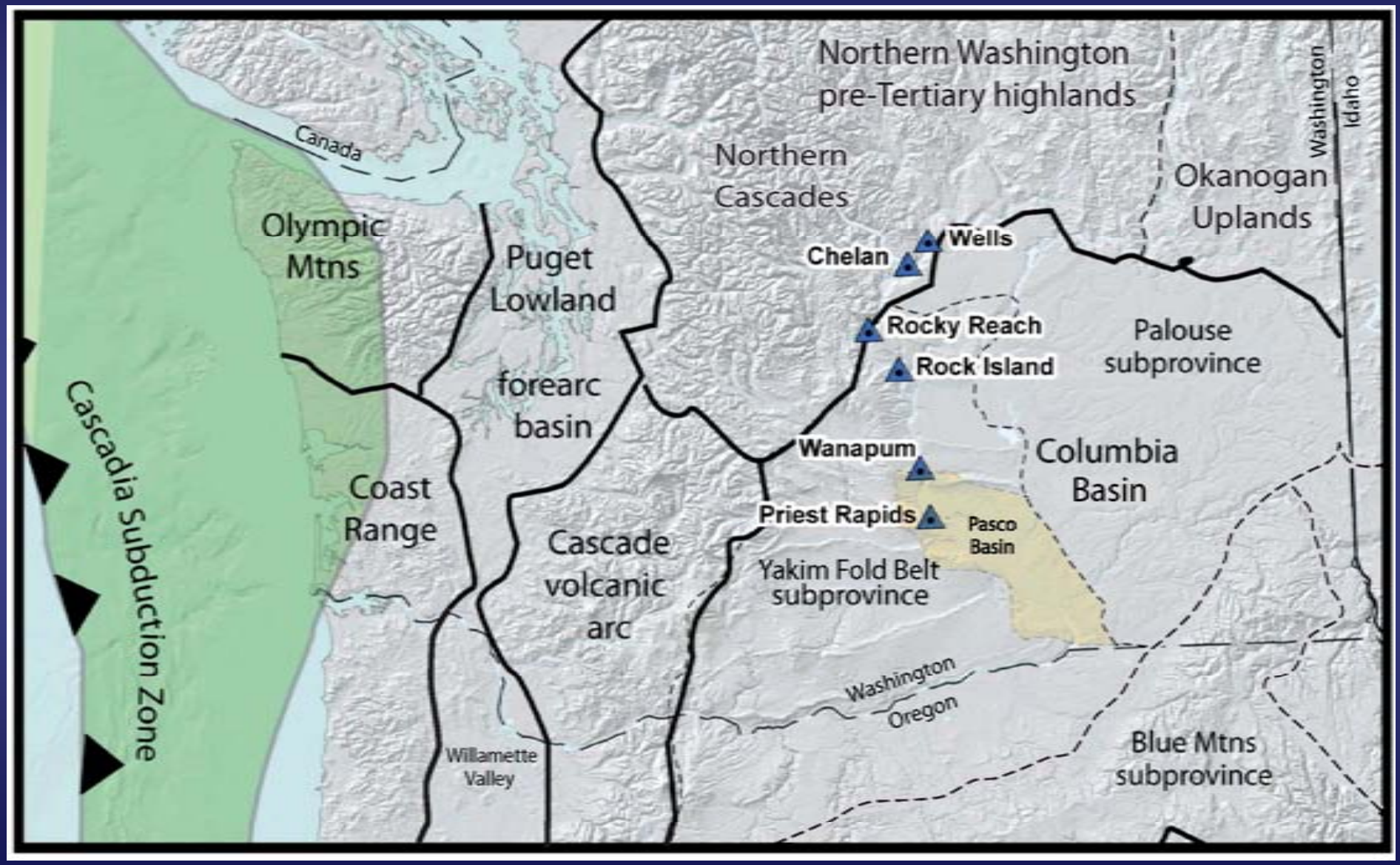
May 22, 2008



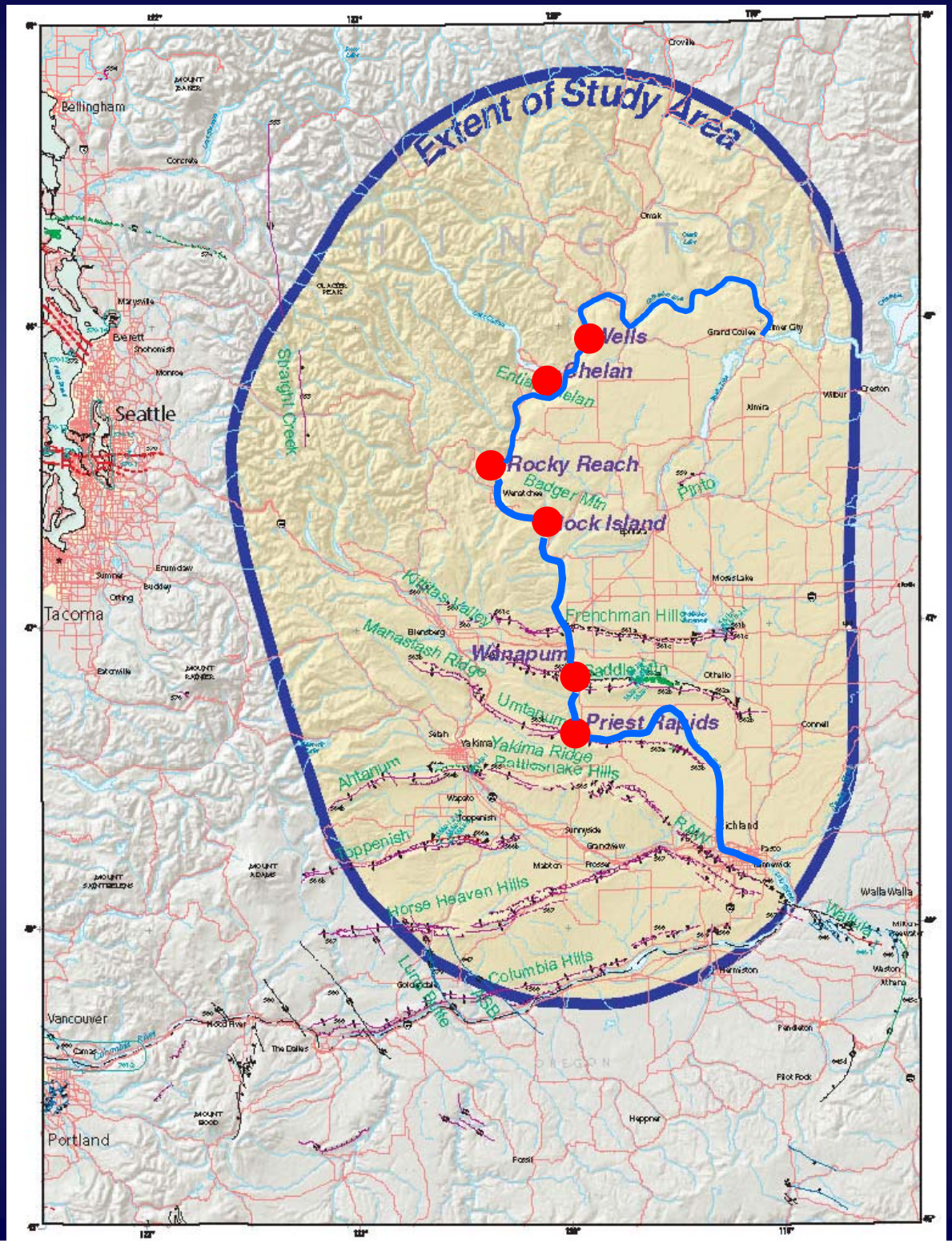
Mid-Columbia Players/Projects

- Chelan PUD, Douglas PUD, & Grant PUD
- Projects
  - Chelan
  - Priest Rapids
  - Rock Island
  - Rocky Reach
  - Wanapum
  - Wells
- Seismic Evaluation Basis – PGA ~ 0.10g

Location of Study Region



Preliminary Map of Active and Potentially Active Faults, Central Washington

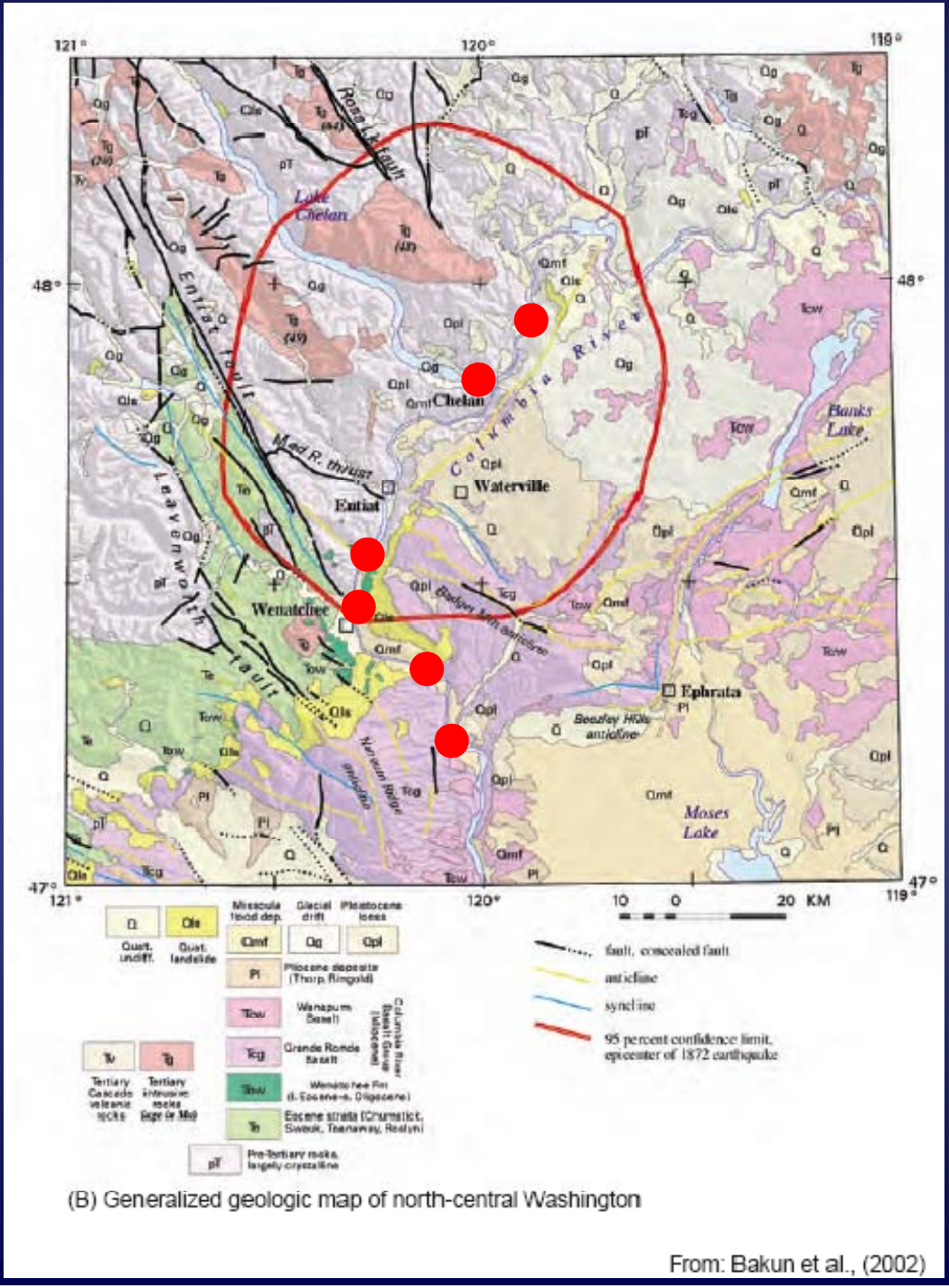


Background

- Technical
  - Re-evaluation of the 1872 Chelan earthquake & implications for the seismic safety evaluation of dams in the Mid-Columbia region
- Regulatory
  - FERC faced with addressing an issue that could have important implications for the Mid-C projects
- Industry
  - Multi-dam owners facing the same technical issues & potential conflicting evaluations (also regulatory)
- Neighbors
  - Others interested in the technical issues and evaluations; dam owners (federal), other federal agencies (USDOE, USGS), WA state dam safety program

Technical Motivator

95% confidence location for the 1872 earthquake (Bakun, et al, 2002), **M** 6.5-7.0



(B) Generalized geologic map of north-central Washington

From: Bakun et al., (2002)

Approach

- FERC & licensee discussions of the issues resulted in agreement on a technical and organizational approach to address the seismic hazard issue in the Mid-C region
- Technical
  - Conduct a probabilistic seismic hazard analysis
- Organizational
  - Collaboration – The PUD would pool their technical & fiscal resources to conduct a regional assessment of the seismic hazard
  - Cooperation – The FERC would invite other agencies to share information with the technical team & sit in on project meetings with the FERC

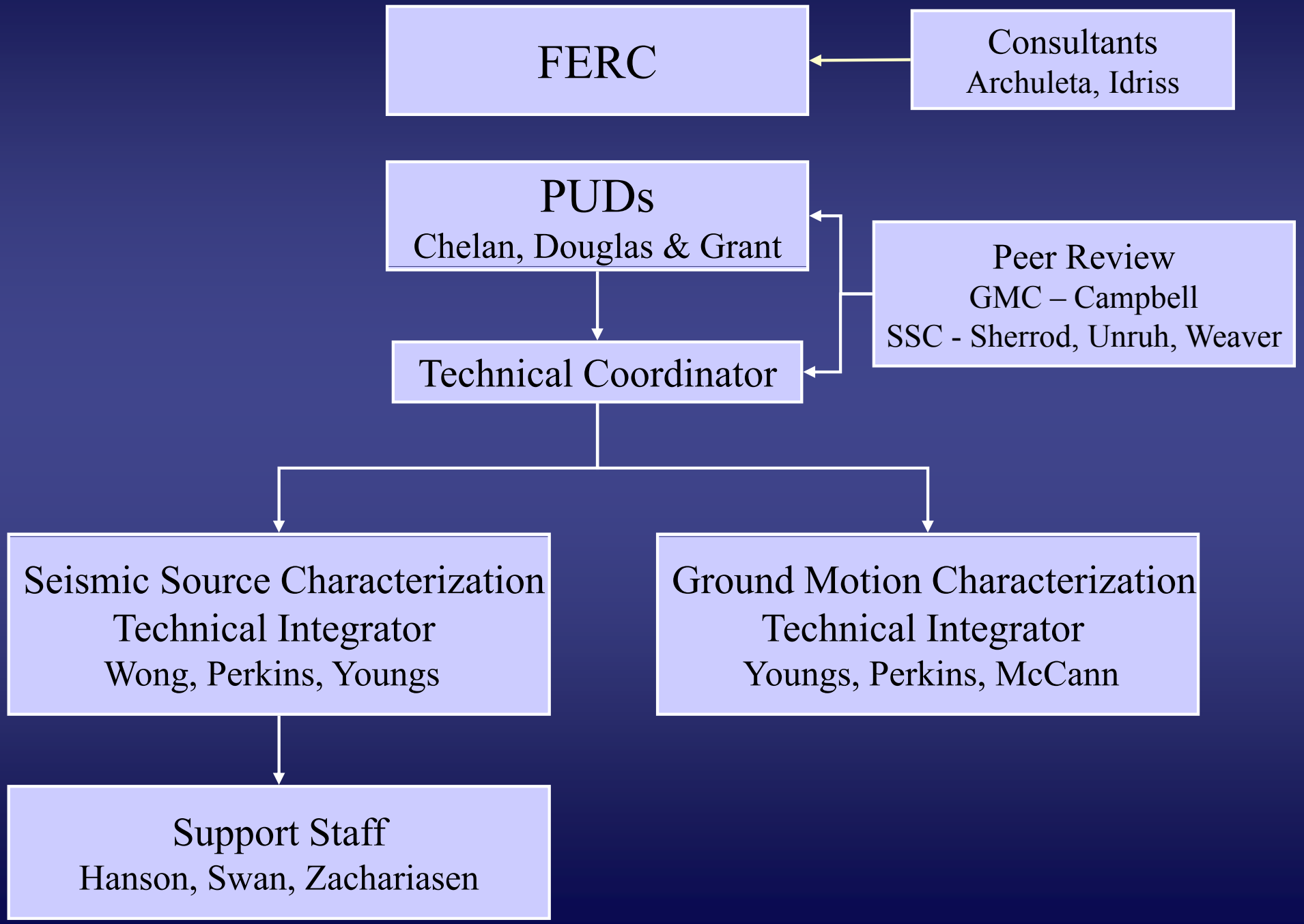
PSHA Project Plan

- Technical
  - PSHA
  - SSHAC process
  - Based on existing information
- Organizational
  - Participating owners
  - Cooperating agencies
- Schedule

Project Participants

- FERC (Headquarters & the regional office)
- Mid-C PUDS – Chelan, Grant & Douglas
- Mid-C Consultants – Geoengineers, Geomatrix, Hatch-Acres, Jacobs, Shannon & Wilson, URS
- Cooperating Agencies – USACE, USBR, USDOE, USGS, WA DOE

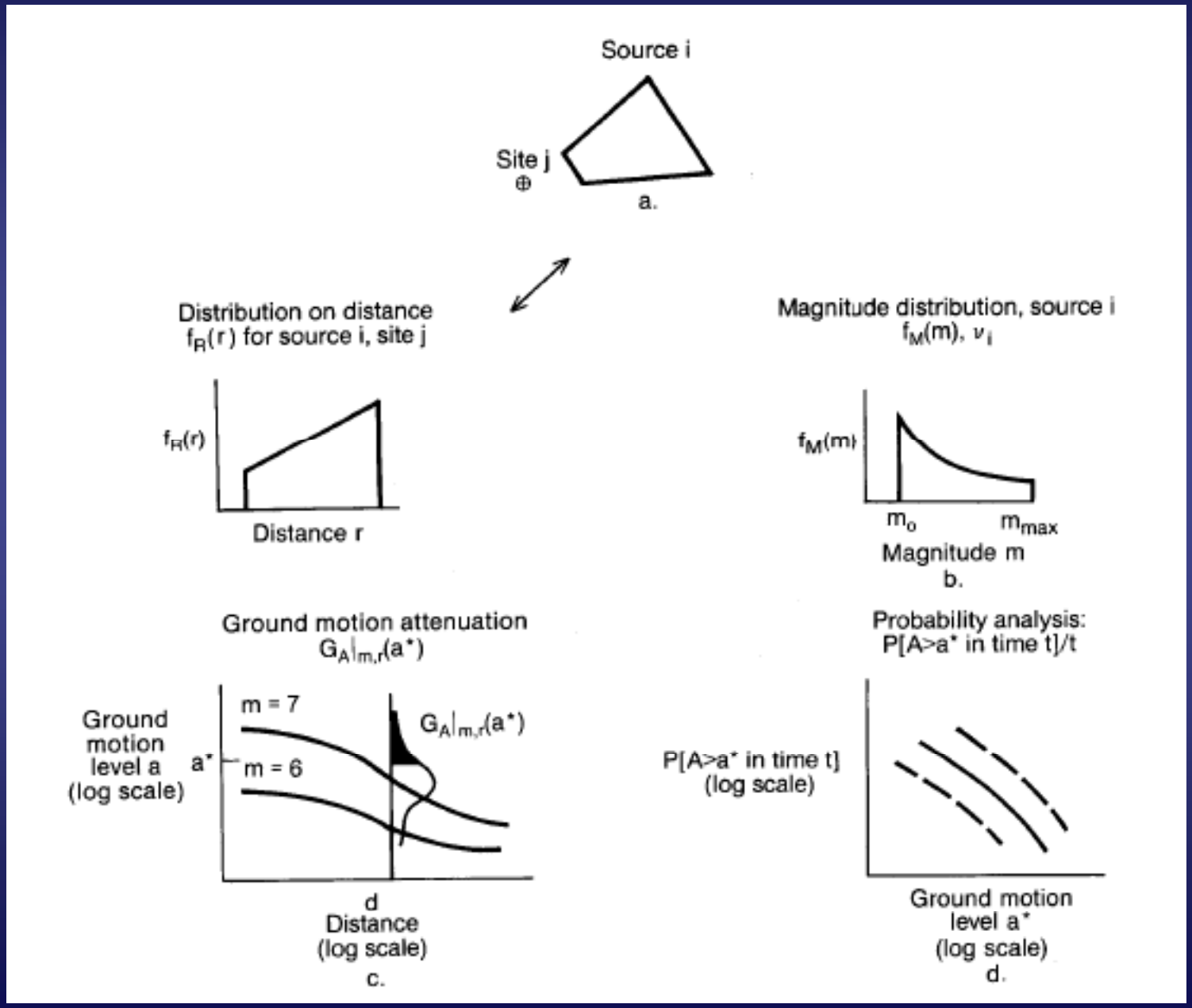
Project Organization



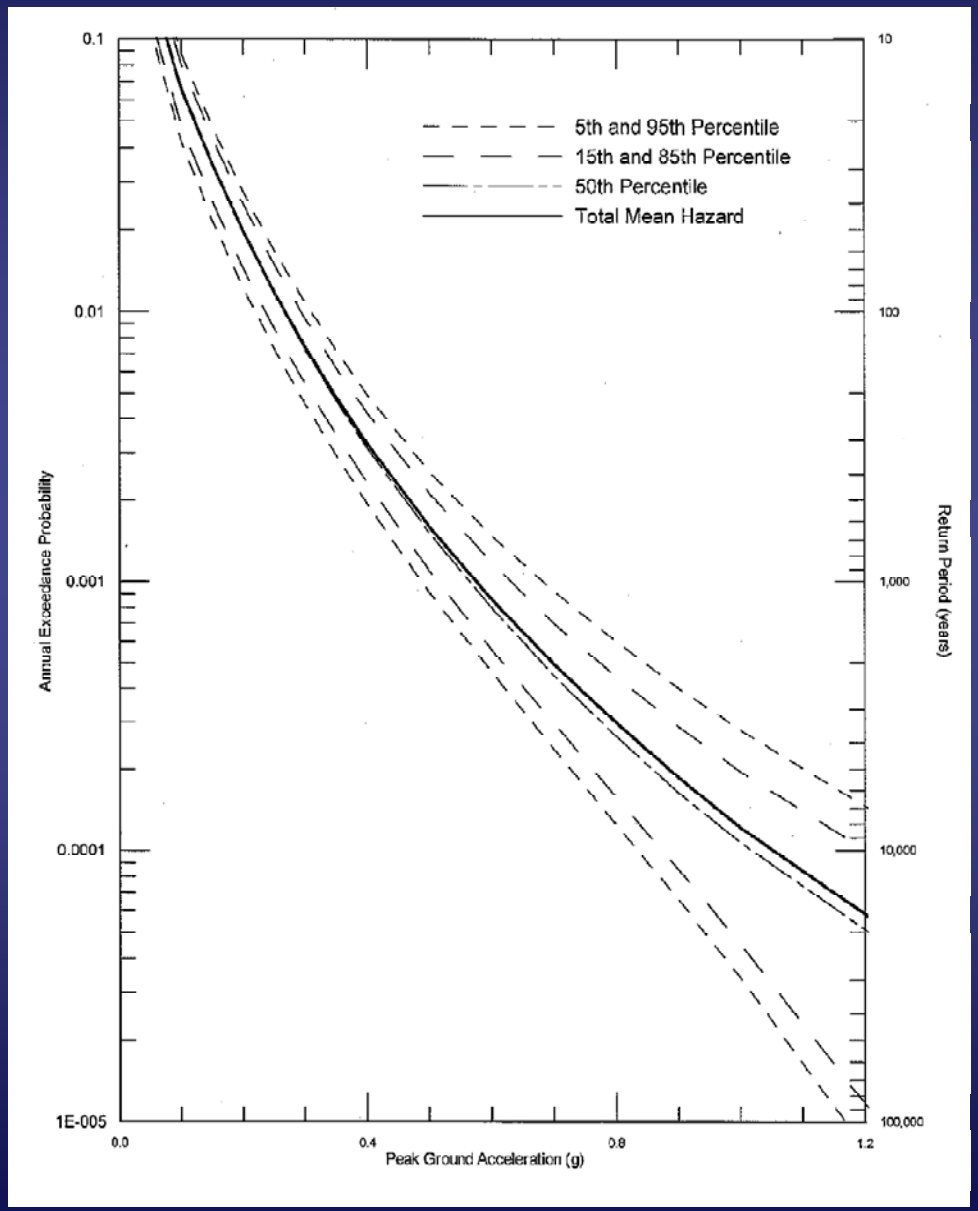
Benefits of Collaboration

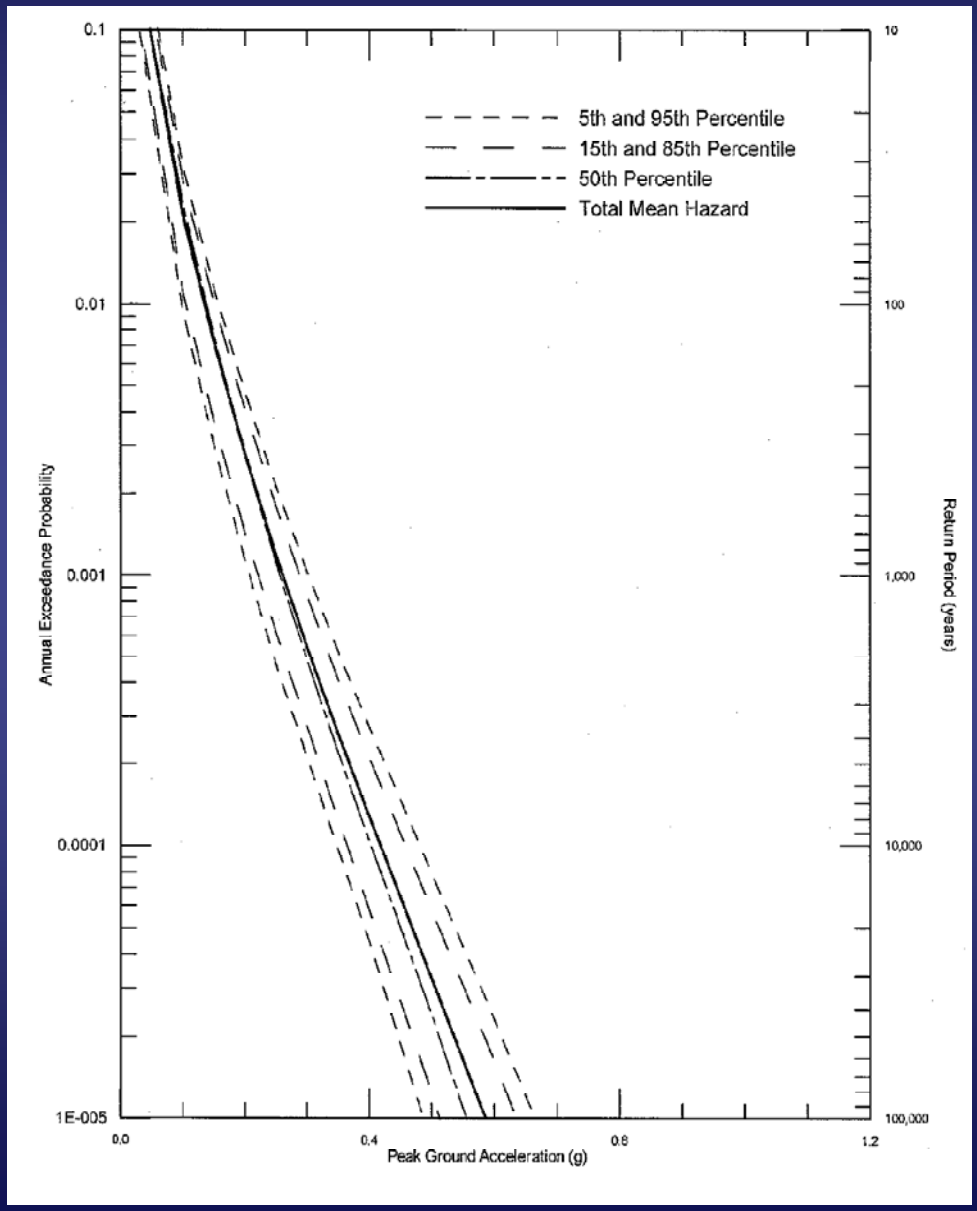
- Increased intellectual robustness & stability in the assessment of seismic hazards in the region
- Technical and fiscal efficiency of pooled resources
- Improved technical coordination among stakeholders

Elements of PSHA



Typical PSHA Result





SSHAC Process

- Mid 90's concern about the approach to evaluate epistemic uncertainty in the source characterization and ground motion attenuation – expert elicitation
- Senior Seismic Hazard Analysis Committee (SSHAC) formed by EPRI, USNRC & USDOE – work published in 1997
- Topics addressed:
  - Goal of a PSHA
  - Project organization & responsibilities
  - Expert elicitation methods
  - Levels of analysis (corvair → cadillac)
  - Peer review
- Currently undergoing review & updating

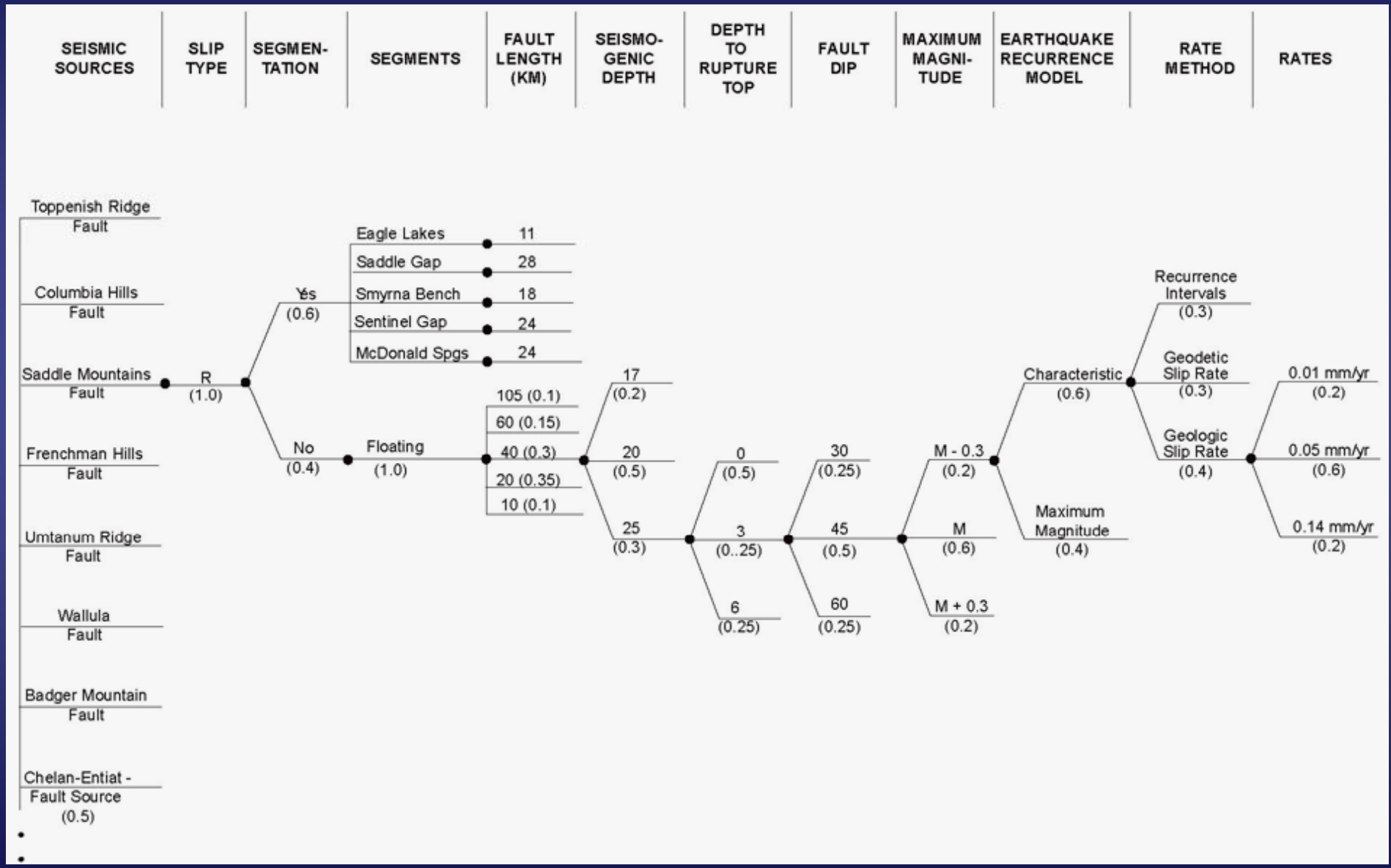
Goal of a PSHA

The goal of a PSHA is to develop inputs that represent the composite distribution of the informed scientific community.

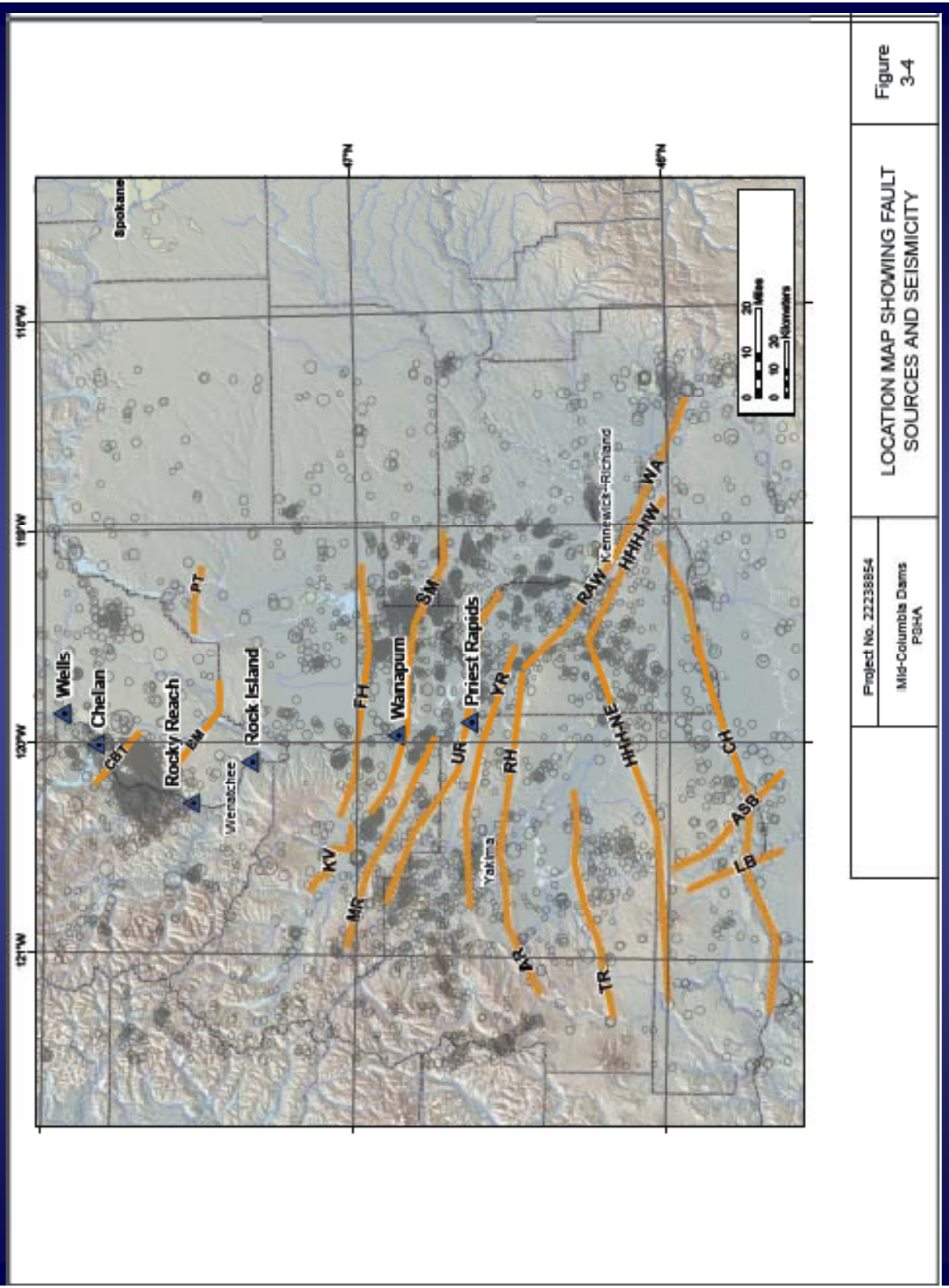
Seismic Source Characterization

- Significant uncertainties in all parts of the PSHA
- For SSC, must rely on expert interpretations of available information
  - Probability of activity of tectonic features
  - Maximum magnitude
  - Fault geometry
  - Recurrence model
- Ground motion attenuation – uncertainties can be large, despite considerable amount of data
  - Data gaps remain (m-d space; faulting type)
- Logic trees are used to model uncertainty in each part of the analysis

Generalized Seismic Source Model Logic Tree



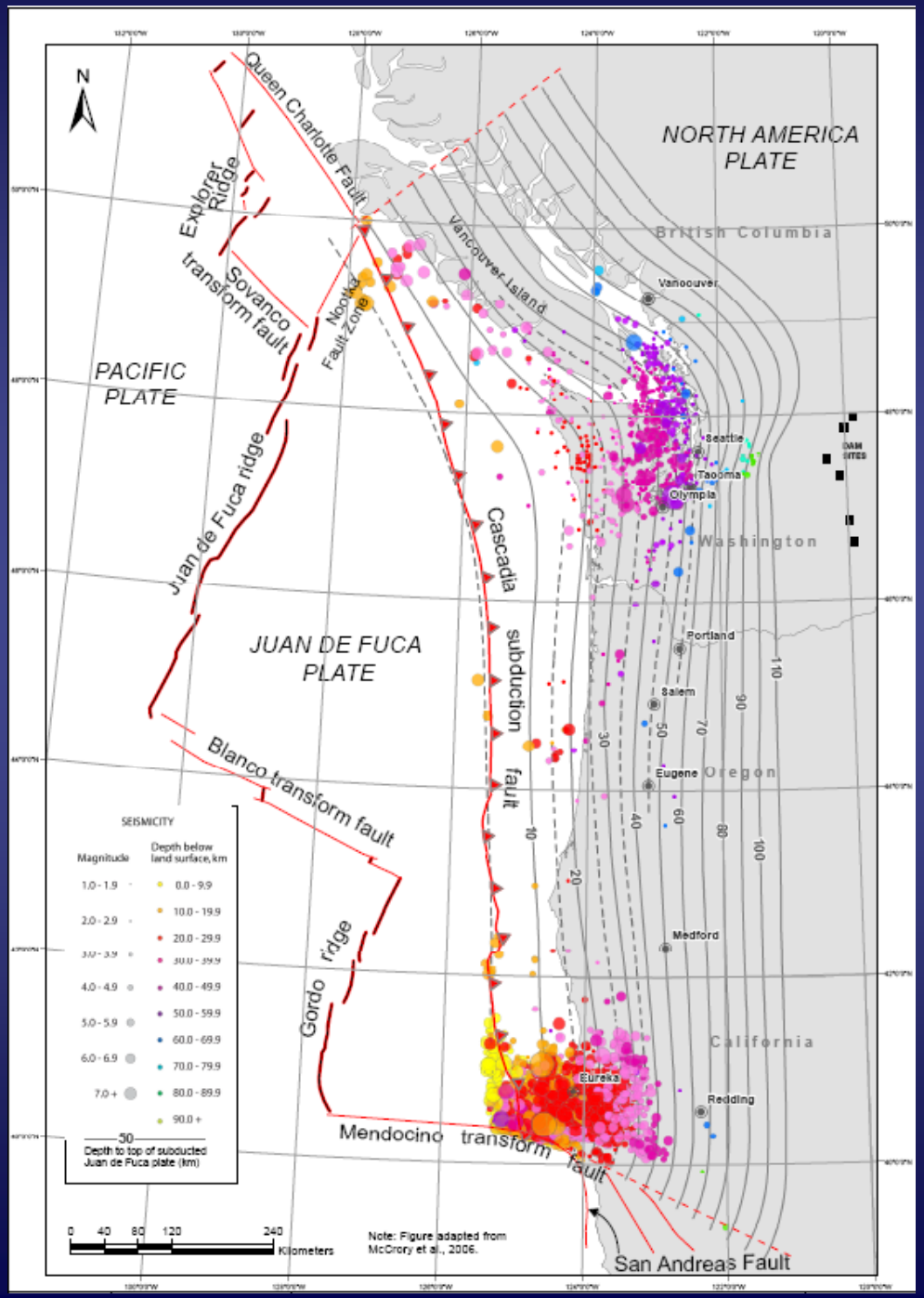
Crustal Sources



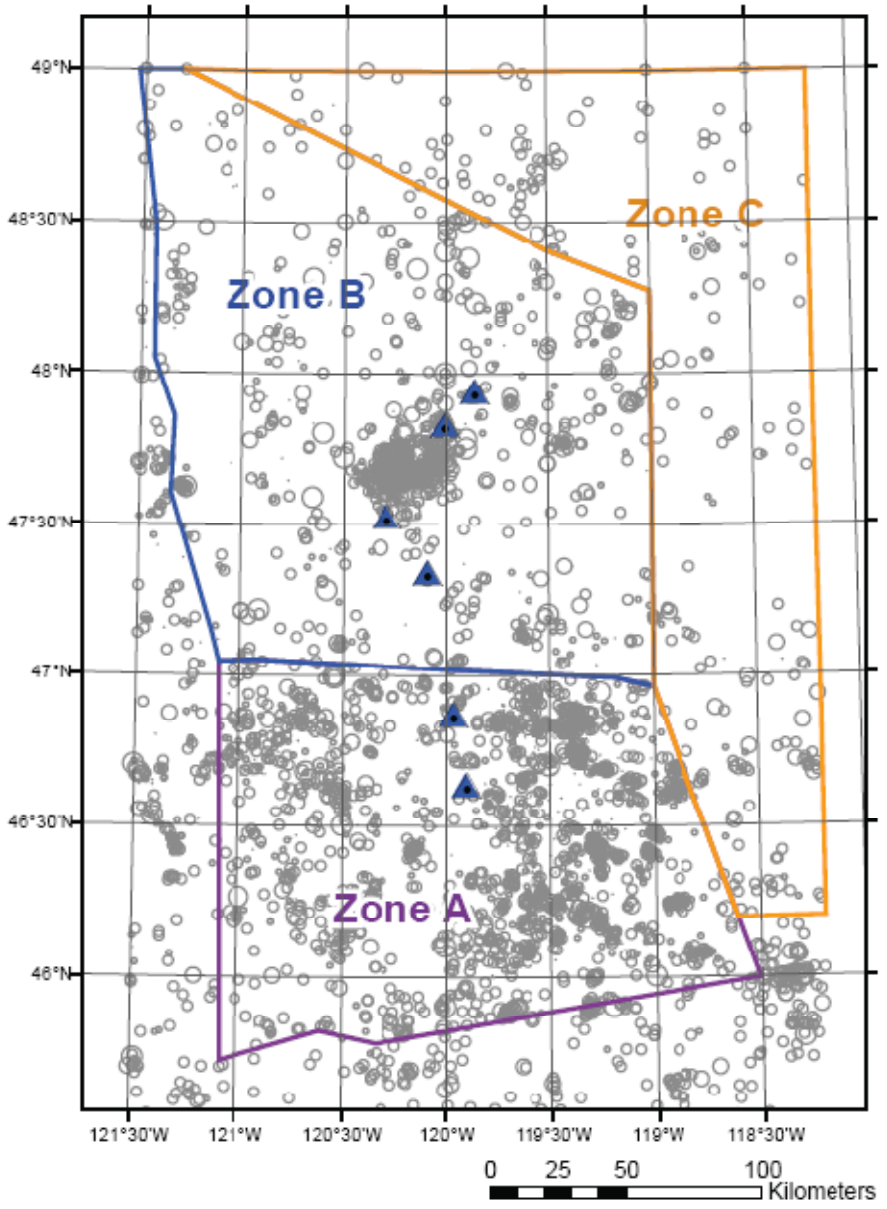
Mid Columbia SSC Model

- Crustal Sources – Faults
  - Columbia Hills anticline
  - Horse Heaven Hills anticline
  - Rattlesnake-Wallula structural trend
  - Toppenish Ridge
  - Ahtanum Ridge/Rattlesnake Hills
  - Yakima Ridge
  - Umtanum Ridge
  - Manastash Ridge
  - Saddle Mountains
  - Frenchman Hills
  - Kittitas Valley faults
  - Arlington-Shutler Butte and Luna Butte faults
  - Badger Mountain anticline
  - Pinto anticline (Pinto fault)
  - Inferred fault associated with the Entiat-Chelan seismic zone

Subduction


N
Queen Charlotte Fault
Explorer Ridge
Sovanco transform fault
Nootka Fault Zone
Vancouver Island
NORTH AMERICA PLATE
British Columbia
Vancouver
PACIFIC PLATE
Juan de Fuca ridge
Cascadia subduction fault
Seattle
Tacoma
Olympia
Washington
JUAN DE FUCA PLATE
Portland
Salem
Eugene
Oregon
Blanco transform fault
Gordo ridge
Medford
California
Eureka
Redding
Mendocino transform fault
San Andreas Fault
SEISMICITY
Magnitude
Depth below land surface, km
1.0 - 1.9
2.0 - 2.9
3.0 - 3.9
4.0 - 4.9
5.0 - 5.9
6.0 - 6.9
7.0 +
0.0 - 9.9
10.0 - 19.9
20.0 - 29.9
30.0 - 39.9
40.0 - 49.9
50.0 - 59.9
60.0 - 69.9
70.0 - 79.9
80.0 - 89.9
90.0 +
Depth to top of subducted Juan de Fuca plate (km)
0 40 80 120 240
Kilometers
Note: Figure adapted from McCrory et al., 2006.

Background Sources



	Mid- Columbia Dams PSHA	AREA SOURCE ZONES FOR PSHA	Figure 3-12
Project No. 22238854			

Ground Motion Attenuation

- Shallow Crustal
  - Reverse earthquakes associated with folds
  - Reverse and strike-slip earthquakes in source zones
  - $5 \leq \mathbf{M} \leq 7.5$
- Cascadia Interface
  - Thrust events $8 \leq \mathbf{M} \leq 9.5$
  - Focal Depths 20-30 km
- Juan de Fuca Intraslab
  - Normal/Strike-slip $5 \leq \mathbf{M} \leq 7.5$
  - Focal Depths 40-100 km

Ground Motion Attenuation

- Crustal
  - Next Generation Attenuation (NGA) models (multi-year; multi-expert project) (~SSHAC Level 4)
  - Supplemented by an epistemic uncertainty model not included in the NGA evaluation
- Subduction
  - Evaluation of existing models (model weights) & review of aleatory variability

Subduction Models

- USGS draft 2007 set
  - Youngs et al. (1997) [0.25]
    - World-wide data
  - Atkinson and Boore (2003) [0.25]
    - World-wide data
  - Zhao et al. (2006) [0.5]
    - Principally Japanese data – all types of events regressed in combined model with differentiating parameters
- Other models
  - Gregor et al. (2006) update of Gregor et al. (2002)
    - Numerical simulation for Cascadia

Summary

- Technical merits
  - Robustness
  - Explicit identification & evaluation of uncertainties
- Project is in its final phases
  - Verification of computer codes and PSHA inputs (3 consultants with 2 different computer codes)
  - Finalization of the ground motion models (crustal & subduction)
  - Site calculations
- Next steps
  - FERC/consultant review
  - How to use the PSHA results in dam safety evaluations?