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30 November - 4 December, 2009

PSHA and Hazard Scenarios

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Nuclear Power Plants in California

(including proposed and cancelled sites)

1.	**<u>Santa Susana Sodium Reactor Experiment</u>**	**1957-1964**	**-closed**
2.	**<u>Vallecitos (PG&E)</u>**	**1957-1963**	**-closed**
3.	Bodega Bay Head (PG&E)	1958-1964	-cancelled
4.	**<u>Humboldt Bay (PG&E)</u>**	**1963-1976**	**-closed**
5.	Point Arena (PG&E)	1966-1972	-cancelled
6.	Malibu (LADWP)	1967	-stopped
7.	Stanislaus (PG&E)	1971-1979	-cancelled
8.	Davenport (PG&E)	early 1970s-1977	-stopped
9.	Sundesert (SDG&E)	1970's-1978	-cancelled
10.	Wasco, Kern County (PG&E-LADWP)	1973	-cancelled
11.	Rancho Seco (SMUD)	1975-1989	-closed
12.	**<u>San Onofre (SCE)</u>**	**1968**	**-operating**
13.	**<u>Diablo Canyon (PG&E)</u>**	**1985**	**-operating**

- PSHA in 10 CFR Parts 50 and 100 of US-NRC — 1997 — -adopted
  [9 years after National Research Council's PSHA Report]

SHA and Important Dates

• US-AEC Established	1947
• DSHA Used Since →	1947
• US-NRC Created	1974
• PSHA Report (US-National Research Council)	1988
• PSHA Introduced Since →	1997

Seismic Hazard Analysis

- DSHA - the standard method is so named to distinguish it from PSHA, now also called “Scenario” Approach
- Neo-DSHA - similar to DSHA, to obtain realistic ground motions using plausible earthquake source and calculating wave propagation from source to site
- PSHA - promoted & endorsed by the US National Research Council in their Panel Report of 1988
- PSHA not open to debate

DSHA

- Characterize Sources of Earthquakes – Faults
  [Selection Criteria, Occurrence Likelihood, Extended Source]
- Estimate Maximum Credible Earthquakes (MCEs)
  [Robustness of Estimate with ¼ Magnitude Round-off]
- Estimate Ground Motions from MCEs by using GM Attenuation Relationships
  [Choice of Mean or above Mean Attn Relationships, lesser M's]
- Select Highest Appropriate GM from one or more MCEs for Design
  [Magnitude-Dependent Spectrum]
- Used Continuously in California Since the 1970s

PSHA(1/2)

- Characterize Sources of Earthquakes – Faults & Areas
  [Faults As in DSHA but less important MCE]

- Estimate Maximum (Credible) Earthquakes (MCEs)
  and Recurrence of Earthquake Magnitudes for the Sources
  [Logic Tree, Seismicity and Slip Rate for Recurrence]

PSHA(2/2)

- Calculate Ground Motions ***probabilistically*** by using GM Attenuation Relationships and Earthquake Recurrence, and “triple” integrating for magnitudes and distances

  [Probability from *Spatial* Attn. Relationships and Time from *Temporal* Recurrence]

- Decide a probability and an exposure time, then obtain the corresponding GM for Design

  [Arbitrary Probability, n combinations of Prob. & Exp. Times, Return Period, and Low Probability GMs Issues]

- First Used in the US Nuclear Power Industry in 1997

DSHA vs PSHA

- Transparency
- Stability of Results
- Variability in Input Data
- Uncertainty or Variability in the Result
- Earthquake Occurrence Temporal Frequency
- Earthquake Sources
- Cost of Analysis
- Selecting Ground Motion for Design

[***Note***:Both can use same Faults and Attn. Relationships]

DSHA vs PSHA(1/4)

- **Transparency**

DSHA - transparent.

Inputs and results - directly related.

PSHA - not transparent.

Inputs and results - not directly correlated.

- **Stability of Results**

DSHA results - as stable as the inputs are.

Increase above the mean, or vice versa as desired.

Not much room for changing results.

PSHA results and inputs – variability.

Quite sensitive to some inputs, being complex calculation.
Results easily manipulatable.

DSHA vs PSHA(2/4)

- **Variability in Input Data**

DSHA - best estimate of input data.

Not necessary to formalize the variability, eg., MCE.

PSHA - expert opinion and logic tree to incorporate variability.

- **Uncertainty or Variability in the Result**

DSHA - results from best estimate inputs.

Usually mean, eg., mean peak ground motion.

PSHA divides uncertainty into

aleatory/random and epistemic/subjective components.

Some questioned why separating into two components.

DSHA vs PSHA(3/4)

- **Earthquake OccurrenceTemporal Frequency**

DSHA - not consider frequency of earthquakes magnitude.

Assumes only the occurrence of MCE at any time.

Exceeds and ***automatically considers all other events***.

PSHA - earthquake recurrence by Gutenberg-Richter Eqn.

Continuous distribution of magnitudes, up to MCE.

Recurrence rate - measure of earthquake activity rate.

Availability and Interpretation of Data (completeness & Eq Budget)

- **Earthquake Sources**

DSHA – faults.

No faults with ground motions, eg., Central Valley.

PSHA – faults & areas.

DSHA vs PSHA(4/4)

- **Cost of Analysis**

DSHA – economic, less time & analysis.

PSHA – expensive, more time & analysis.

- **Selecting Ground Motion for Design**

DSHA - compares GMs from all MCEs.

Ones impact most - for design.

PSHA first peak acceleration with given probability and exposure time, the non-unique n combinations.

Source for that peak acceleration - by ***deaggregation***.

Followed by standard DSHA procedure.

Personal Experience with PSHA

- **San Onofre** NPP - Christianitos fault by Gutenberg-Richter equation, inadequate data.
- **Diablo Canyon** NPP - Hosgri fault, no problem with DSHA and problem with PSHA.
- **Bolsa Chica** Project - Newport-Inglewood fault, unrealistic result by PSHA.
- **Hospital** Seismic Reports - Too low hazard for Central Valley.
- **California Seismic Hazard Map** for Caltrans - Critical input not available for many faults and PSHA results not correlated with proximity to earthquake source.

PSHA CREDIBILITY IN DOUBT

- Yucca Mountain Nuclear Waste Disposal Facility project for the US Department of Energy on ***Extreme Ground Motions***

- PEGASOS project for SwissNuclear on ***Overestimated Ground Motions***

CONCLUSIONS & RECOMMENDATIONS

- DSHA demonstrated its stability and usefulness in engineering, be enhanced by including the variability of inputs and results
- Neo-DSHA can be used for realistic seismic sources in conjunction with DSHA
- PSHA demonstrated its lack of credibility, with its intractable and costly method, and must be replaced by DSHA for engineering
- Seismic Risk Analysis can use PSHA or DSHA*.

*Klugel, J.-U., Mualchin, L. and Panza, G. F. (2006): Eng. Geology: 88, 1-22.