Approaches for Developing Uniform Hazard Spectra at Critical Facilities

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Discussion Topics

- Why evaluation is needed
- Definitions of different approaches for developing soil UHS that are consistent with rock UHS
  - Approaches 1, 2A, 2B, 3, and 4
- Example of Approach 1/2 calibrated to Approach 3 at LANL for pre-conceptual facility evaluation

Why Evaluation is Needed

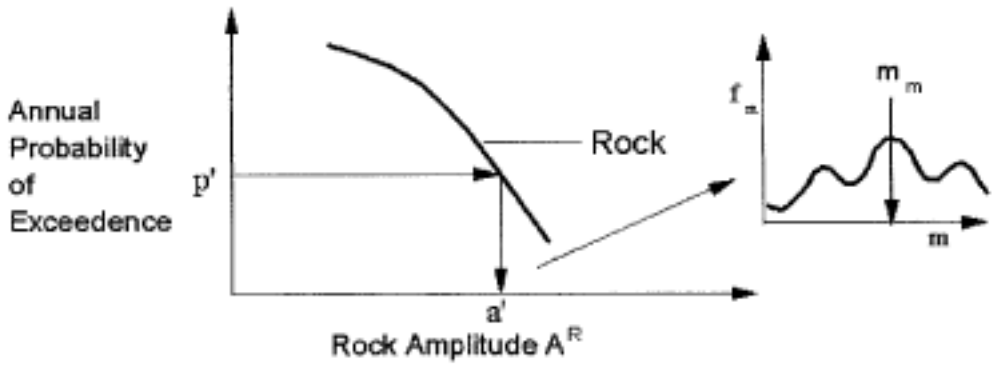
- For embedded facilities, need to develop hazard-consistent motions at several elevations within the soil profile
  - ASCE 4 allows for two approaches;
    - FIRS input + convolution
    - Deconvolution of surface DRS + check of in-column (free-field) motion at foundation level
  - FIRS and in-column motion aim to maintain consistent risk with the hazard defined in the PSHA
- PSHA may not be able to be repeated
  - Too costly
  - Attenuation models of the soil site may not be available
- Need a method for developing input motions at multiple elevations within the soil profile

Approaches for Developing Soil UHS

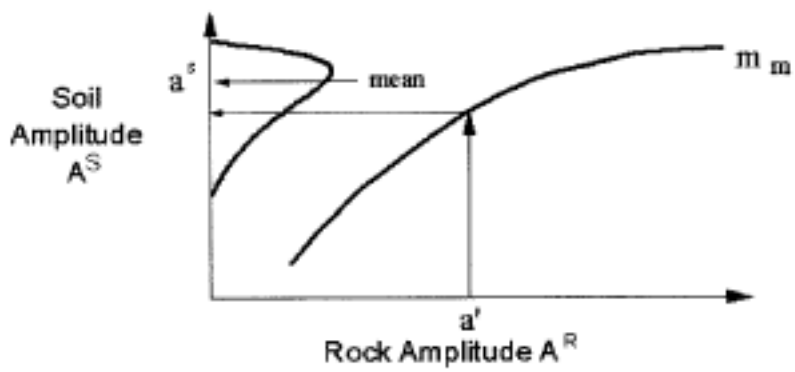
- Approach 1
  - Direct scaling of rock UHS
  - Appropriate if soil uncertainties are small or can be explicitly accounted for
  - Implies that a single, broadband motion representing the rock UHS will drive the soil column
  - Recognized that this may be unconservative
    - May "over-drive" soil column
    - Won't properly account for NL soil effects expected for a broad range of earthquakes considered in the definition of the rock UHS

Approach 1

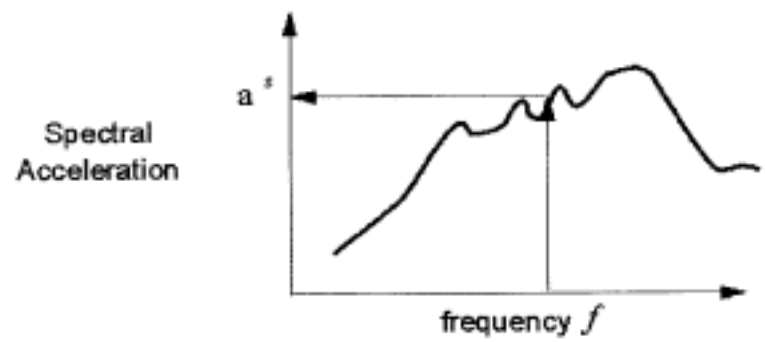
Source: NUREG/CR-6728



A. Rock Seismic Hazard Curve



B. Soil Amplitude vs. Rock Amplitude, given a'



C. UHS on Soil

Approach 2A

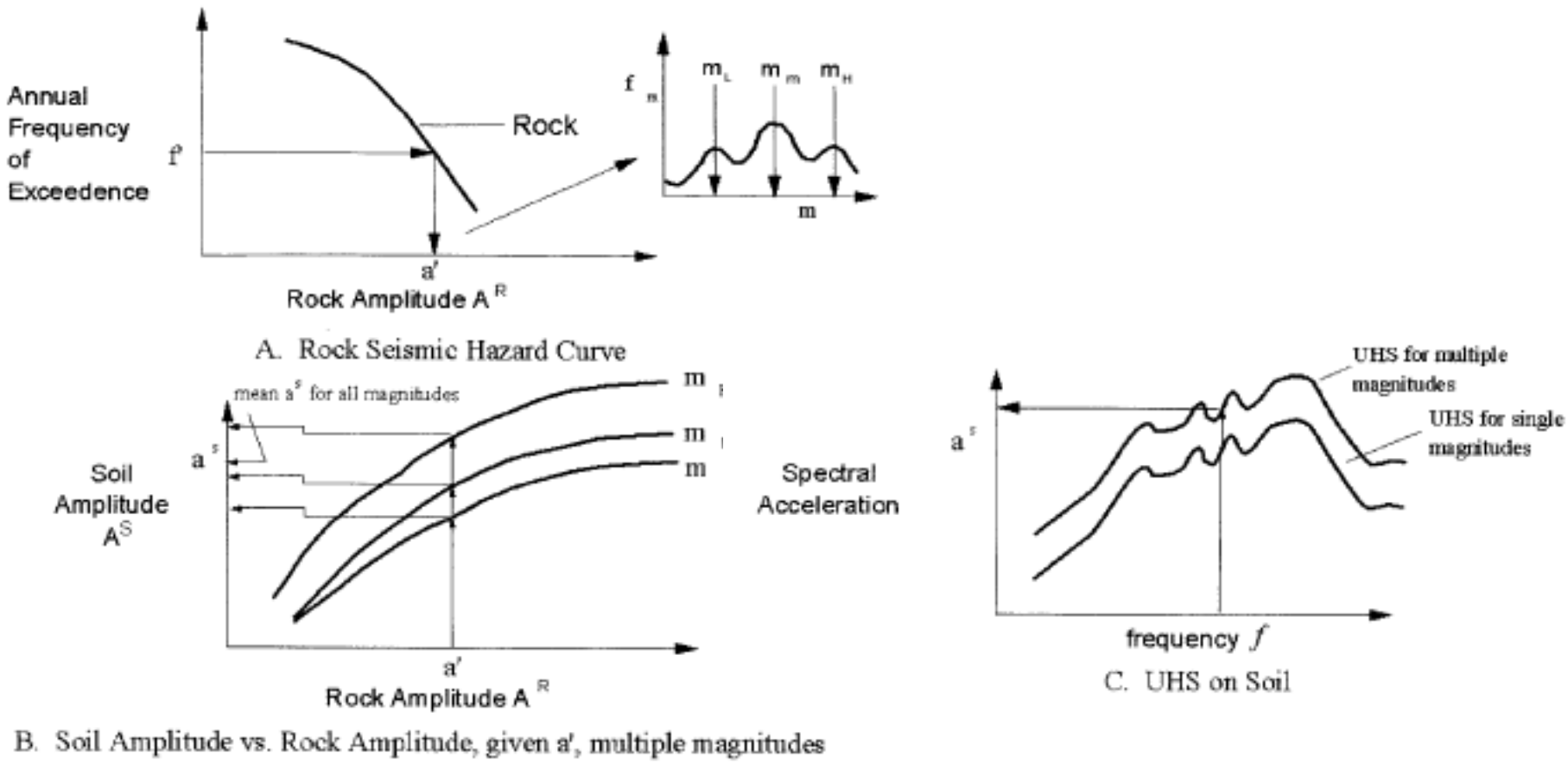
- To minimize overestimating NL effects, the rock input spectra from the PSHA can be modified into a “low frequency” (1 Hz) and “high frequency” (10 Hz) spectrum
- Spectra are generated from the deaggregated hazard data (M and D)
- Resulting soil UHS can be enveloped to obtain overall soil UHS
- Better accounts for effects of magnitude of input spectra on NL soil effects

Approach 2B

- Further refinement of Approach 2A wherein multiple spectra are defined at the low and high frequency
- Better accounts for the variability in input magnitudes and distances defined in the PSHA
- Recognizes that magnitude, for a given rock amplitude, has a strong effect on NL soil response

Approach 2A/2B

Source: NUREG/CR-6728



Approach 4

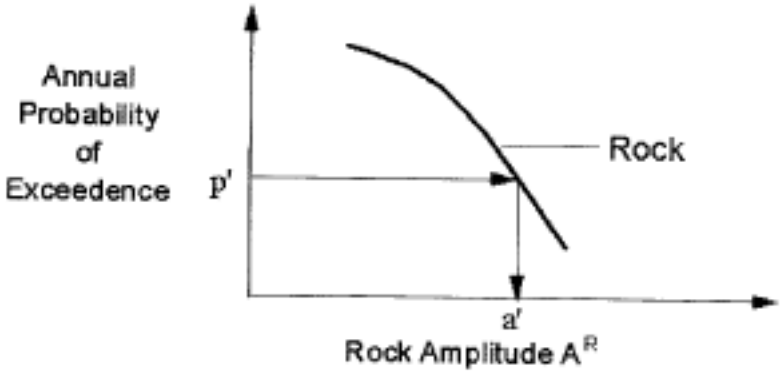
- Approach based on integration accounting for soil amplitude, magnitude, and distance
- Considers full range of soil response effects from every realization of the rock input motions
- Captures full variability associated with all ground motion events considered in the PSHA
- Drawbacks
  - Need applicable soil attenuation equations
  - Empirical attenuation equations use observations at multiple sites, usually on similar soil conditions
    - For our particular site, the attenuation equations might not be applicable

Approach 3

- Simplification of Approach 4
- Discretizes rock motions to the entire hazard over ranges where soil amplification is relatively constant with magnitude

Approach 4

Source: NUREG/CR-6728



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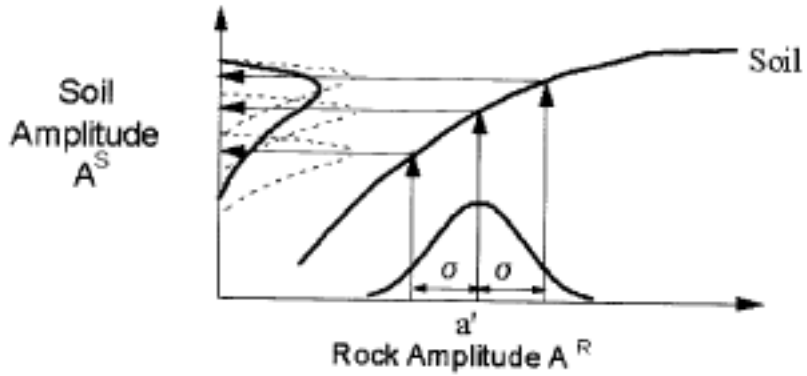
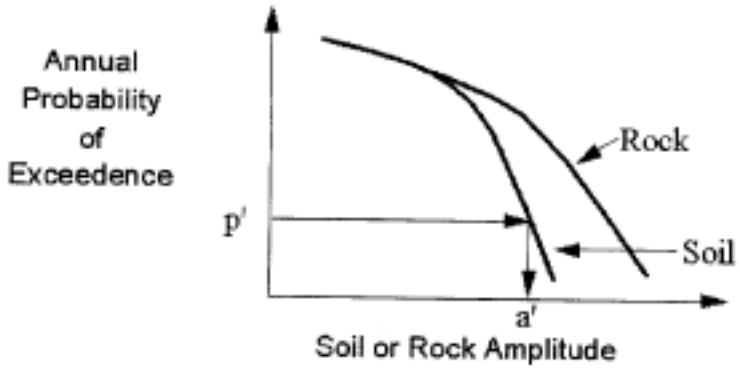


B. Soil Amplitude vs. Rock Amplitude, given M



C. Soil Seismic Hazard Curves

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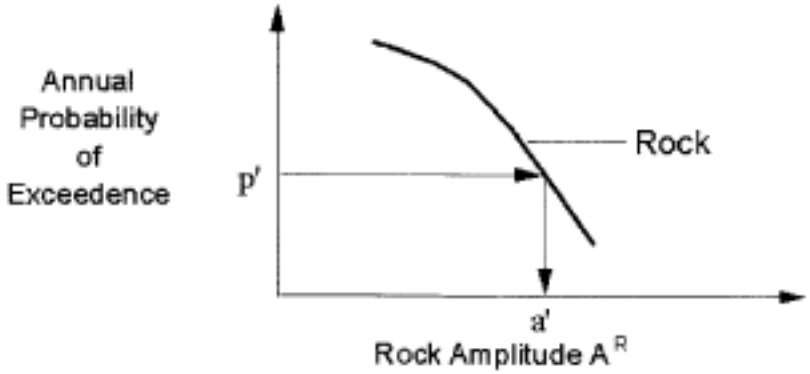
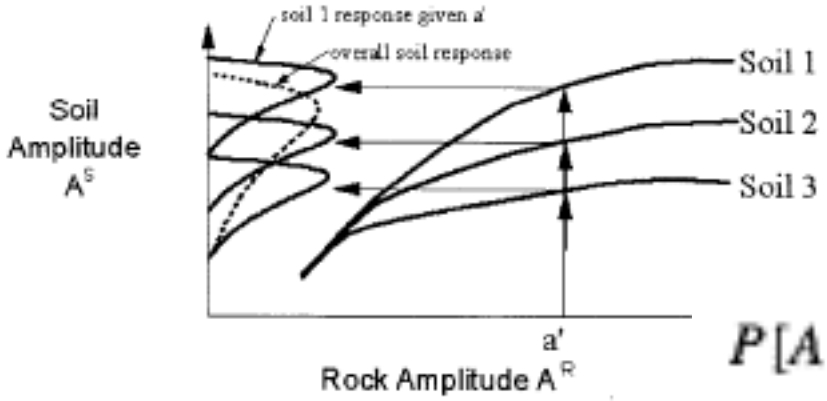
Approach 3

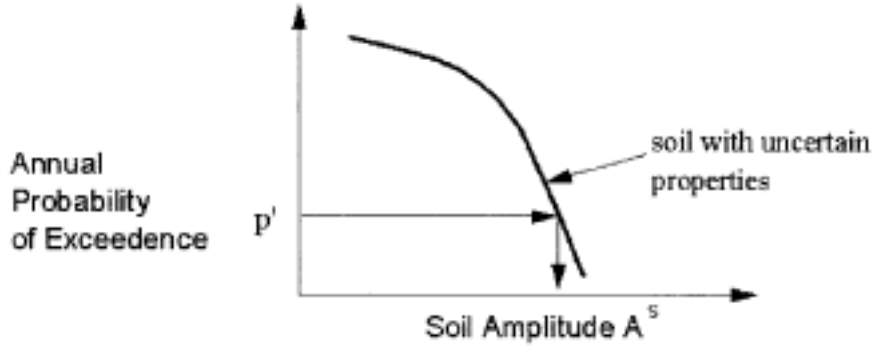
Source: NUREG/CR-6728



A. Rock seismic hazard curve



B. Soil amplitudes vs. rock for three sets of soil ch



C. Soil seismic hazard curves

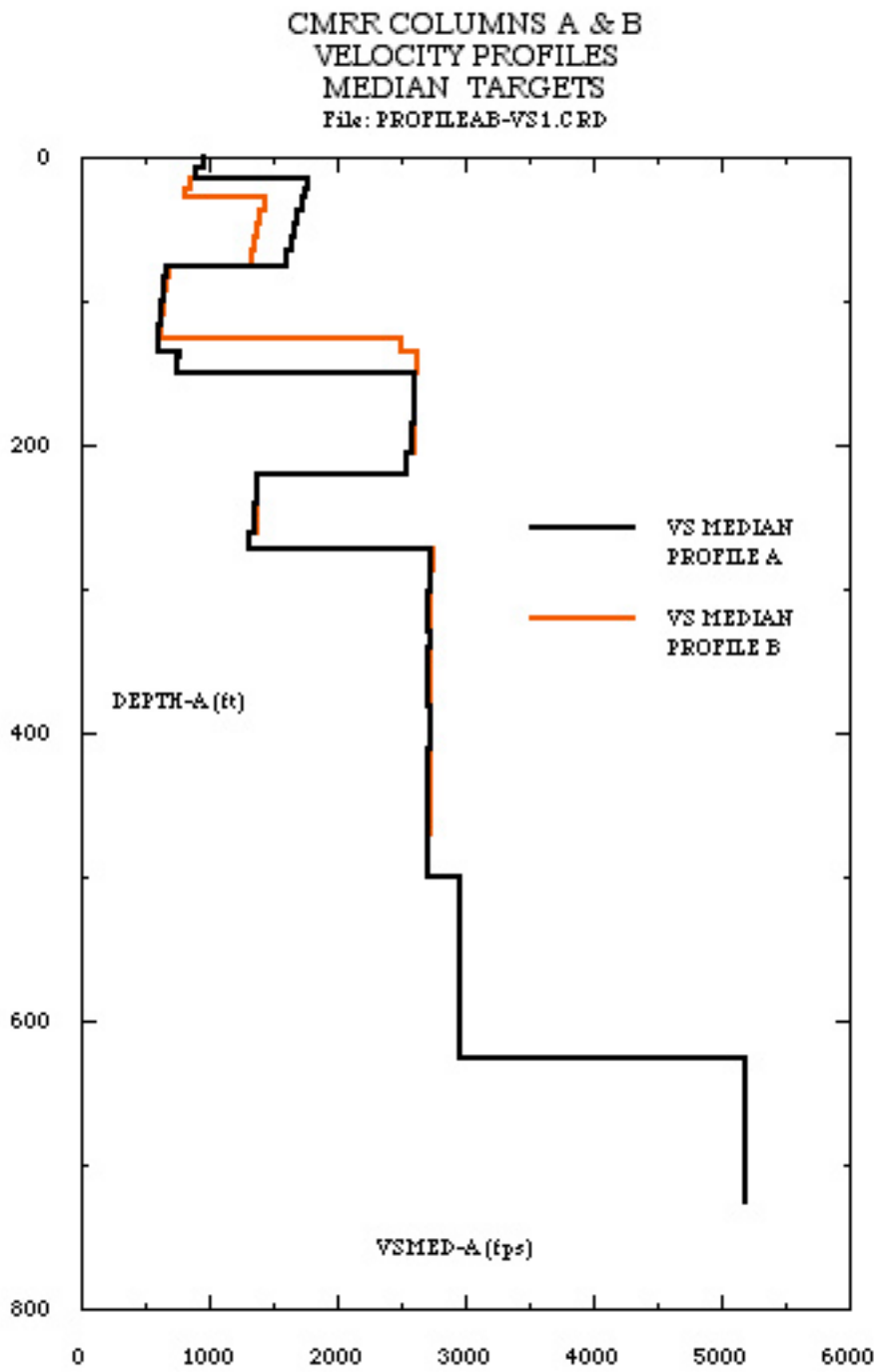
$$P[A^s > z] = \int P[AF(a', m') > \frac{z}{a} | a] f_a(a) da$$

LANL Example

- Tasked with performing SSI analysis for proof-of-concept evaluation of a pre-conceptual facility
  - Evolving design
  - Method for providing estimates is valid for proof-of-concept evaluation
- LANL PSHA provides rock and surface UHRS
  - Surface UHRS includes amplification factors accounting for topography and differences between Method 2/3
- Need to estimate spectra at multiple depths in a manner consistent with the development of the PSHA motions

LANL Example (cont.)

- Iterated soil profiles retrieved from PSHA
  - Two base case profiles considered
  - Include nonlinear soil response from Approach 3
- 60 realizations for each base case developed
- Convolve rock UHRS and compute mean S_a at surface
- To account for Method 3 effects, compute $Sa_{UHRS}/Sa_{convolve}$ at surface
- Ratio used to scale in-layer motions to incorporate "Method 3 effects"



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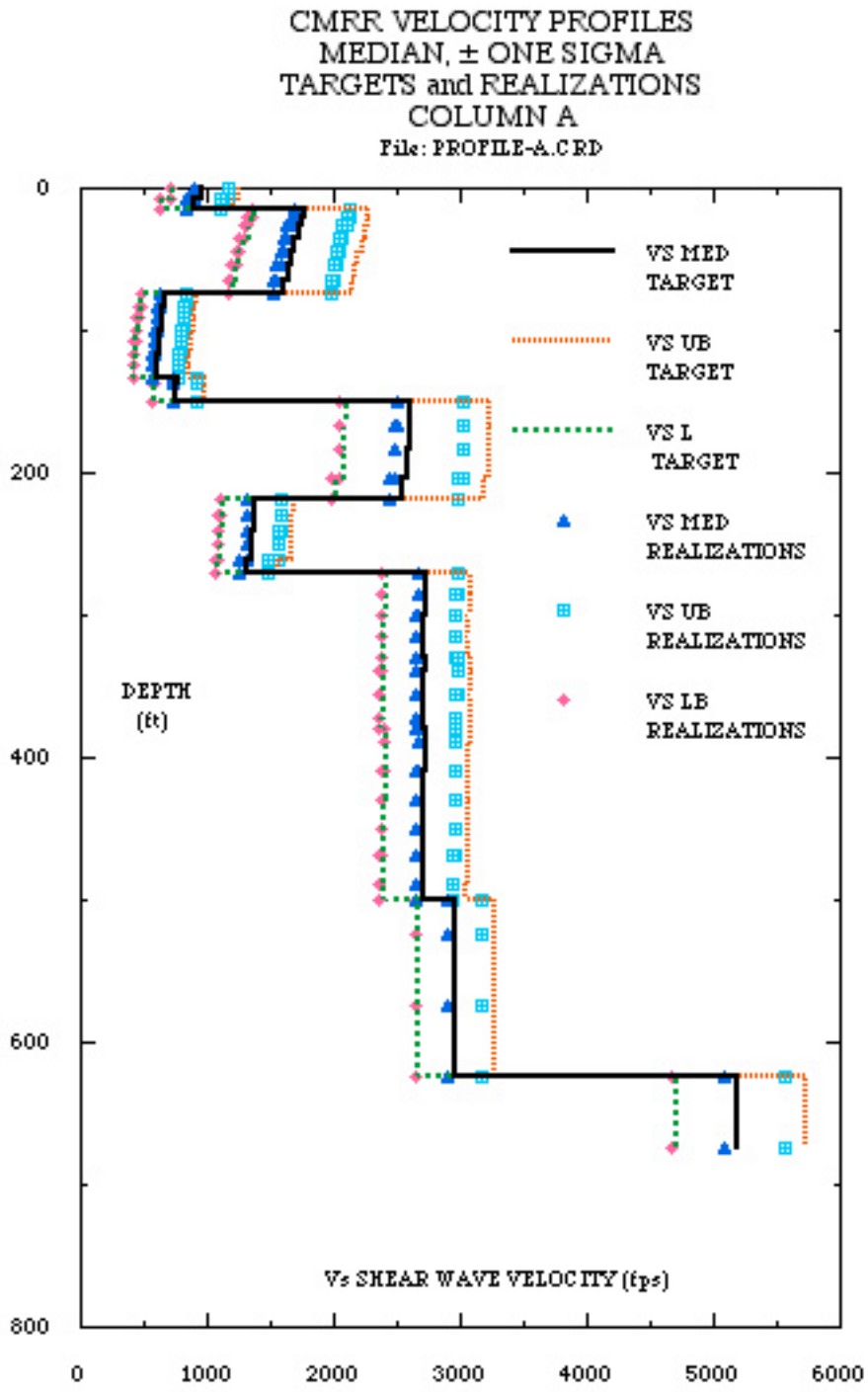

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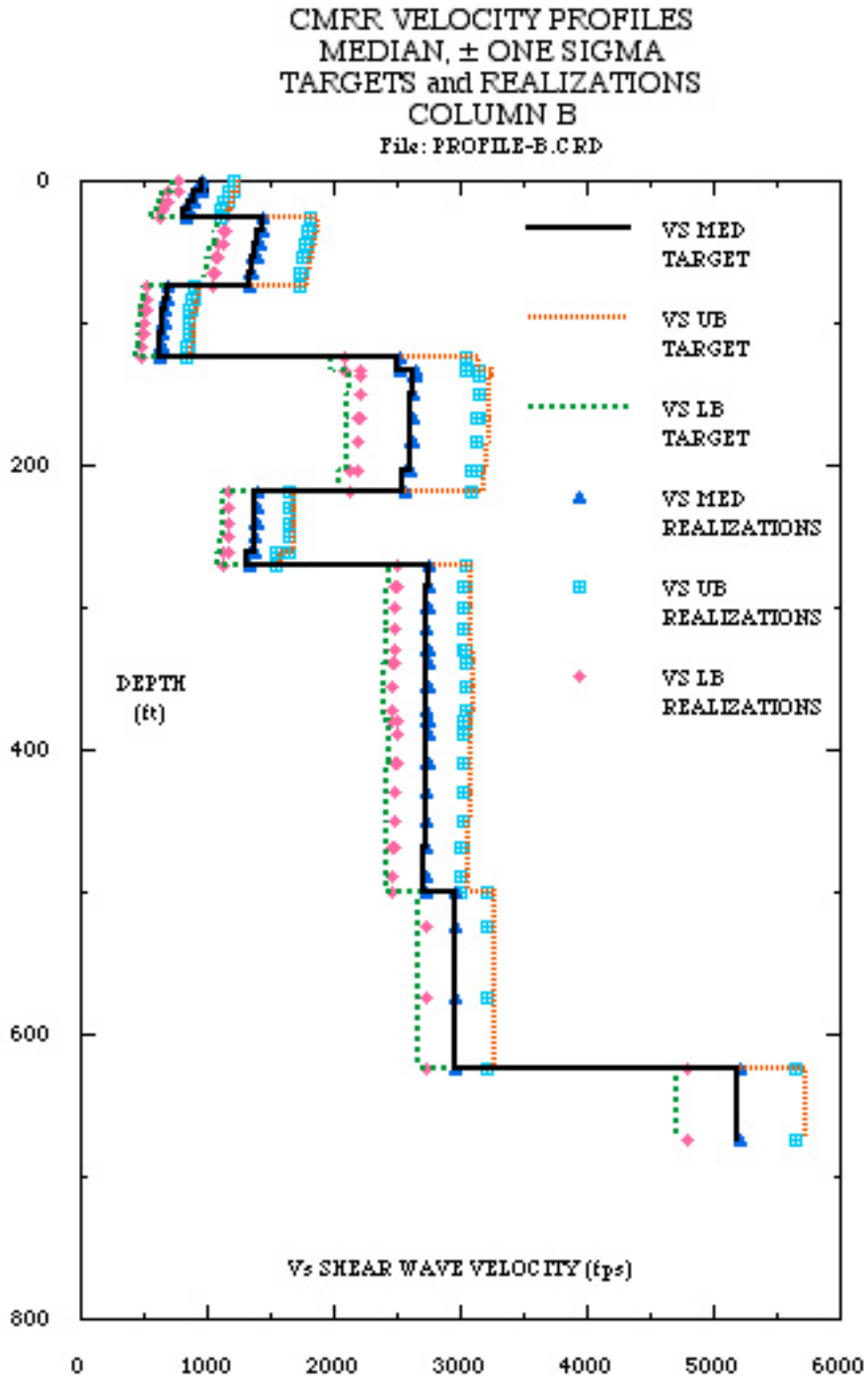

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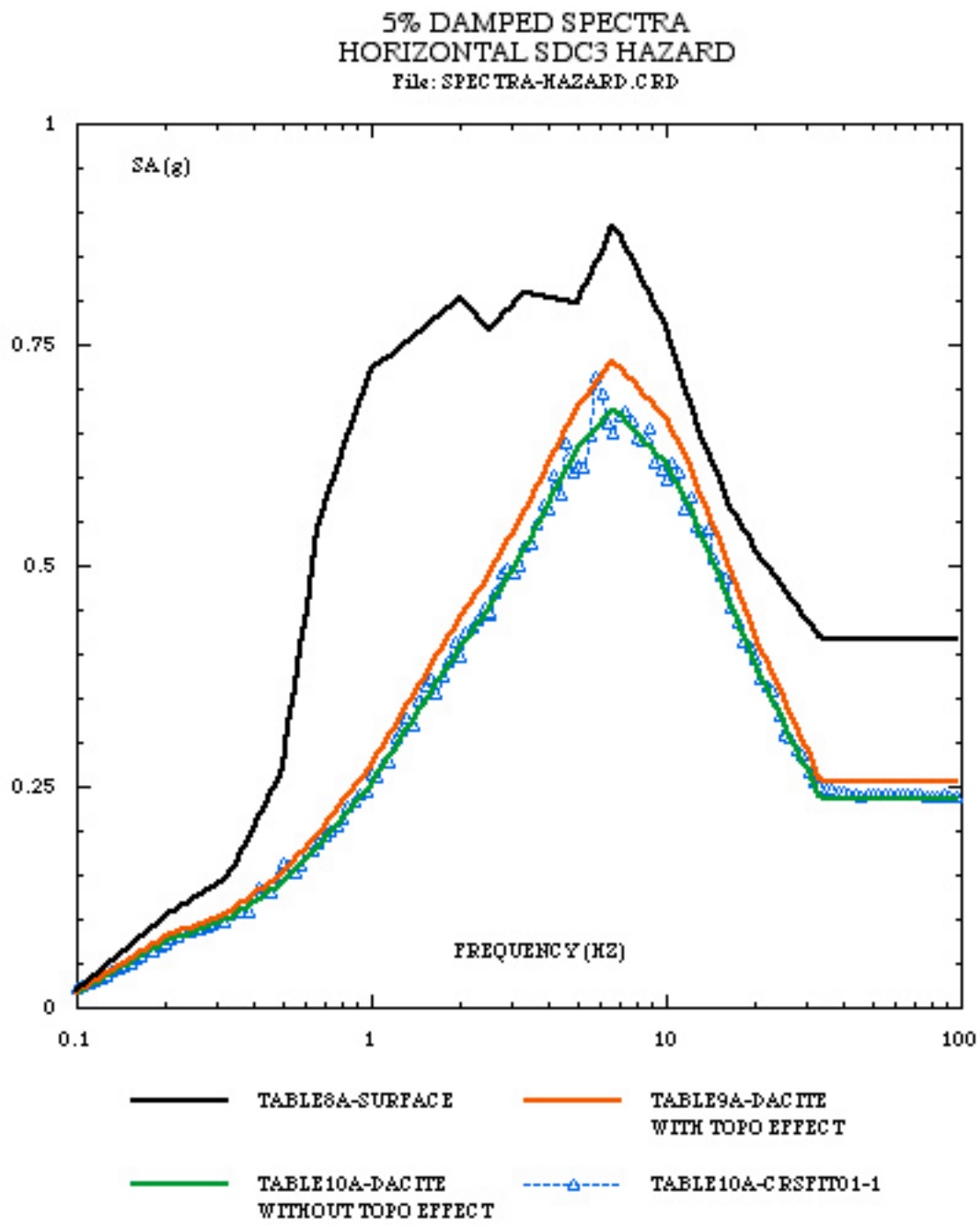

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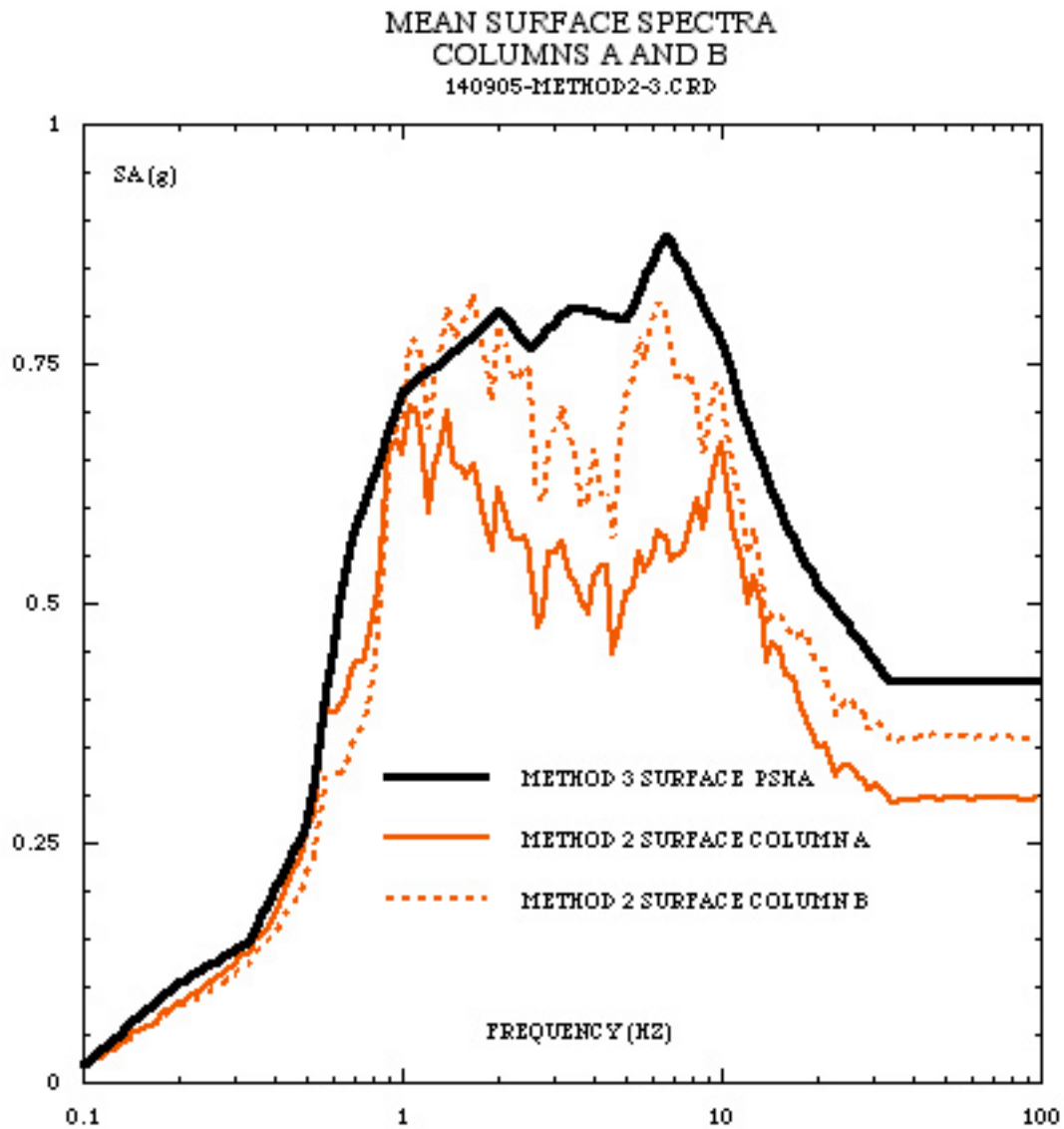

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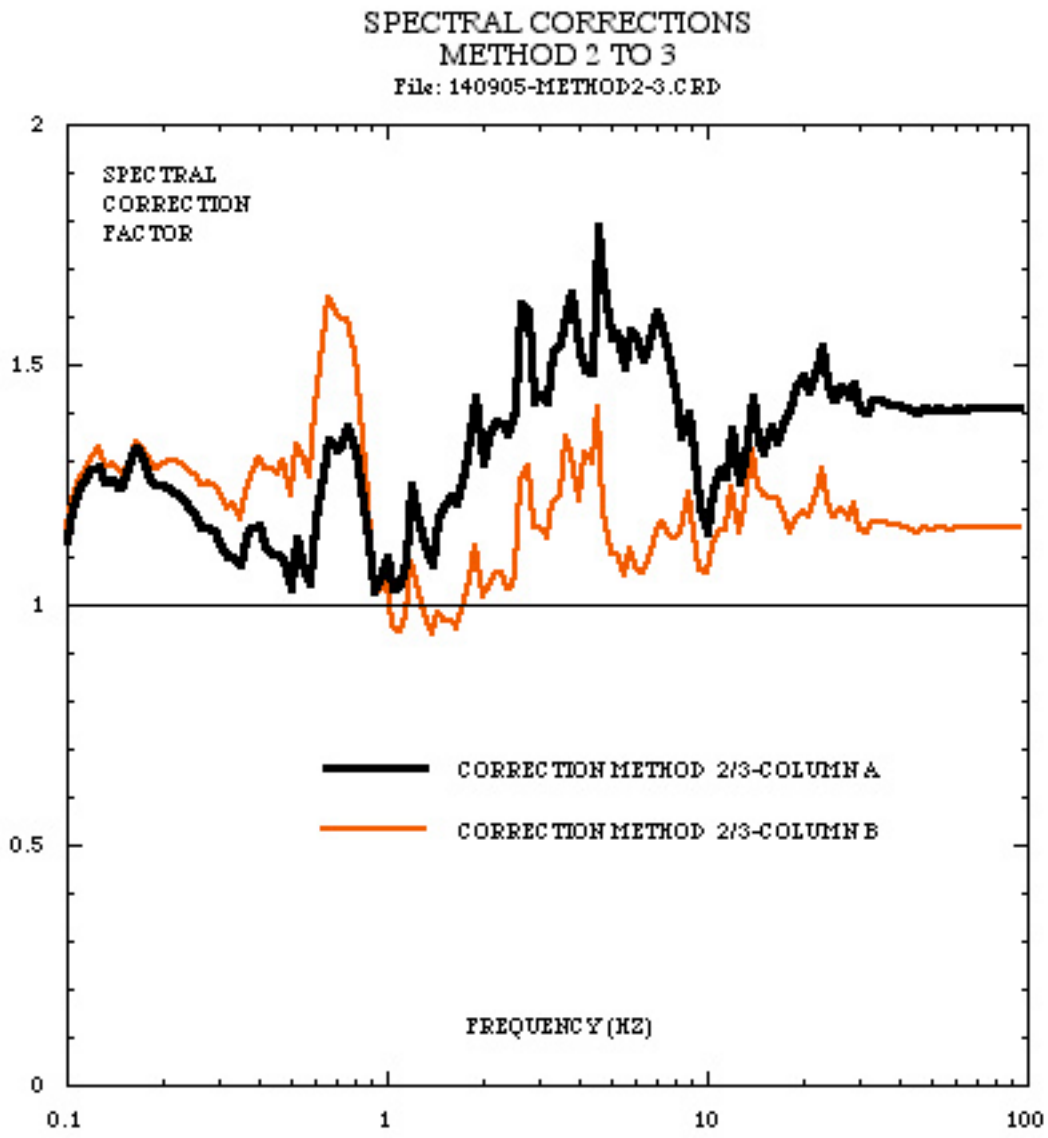

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Conclusions

- Standard ASCE 4 discusses four approaches for developing UHRS on soil or rock sites
- Approaches aim to maintain consistency with rock hazard defined by a PSHA
- Example presented that incorporated Approach 3 effects for developed of in-layer motions for a pre-conceptual evaluation