

StrongMotions
Knowledge and Clarity **Inc.**

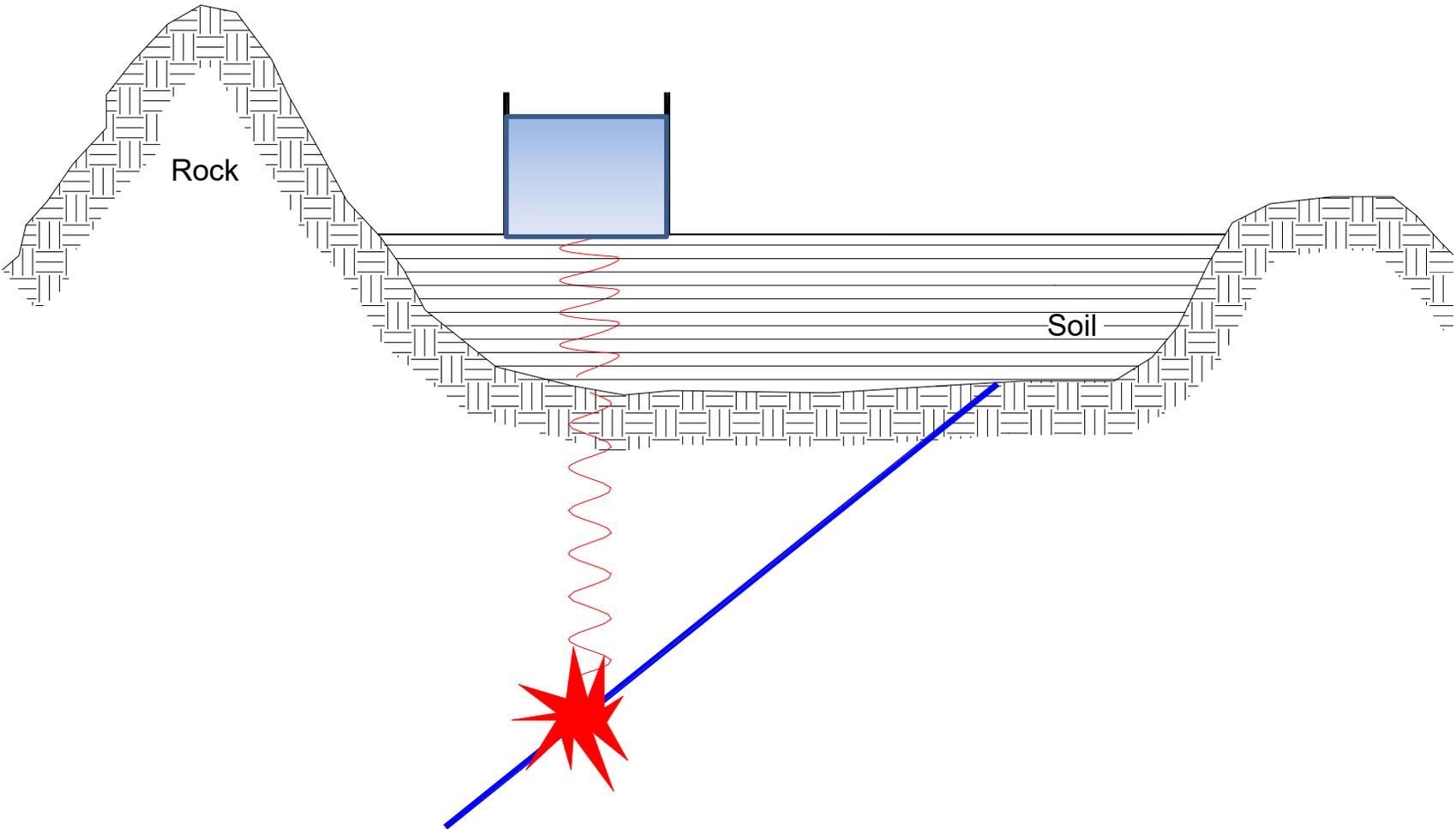
Site-Specific Ground Motions for Seismic Design of LNG Tanks

Praveen K. Malhotra

October 21, 2021

ACI Convention

Overview



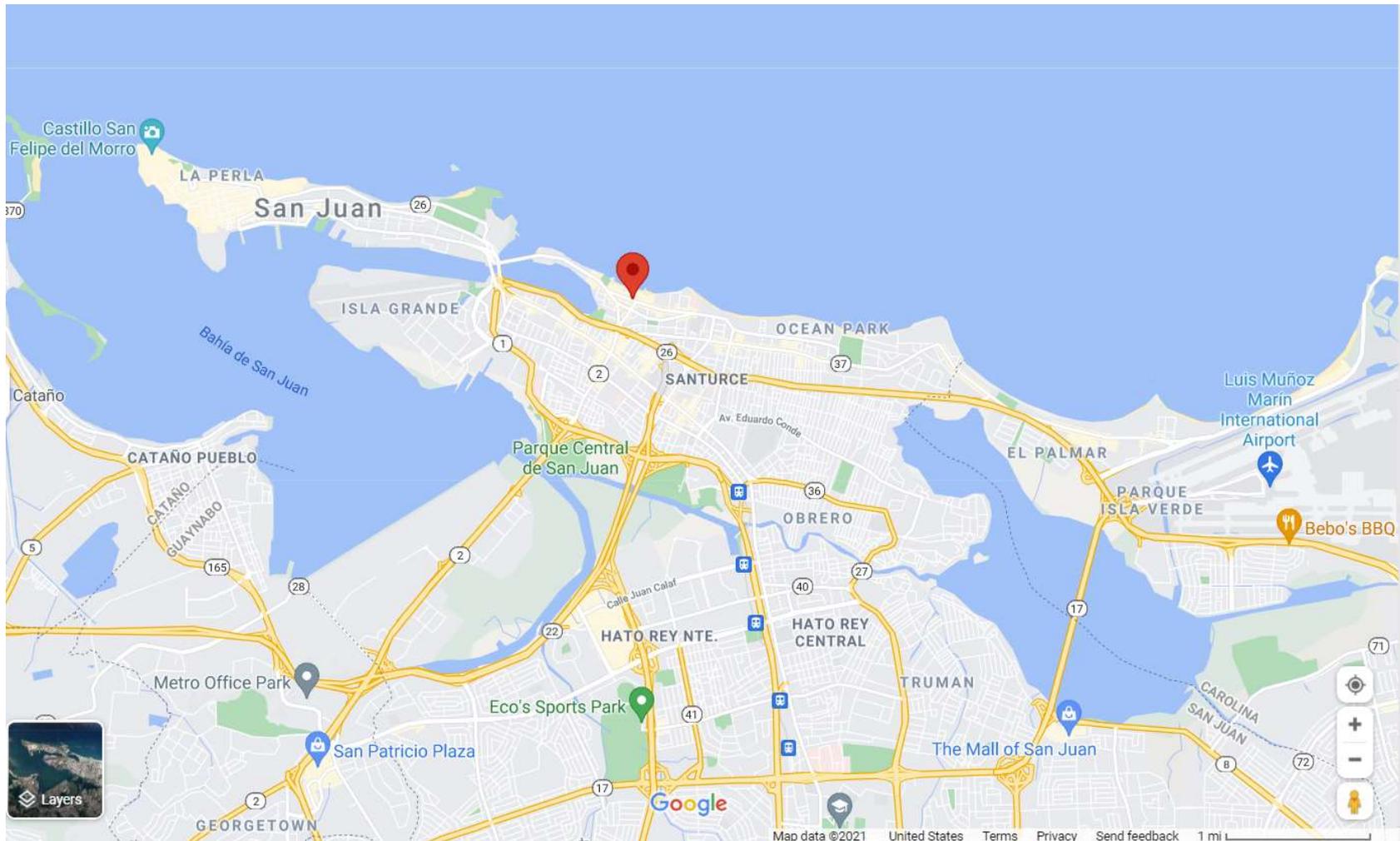
Probabilistic Seismic Hazard Analysis (PSHA) by the USGS

- The USGS perform the work of geologists and seismologists to generate ground motions for 'rock like' conditions throughout the USA
- Engineers need to adjust these ground motions for local soil conditions at the site
- Engineers also need to make some other adjustments to meet code requirements
- Those adjustments are discussed in this presentation

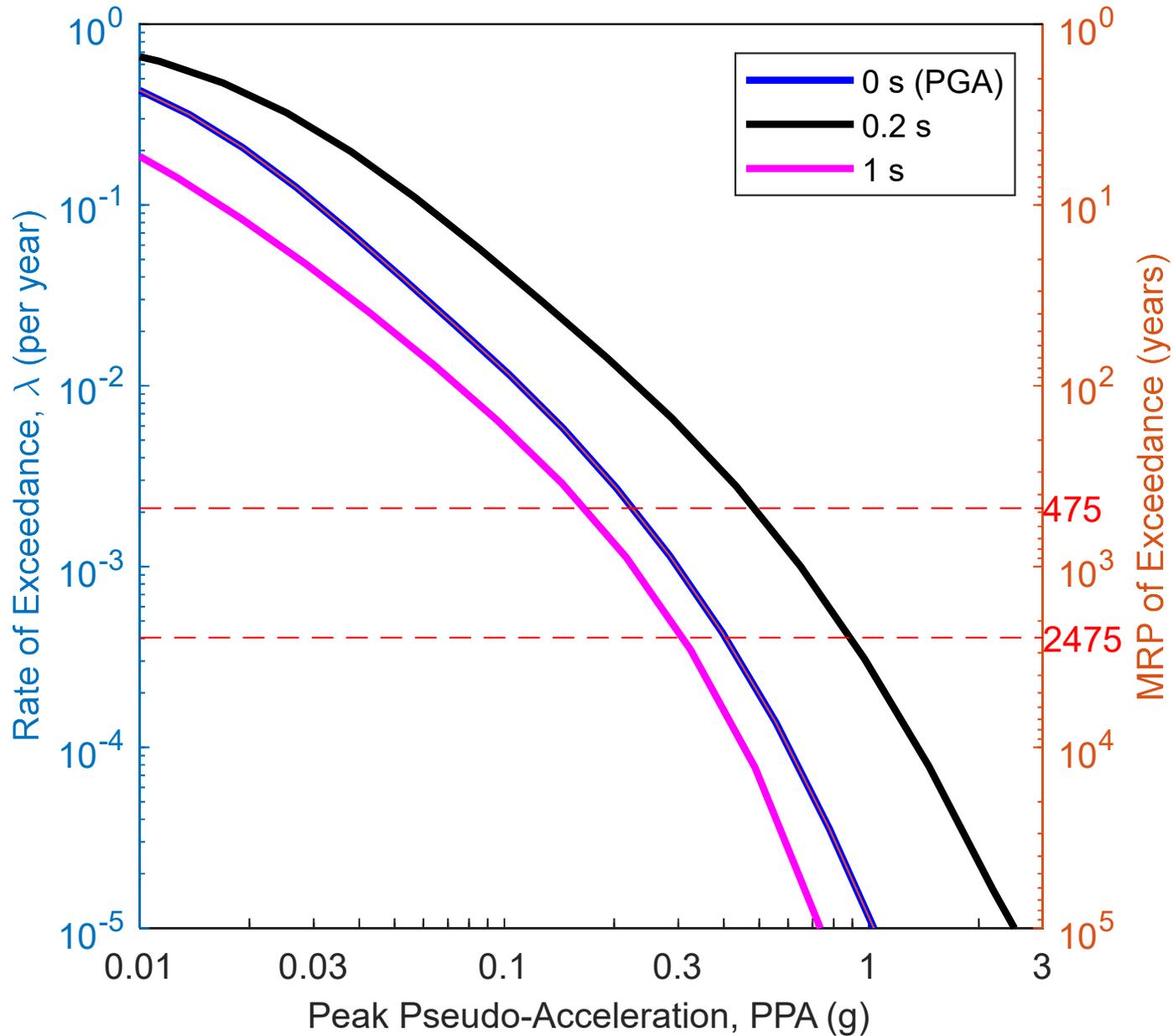
API 625, ACI 376, NFPA 59A Require Ground Motions for Dual Level Design of LNG Tanks

- The tank system shall be designed to continue to operate during and after OBE event
 - OBE ground motion is exceeded with a mean return period (MRP) of 475 years
- The tank system shall be designed to provide for no loss of containment capability during and after SSE event
 - SSE ground motion is same as the Maximum Considered Earthquake Risk-Targeted (MCE_R) ground motion as per ASCE 7

Example Site in San Juan, PR



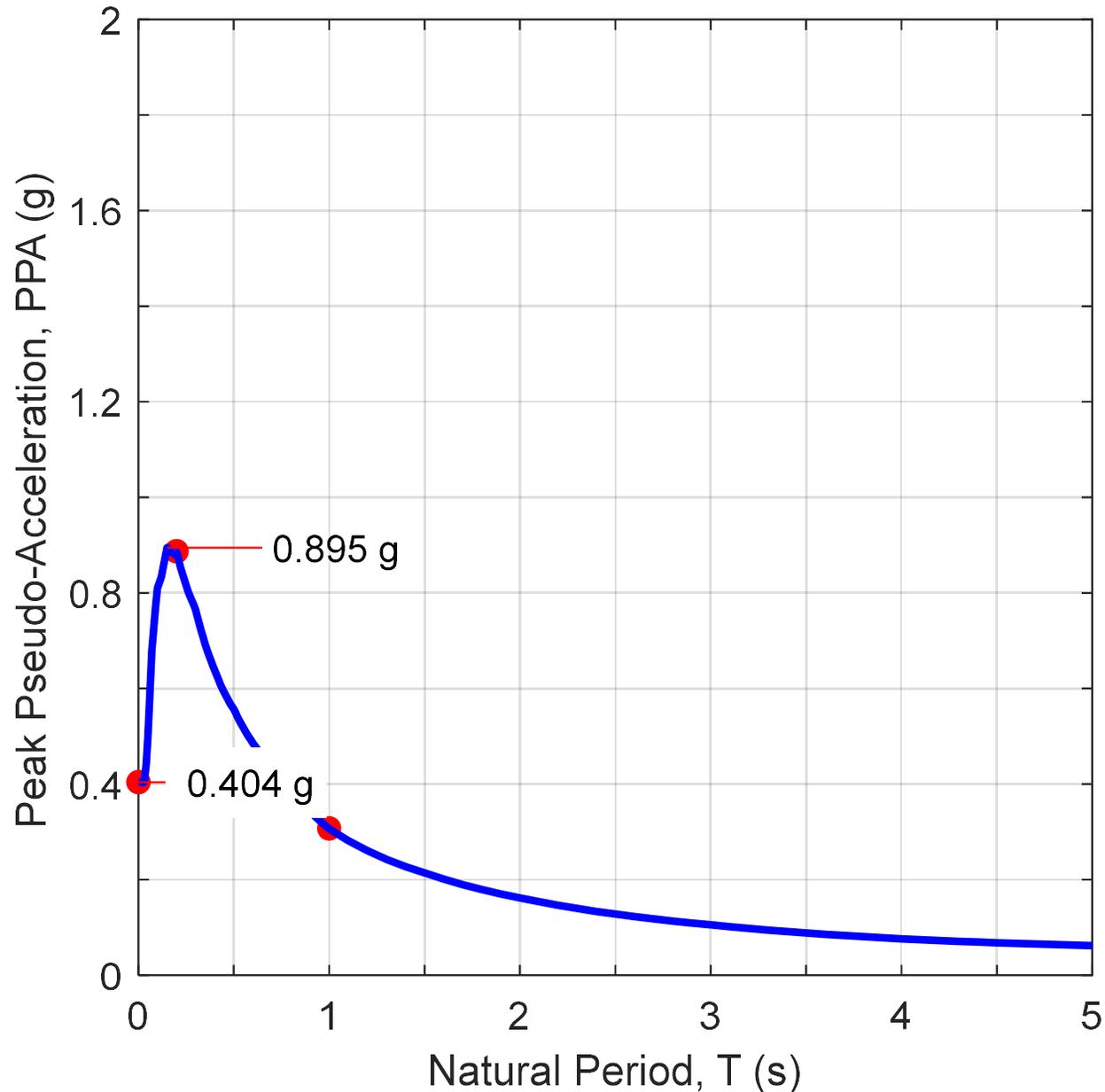
USGS Hazard Curves for Firm-Rock



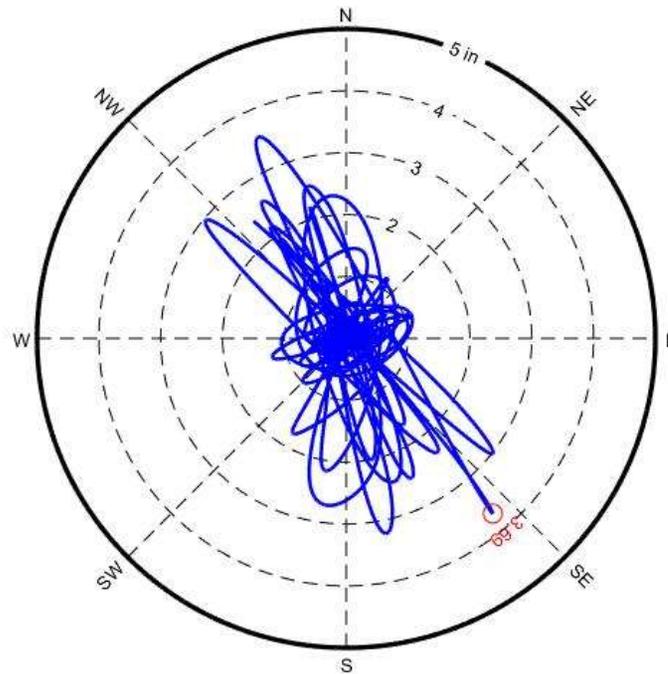
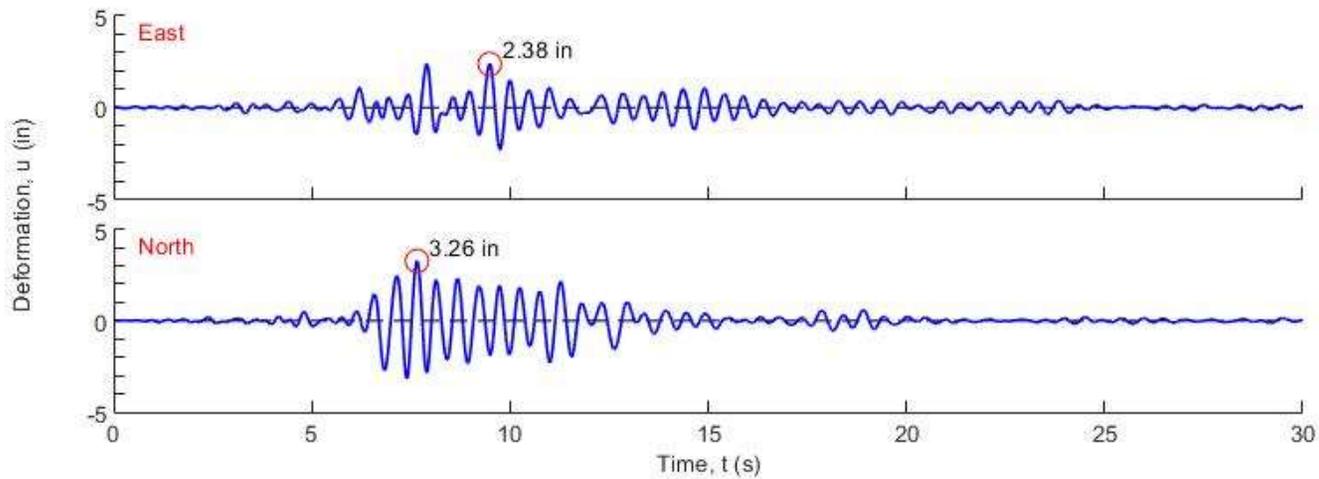
475- and 2475-year MRP Ground Motions

T (s)	PPA (g)	
	475-year	2475-year
0 (PGA)	0.2242	0.4041
0.2	0.4829	0.8870
1	0.1649	0.3073

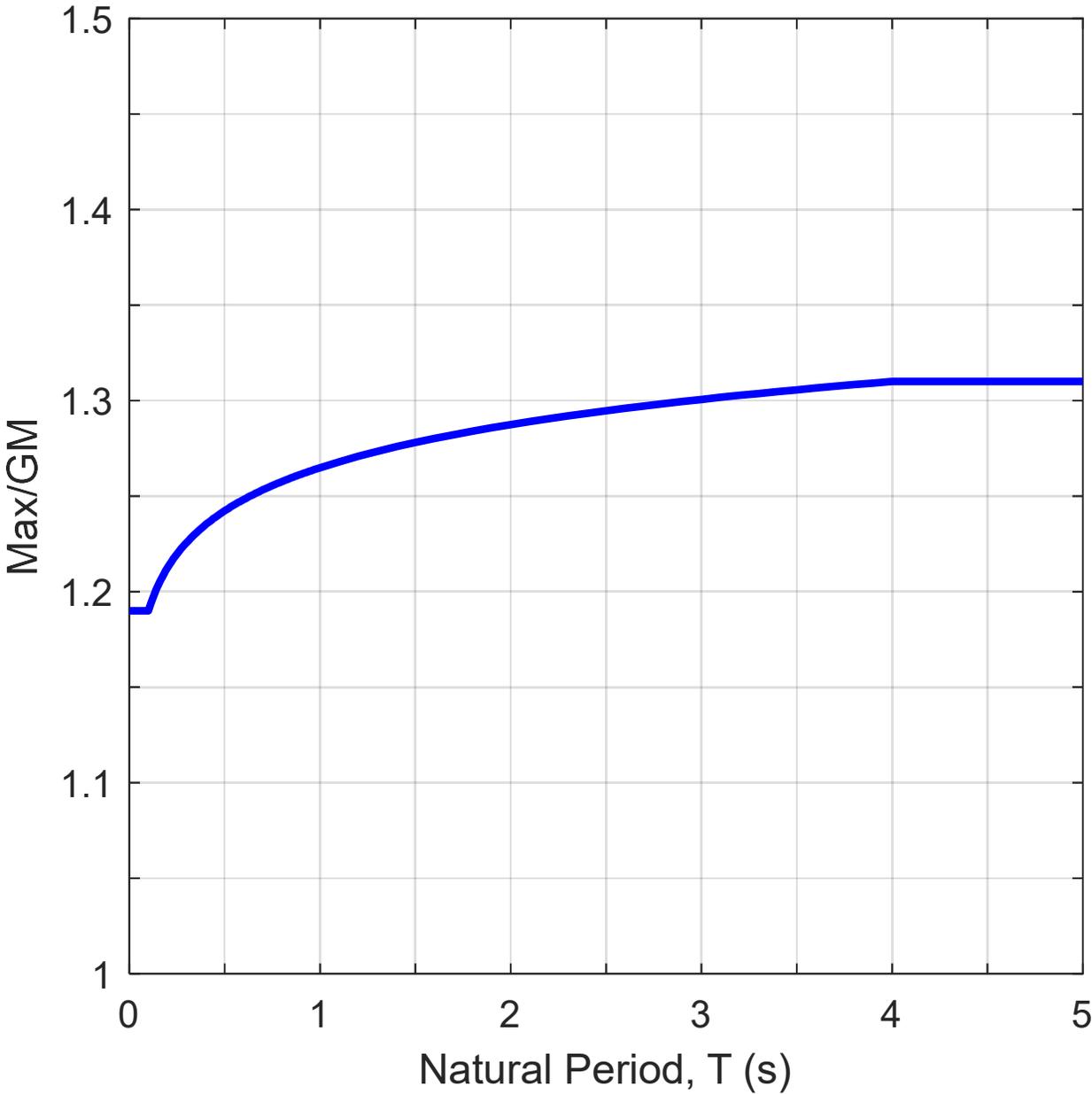
2475-year MRP Uniform Hazard Response Spectrum (UHRS)



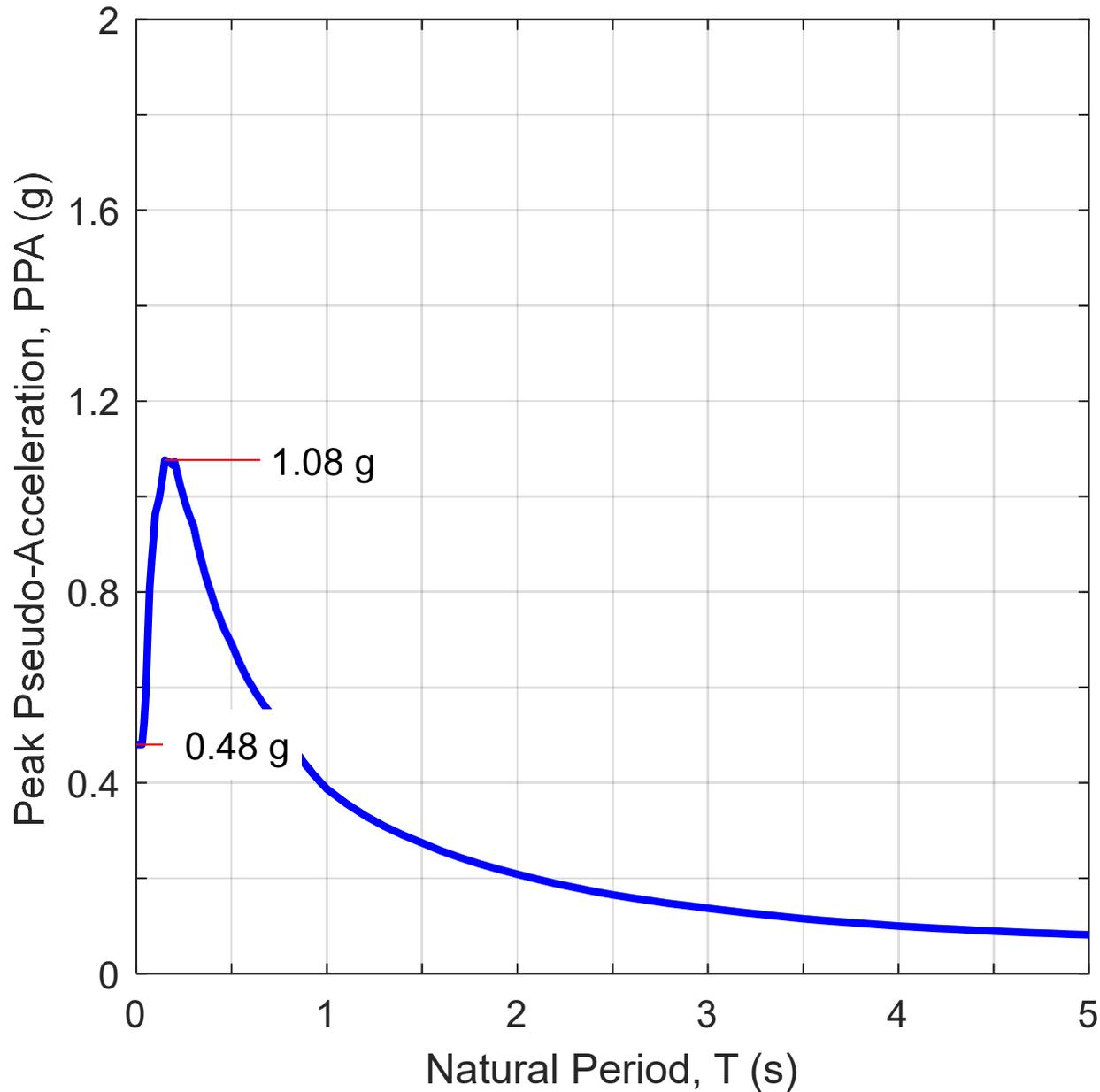
Geometric-Mean (GM) and Maximum-Horizontal (Max)



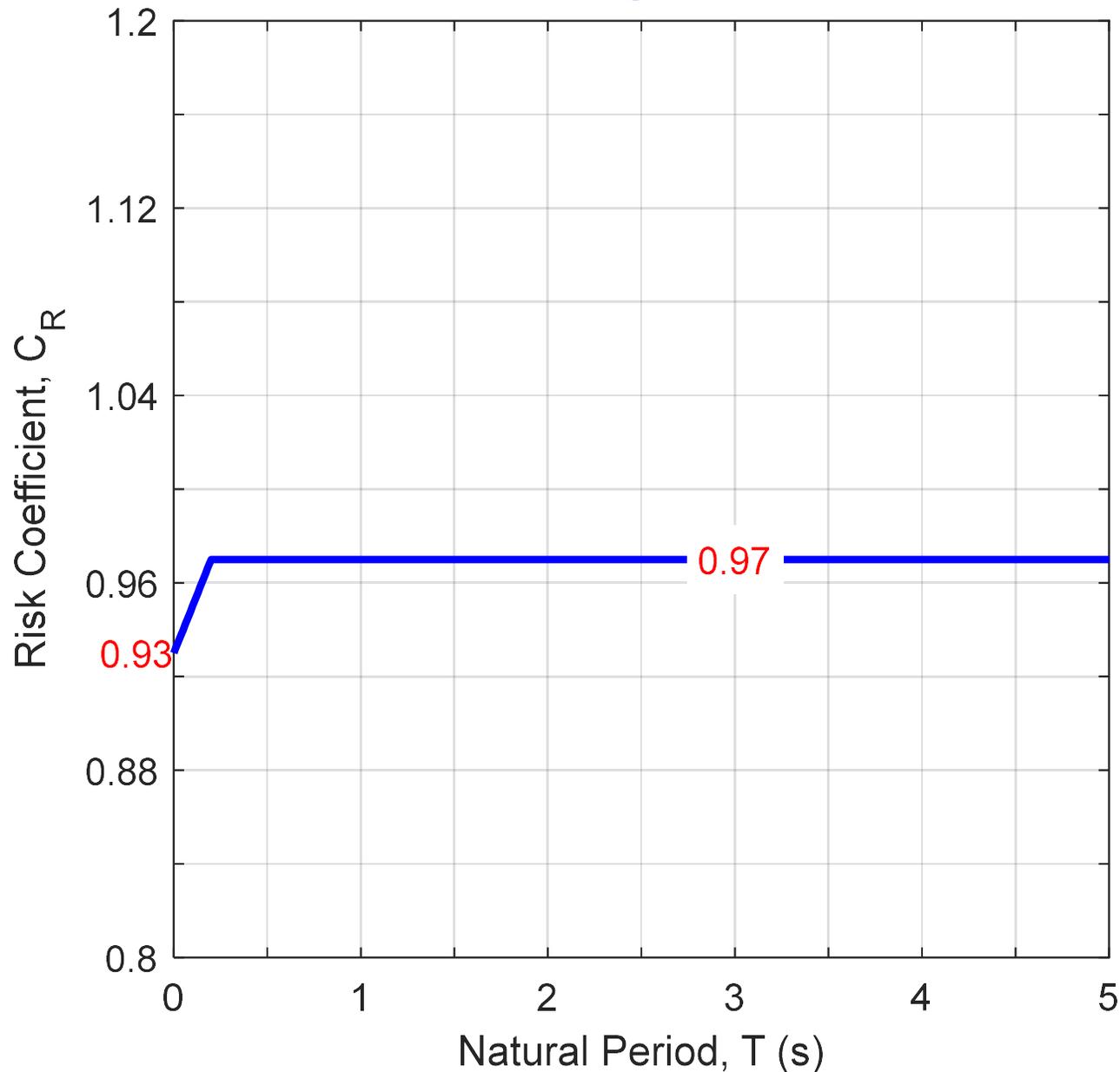
Max/GM



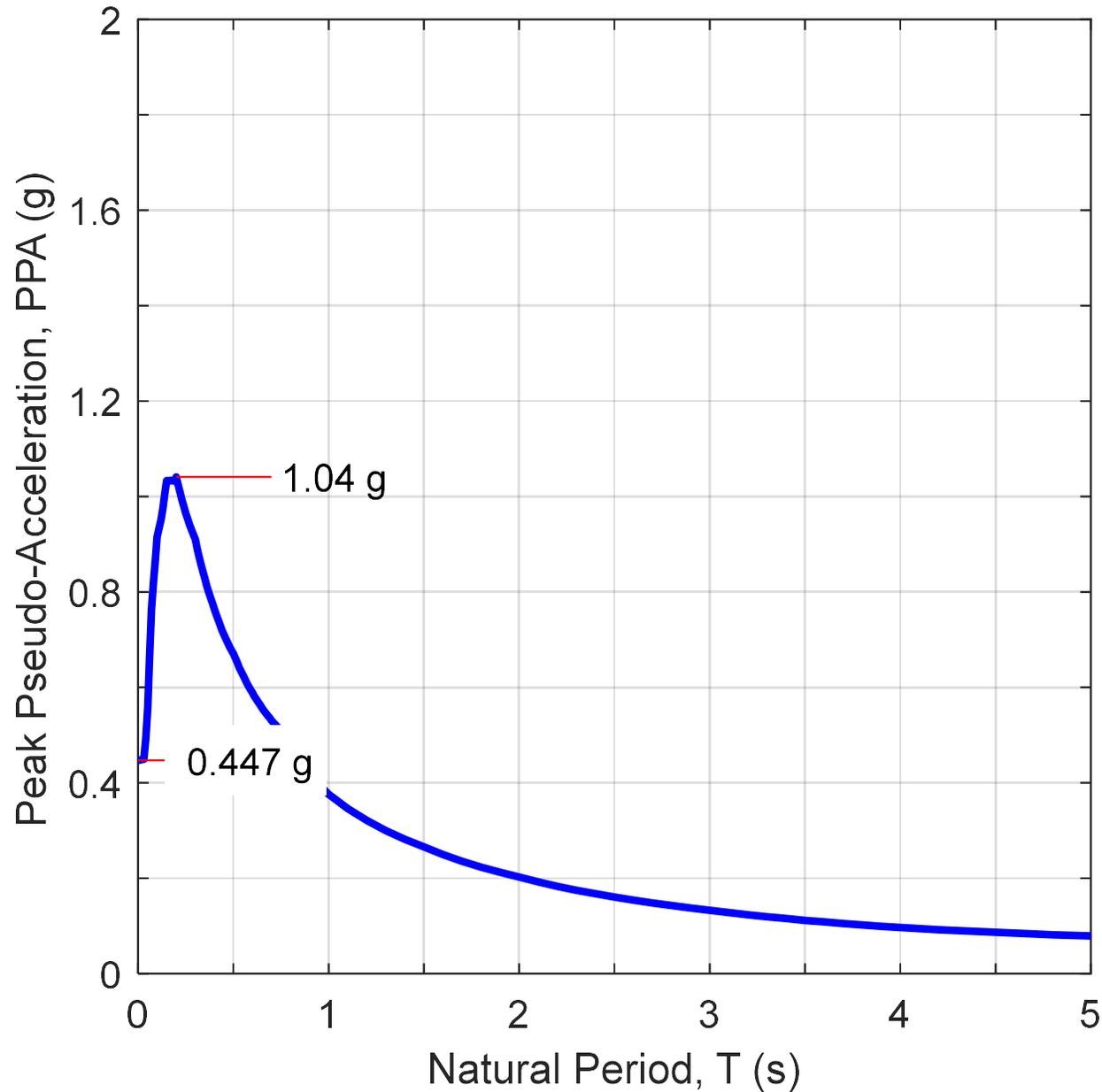
2475-year MRP Max UHRS



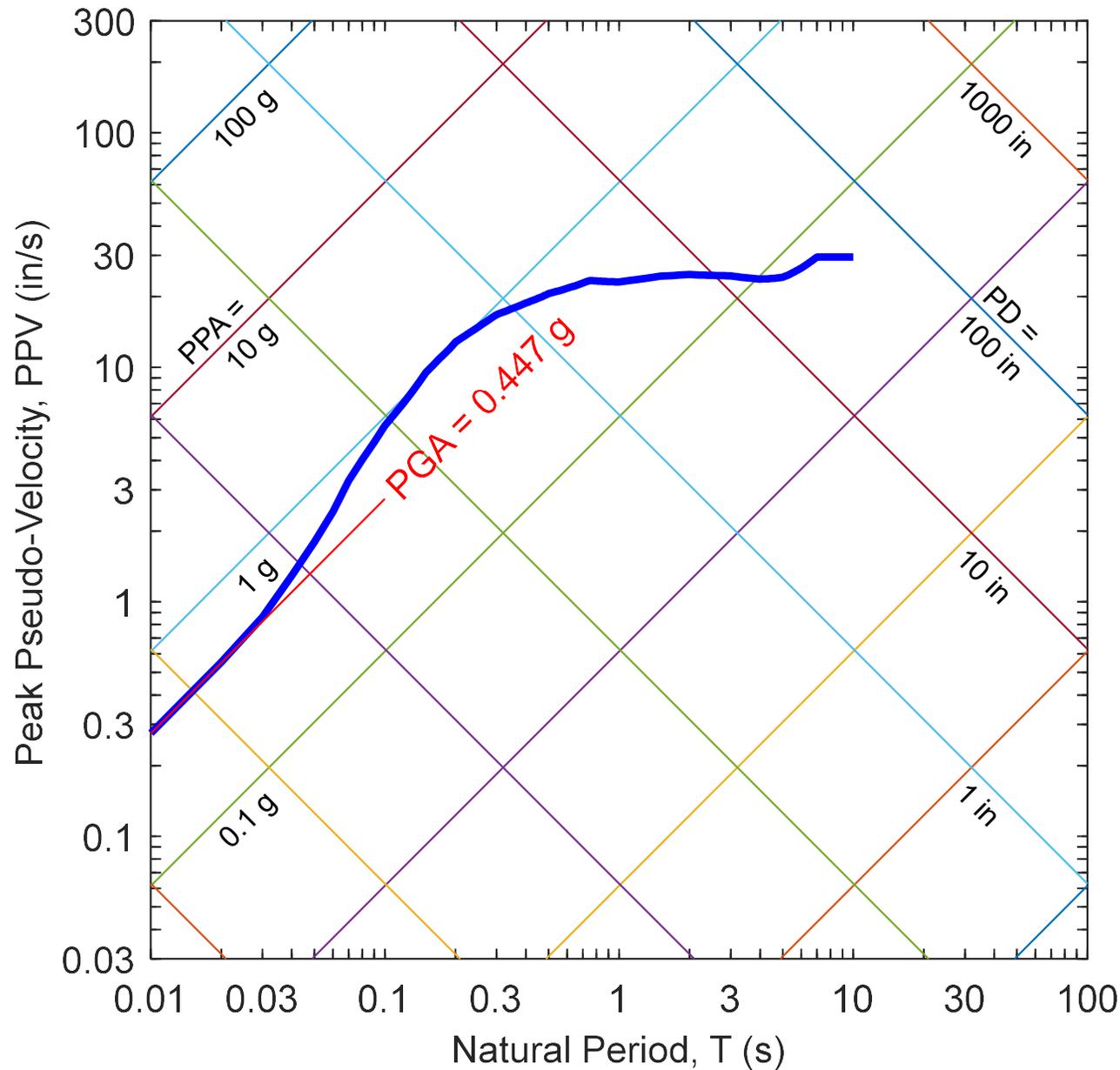
Risk Coefficients for Converting UHRS to Risk Targeted RS



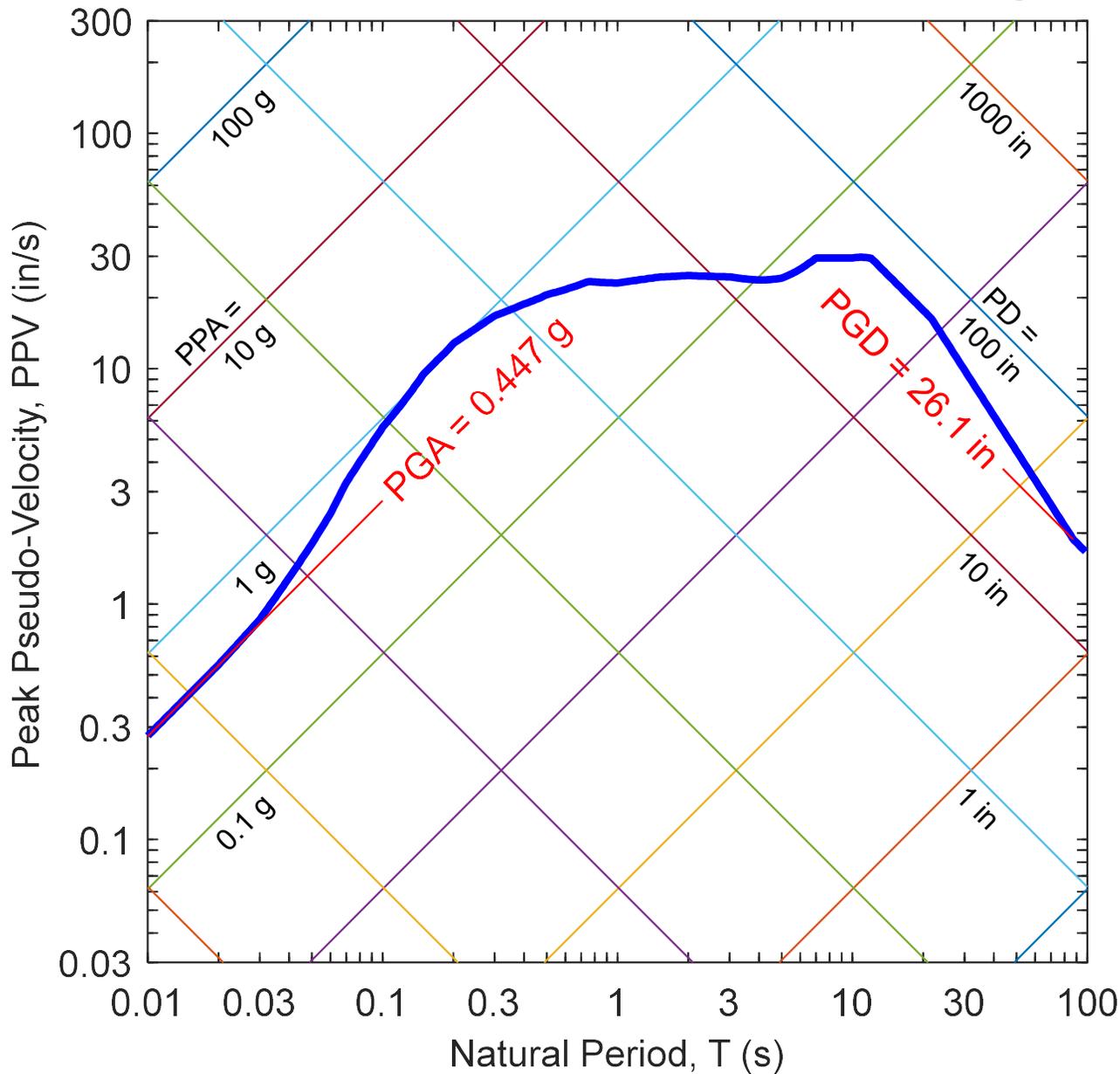
MCE_R RS of Rock-Outcrop Motion



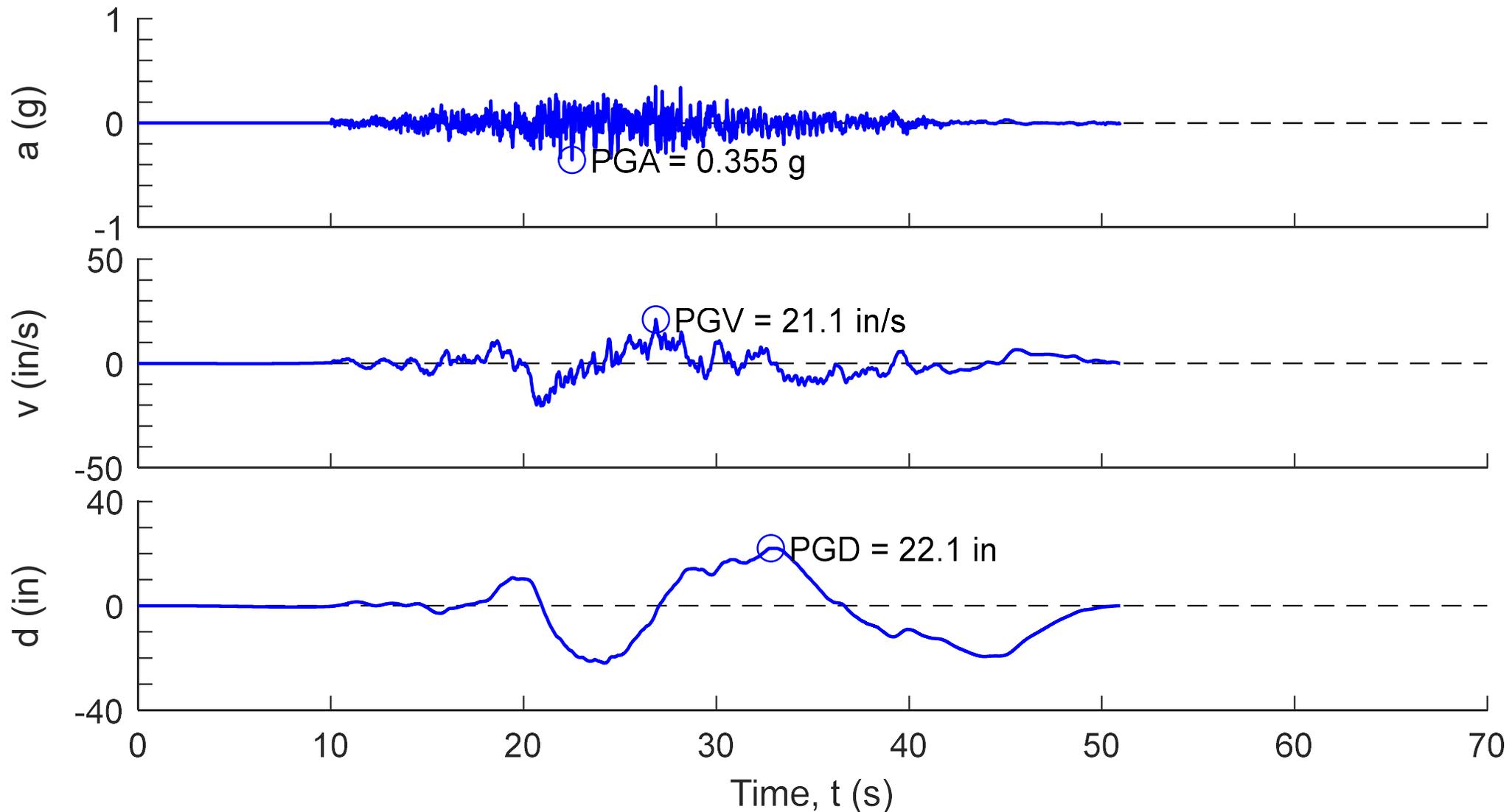
Tripartite Plot of MCE_R Rock-Outcrop RS



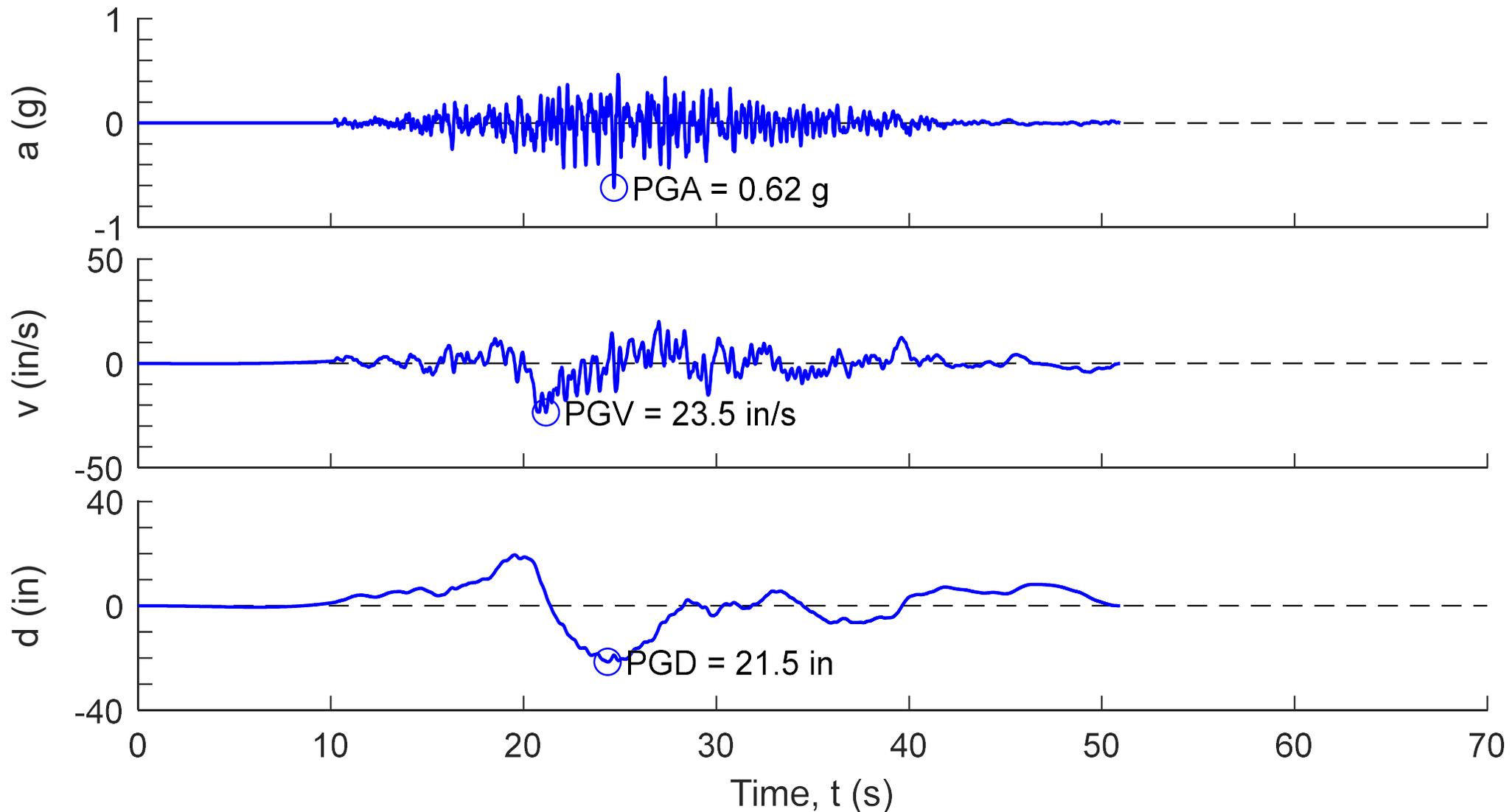
MCE_R Rock-Outcrop RS with Displacement-Sensitive Region



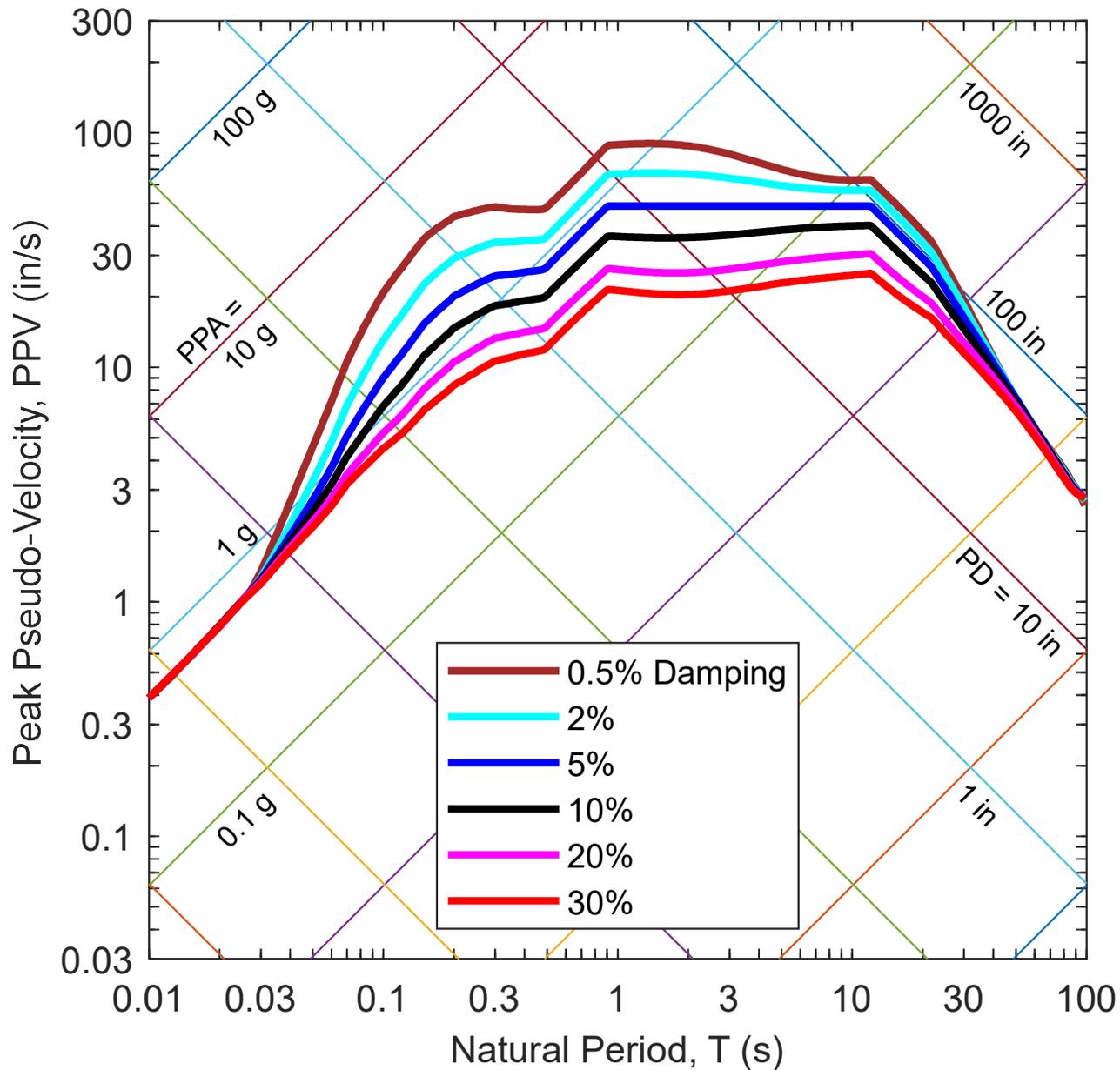
Spectrum-Compatible MCE_R Rock-Outcrop Ground Motion



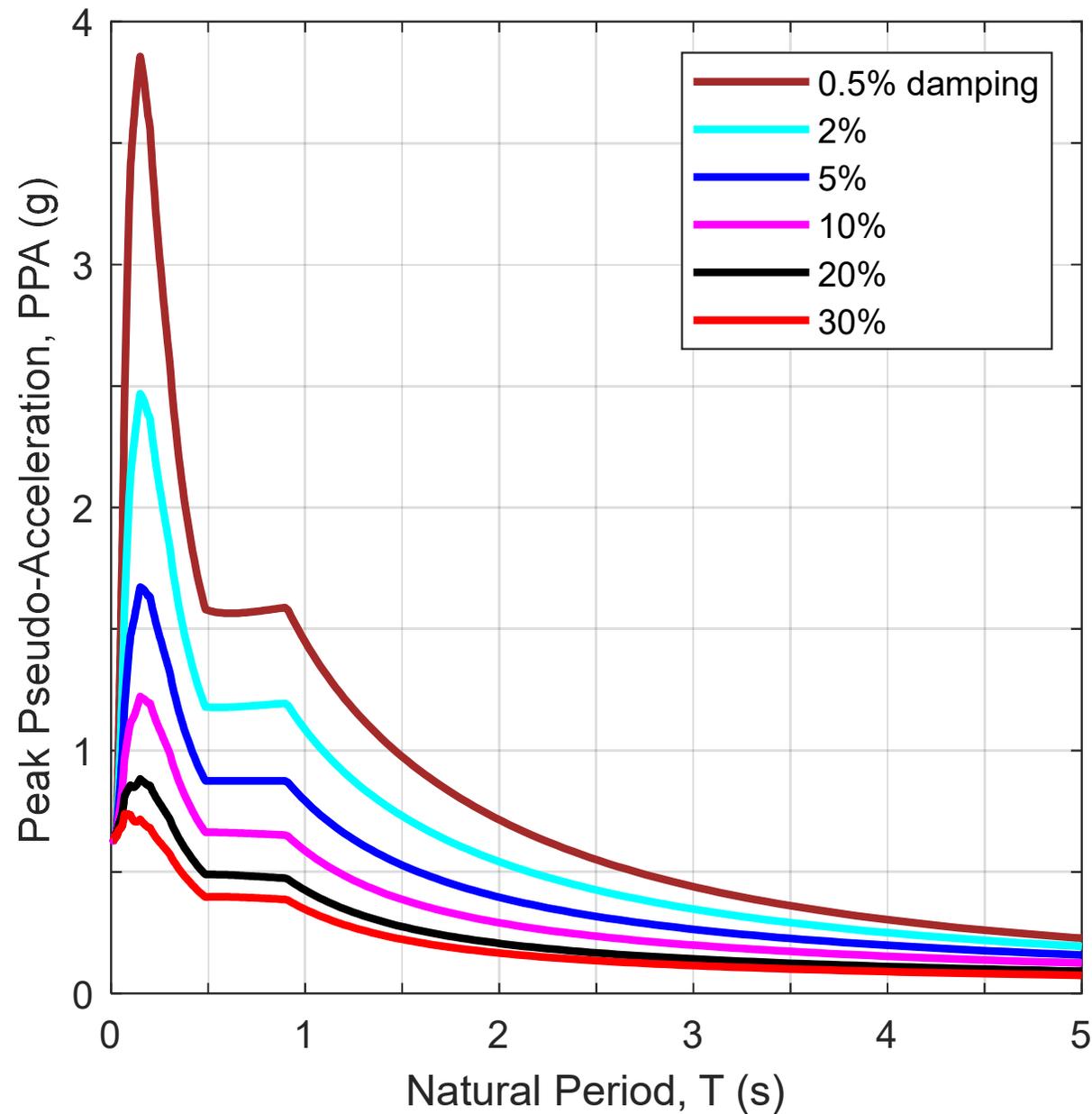
Free-Surface Motion from Dynamic Site Response Analysis (SRA)



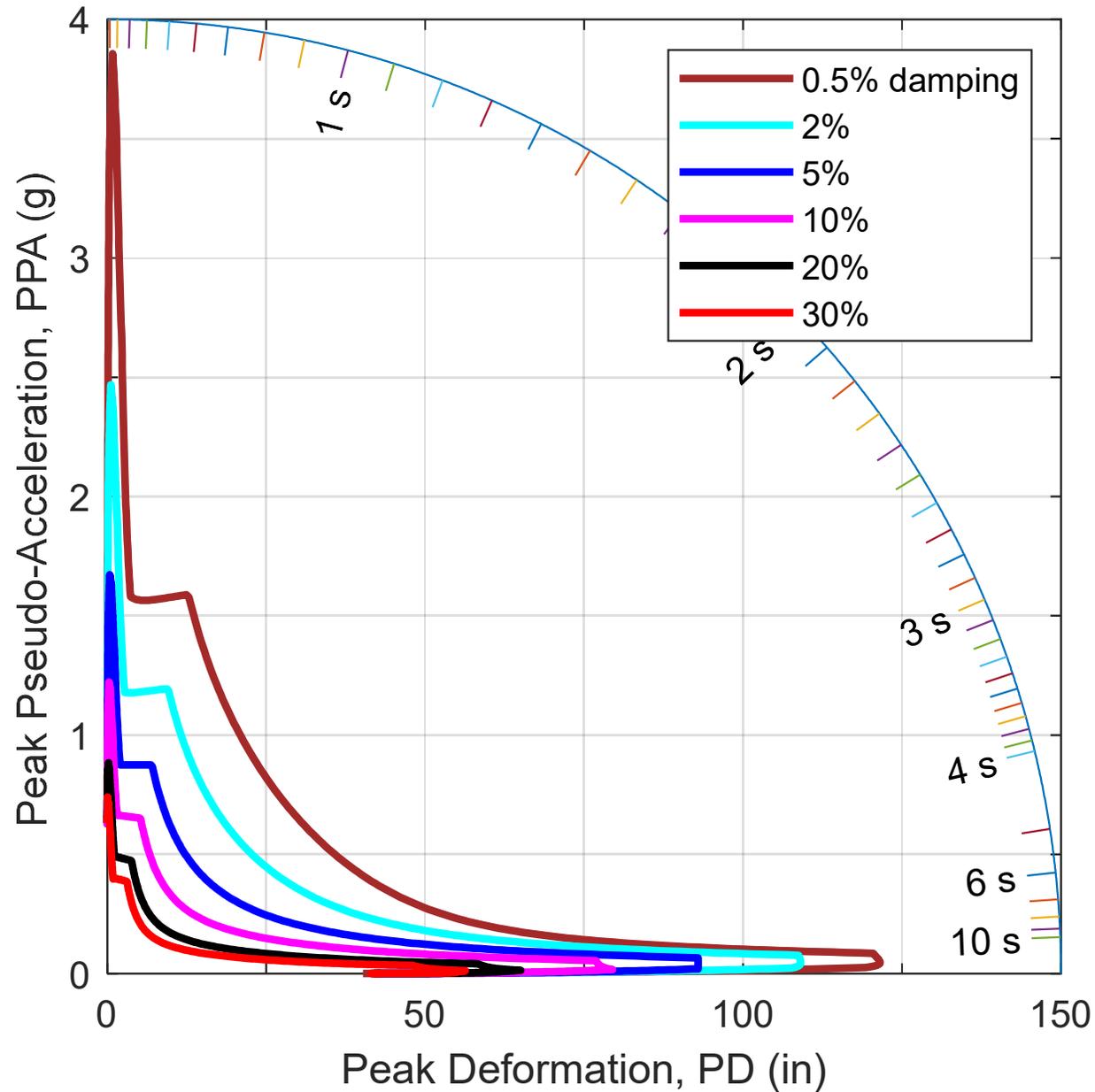
Free-Surface $MCE_R = SSE$ RS for Various Damping



Pseudo-Acceleration Plots of MCE_R RS



Acceleration-Deformation Plots of MCE_R RS



Comments

- PSHA is highly uncertain and subjective
- Engineers should not repeat the PSHA by the USGS
- Engineers should make the following adjustments:
 - Soil response
 - GM to Max
 - UHRS to risk-targeted
 - Displacement-sensitive region
 - Damping
- Engineers can also generate spectrum-compatible ground motions for dynamic analyses

Upcoming Book

- Malhotra, P. K. (2022). “Site-Specific Ground Motions for Seismic Design of Buildings and Other Structures.” ASCE Press. Under publication.