Technical Basis for Certification of Seismic Design Criteria for the Waste Treatment Plant, Hanford, Washington - 8188

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ABSTRACT

In August 2007, Secretary of Energy Samuel W. Bodman approved the final seismic and ground motion criteria for the Waste Treatment and Immobilization Plant (WTP) at the Department of Energy's (DOE) Hanford Site. Construction of the WTP began in 2002 based on seismic design criteria established in 1999 and a probabilistic seismic hazard analysis completed in 1996. The design criteria were re-evaluated in 2005 to address questions from the Defense Nuclear Facilities Safety Board (DNFSB), resulting in an increase by up to 40% in the seismic design basis. DOE announced in 2006 the suspension of construction on the pretreatment and high-level waste vitrification facilities within the WTP to validate the design with more stringent seismic criteria. In 2007, the U.S. Congress mandated that the Secretary of Energy certify the final seismic and ground motion criteria prior to expenditure of funds on construction of these two facilities. With the Secretary's approval of the final seismic criteria in the summer of 2007, DOE authorized restart of construction of the pretreatment and high-level waste vitrification facilities.

The technical basis for the certification of seismic design criteria resulted from a two-year Seismic Boreholes Project that planned, collected, and analyzed geological data from four new boreholes drilled to depths of approximately 1400 feet below ground surface on the WTP site. A key uncertainty identified in the 2005 analyses was the velocity contrasts between the basalt flows and sedimentary interbeds below the WTP. The absence of directly-measured seismic shear wave velocities in the sedimentary interbeds resulted in the use of a wider and more conservative range of velocities in the 2005 analyses. The Seismic Boreholes Project was designed to directly measure the velocities and velocity contrasts in the basalts and sediments below the WTP, reanalyze the ground motion response, and assess the level of conservatism in the 2005 seismic design criteria.

The characterization and analysis effort included 1) downhole measurements of the velocity properties (including uncertainties) of the basalt/interbed sequences, 2) confirmation of the geometry of the contact between the various basalt and interbedded sediments through examination of retrieved core from the corehole and data collected through geophysical logging of each borehole, and 3) prediction of ground motion response to an earthquake using newly acquired and historic data. The data and analyses reflect a significant reduction in the uncertainty in shear wave velocities below the WTP and result in a significantly lower spectral acceleration (i.e., ground motion). The updated ground motion response

analyses and corresponding design response spectra reflect a 25% lower peak horizontal acceleration than reflected in the 2005 design criteria. These results provide confidence that the WTP seismic design criteria are conservative.

INTRODUCTION

The U.S. Department of Energy (DOE) is constructing a Waste Treatment and Immobilization Plant (WTP) to treat and vitrify underground tank waste stored at the Hanford Site in southeastern Washington State (see Fig. 1.) The WTP comprises four major facilities: a pretreatment facility to separate the tank waste into high level waste (HLW) and low-activity waste (LAW) fractions, a HLW Vitrification facility to immobilize the HLW fraction in borosilicate glass, a LAW Vitrification facility to immobilize the LAW fraction in borosilicate glass, and an Analytical Laboratory to support operations of the three treatment facilities.

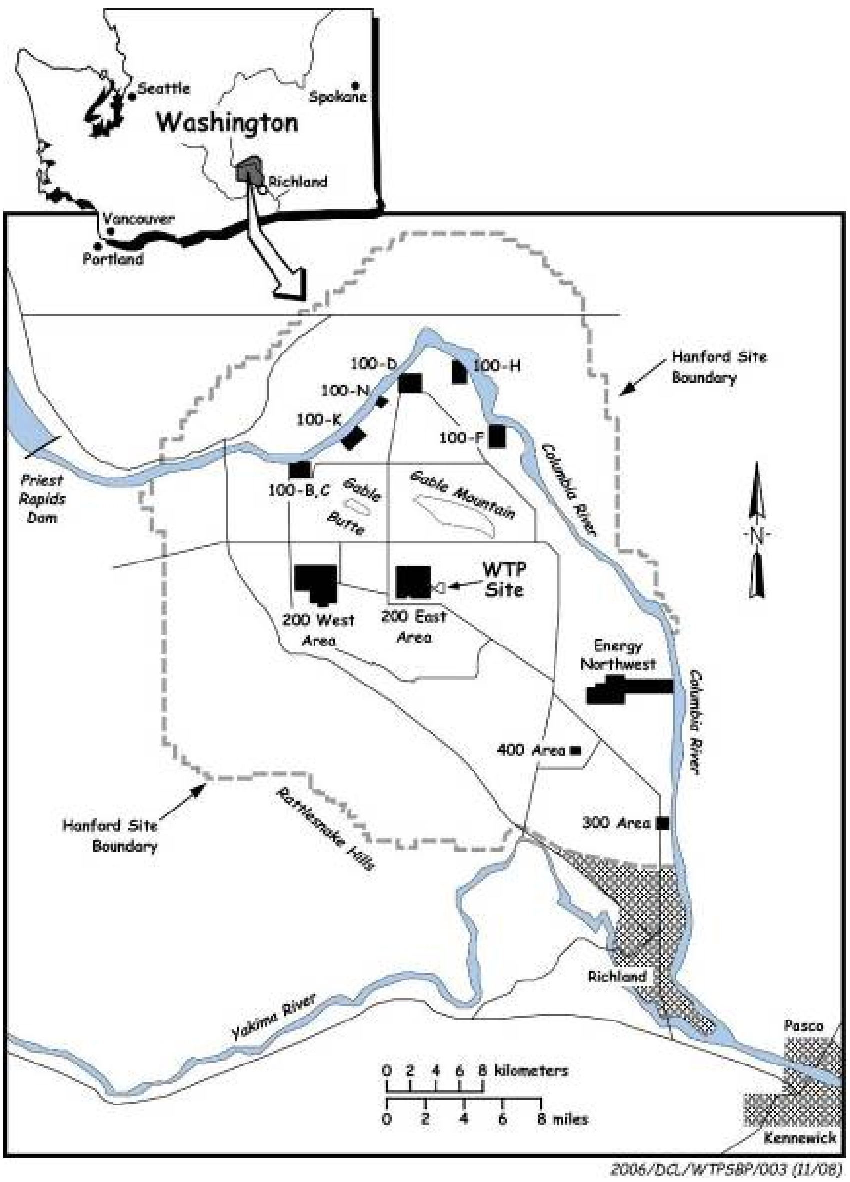

Fig. 1. Location of the Waste Treatment and Immobilization Plant (WTP) site.

The Hanford Site and WTP are situated on a sequence of sedimentary units (Hanford and Ringold Formations) that overlie the Columbia River Basalt Group (CRBG). The CRBG is a sequence of flood basalt flows that erupted between 17 and 6 million years ago from fissures or vent systems in Oregon, Washington, and Idaho, and forms the main bedrock of the WTP. The upper four basalt flows (Saddle Mountains Basalt) were laid down over a period of time which allowed sediments of the Ellensburg Formation to accumulate between basalt layers. The general stratigraphy of geologic units of interest below the WTP is shown in Fig. 2.

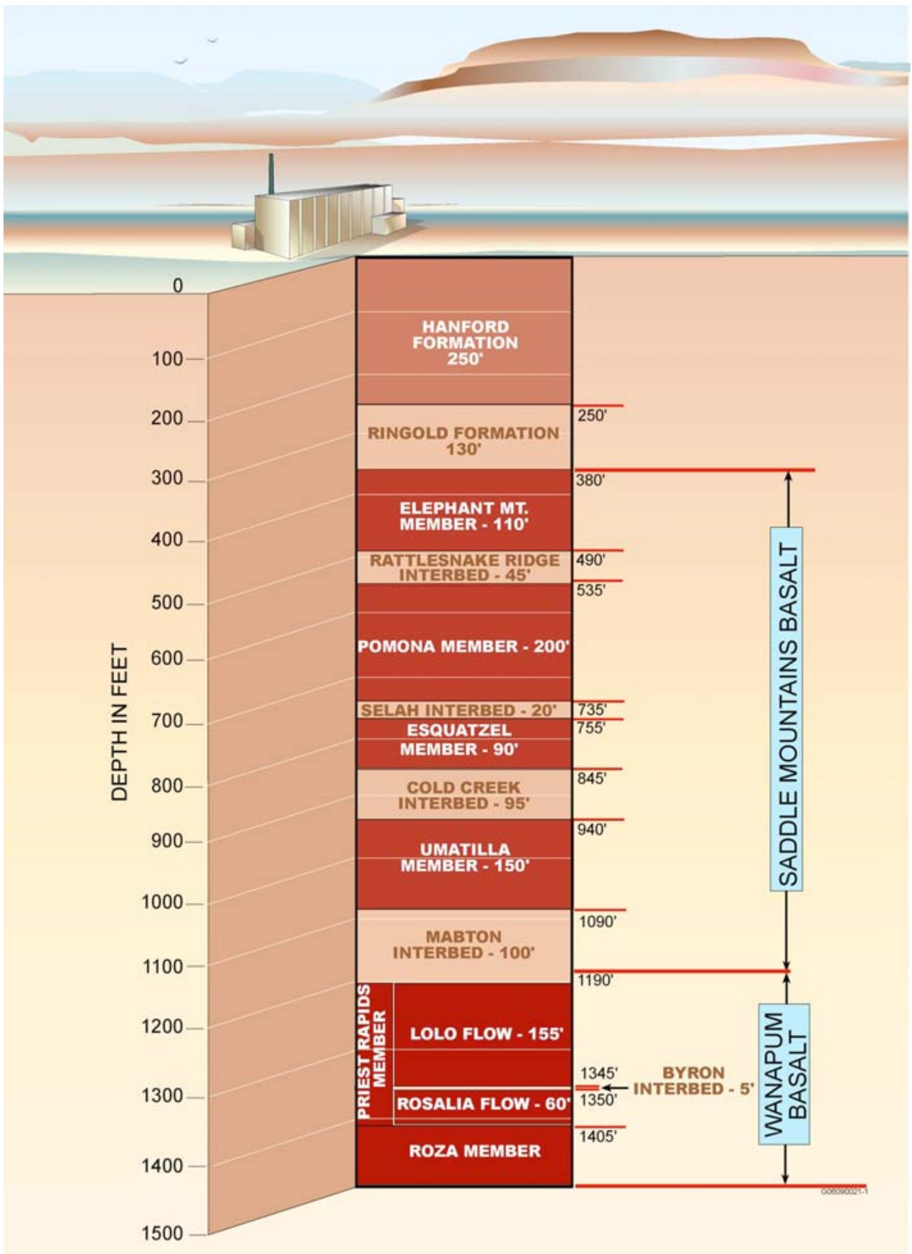

Fig. 2. General stratigraphy and approximate depths below ground surface of geologic units of interest below the WTP.

The seismic design basis for the WTP was established in 1999 based on a probabilistic seismic hazard analysis completed in 1996 [1]. The Defense Nuclear Facilities Safety Board (DNSFB) subsequently initiated a review of the seismic design basis of the WTP. In March 2002, the DNFSB staff questioned the assumptions used in developing the seismic design basis, particularly the adequacy of the site geotechnical surveys, and subsequently raised additional questions about the probability of earthquakes, adequacy of the "attenuation relationships" that describe how ground motion changes as it moves from its source in the earth to the site, and large uncertainty in the extrapolation of soil response data from California to the Hanford Site. Between 2002 and 2004, the DOE Office of River Protection (ORP) responded and resolved many of the questions raised, and developed a plan to acquire additional site data and analysis to address remaining questions. The key features of this plan were 1) acquiring new soil data down to about 500 ft (152 m), 2) reanalyzing the effects of deeper layers of sediments interbedded with basalt down to about 2,000 ft (610 m) that may affect the attenuation of earthquake ground motions more than previously understood, and 3) applying new models for ground motions as a function of magnitude and distance at the Hanford Site.

In 2004 and 2005, the Pacific Northwest National Laboratory (PNNL) led efforts for DOE-ORP to address features 1 and 2 of the plan by collecting site-specific geologic and geophysical characteristics of the WTP site and conducting modeling of the WTP site-specific ground motion response. New geophysical data were acquired, analyzed, and interpreted with respect to existing geologic information gathered from other Hanford-related projects in the WTP area. Limited information from deep boreholes was collected and interpreted to produce a model of the deeper rock layers consisting of the interlayered basalts and sedimentary interbeds. The earthquake ground motion response was modeled, and a series of sensitivity studies was conducted to address areas in which the geologic and geophysical information has significant remaining uncertainties. This effort culminated in 2005 with issuance of an updated seismic response analysis for the WTP site [2, 3]. The updated seismic response analysis used existing and newly acquired seismic velocity data, statistical analysis, expert elicitation, and ground motion simulation to develop interim design ground motion response spectra which enveloped the remaining uncertainties. The uncertainties in these response spectra were enveloped at approximately the 84^{th} percentile to produce conservative design spectra, which contributed significantly to an increase in the seismic design basis (see Fig. 3).

A key uncertainty identified in the 2005 analysis was the velocity contrasts between the basalt flows and sedimentary interbeds below the WTP. Results of modeling indicated that the velocity structure of the upper four basalt flows and the interlayered sedimentary interbeds produces strong reductions in modeled earthquake ground motions propagating through them. Uncertainty in the strength of velocity contrasts between these basalts and interbeds primarily resulted from an absence of measured shear wave velocities (Vs) in the interbeds. For the 2005 analysis, Vs in the interbeds was estimated from older, limited compressional wave (Vp) data using estimated ranges for the ratio of the two velocities (Vp/Vs) based on analogues in similar materials. A range of possible Vs for the interbeds and basalts was used and produced additional uncertainty in the resulting response spectra.

In late 2005, DOE-ORP initiated planning for the Seismic Boreholes Project (SBP) to emplace additional boreholes at the WTP site and obtain direct Vs measurements and other physical property measurements in these layers. The goal was to reduce the uncertainty in the response spectra and seismic design basis, and potentially recover design margin for the WTP. PNNL was selected to manage the SBP, with oversight from DOE-ORP and the U.S. Army Corps of Engineers (USACE). The priority of the SBP activities was elevated in 2006 as a result of fiscal year 2007 congressional authorization that limited fiscal year 2007 expenditures for the WTP until "…the date on which the Secretary of Energy certifies to

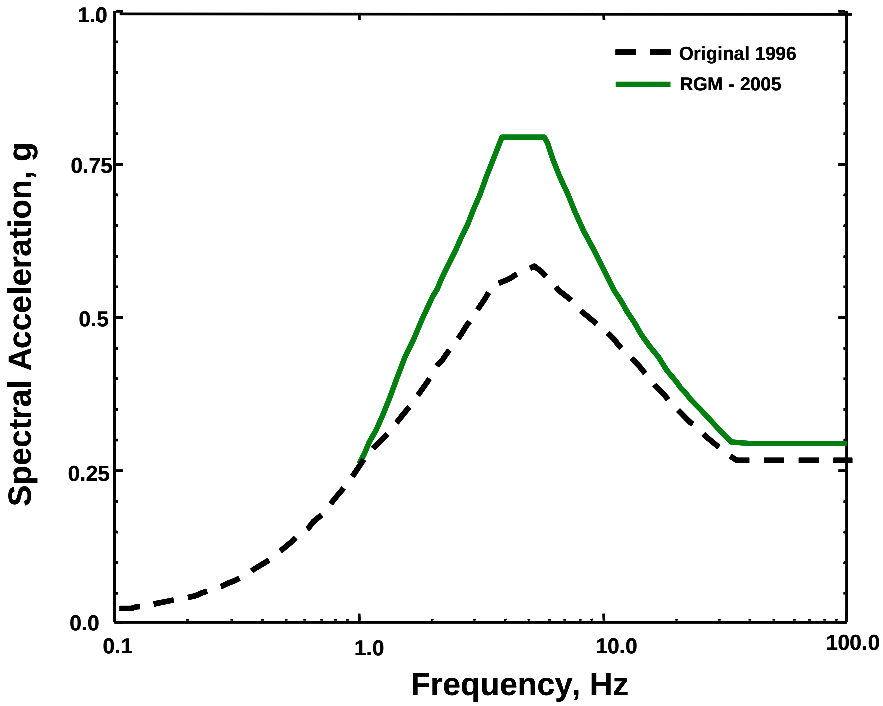

Fig. 3. Original 1996 and revised 2005 horizontal design spectra (RGM) at 5% damping [2]

the congressional defense committees that the final seismic and ground motion criteria have been approved by the Secretary …”[1]

APPROACH

The approach to the SBP involved four main elements: 1) planning and site preparation, 2) new borehole installation, 3) data collection, and 4) site seismic response analysis. A multi-contractor project team was formed to plan and implement the project, including all health and safety supervision and control, project management and technical direction, interface control, contracting, and environmental compliance. Three test boreholes were installed adjacent to the HLW Vitrification and Pretreatment facilities at the WTP to conduct downhole logging and obtain adequate data to determine the variability of shear wave velocities and other physical properties across the footprint of the two facilities impacted by the revised design basis. A single wireline corehole adjacent to one of the test boreholes was also installed to provide correlation of the geology to the geophysical logging data. All four boreholes (three “test” or “deep” boreholes and one corehole) were drilled to a depth of approximately 1400 ft (427 m) below ground surface, so as to penetrate and extend past the four sedimentary interbeds and four basalt members of interest. Locations of the four boreholes C4993, C4996, C4997, and C4998 are depicted in Fig. 4. A suite of geologic and geophysical data including in situ velocities and densities were collected from the new boreholes and are summarized in Table I. The project elements of 1) Planning and Site Preparation, 2) New Borehole Installation, and 3) Data Collection were completed in 2006 and early 2007, and

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[1] John Warner National Defense Authorization Act for Fiscal Year 2007. Public Law 109-364 (H.R.5122 ENR), Sec. 3120, Limitations on Availability of Funds for Waste Treatment and Immobilization Plant.

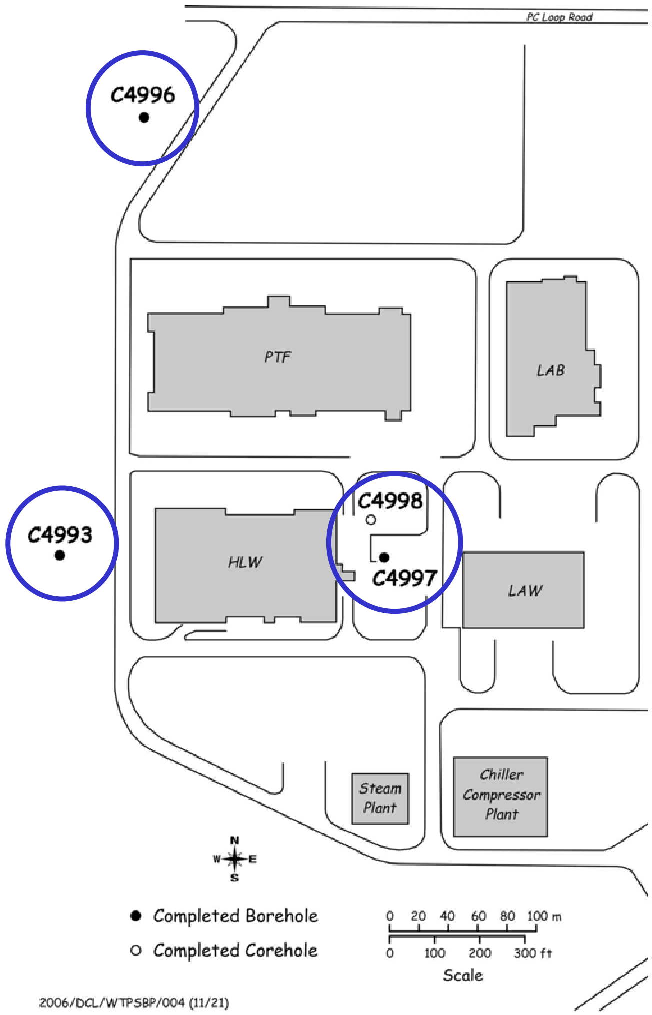


Fig. 4. Location of four new boreholes installed adjacent to WTP Pretreatment (PTF) and HLW Vitrification (HLW) facilities.

reported previously [4]. The approach used to analyze the new borehole data, perform the site response analysis, and develop final design response spectra is described below.

Data and interpreted results of in situ velocity and density measurements from each borehole were evaluated and analyzed to produce a set of final site-specific velocity and density models representing the WTP site. The objective was to integrate data from the new boreholes and previous site-specific studies into a set of models for use in evaluating the seismic response of the WTP.

New site response modeling and analysis was performed to process the new velocity and density models and determine the overall impact of reduced uncertainty on the design response spectra for the WTP Site. Geomatrix Consultants of Oakland, California, was selected to update the WTP site seismic response calculations completed in 2005 by incorporating the new velocity and density models and other geophysical data collected from the WTP site boreholes. A panel of experts was convened to review the new borehole data and provide input on the approach and range of values of the input parameters to the site response models. A full probabilistic analysis was completed and generated a distribution of relative site response curves for the WTP site. C.J. Costantino and Associates applied the 84th percentile results of

Table I. Data Collected from WTP Seismic Boreholes

Property	Method
Shear (s) and compression (p) wave velocity	❑ Suspension (p-s) logging ❑ Downhole logging (impulsive and vibratory sources)
Density	❑ Gravity-density logging ❑ Compensated density (γ-γ logging)
Geometry of contact (depths/thicknesses)	❑ Geologic logs (examination of core/cuttings) ❑ Geophysical logging suite – Compensated density (γ-γ) – Neutron porosity – Dual induction resistivity – Full waveform sonic
Modulus reduction and damping	❑ Resonant column and torsional shear tests
Sediment particle size	❑ Gradation testing
Borehole condition	❑ Acoustic televiewer ❑ Caliper logging ❑ Gyroscope surveys

the site response analysis to generate a WTP site-specific ground motion design response spectra (WSGM). DOE used these results to confirm the existing seismic design criteria for the WTP established in 2005 was conservative.

SITE SPECIFIC VELOCITY AND DENSITY MODEL RESULTS

Shear and compression wave velocity measurements were made using two basic techniques, suspension and downhole logging. Suspension logging measures the velocities near the borehole wall using high-frequency signals produced and recorded on a string of instruments suspended in the boreholes. Downhole logging measures velocities over a larger area surrounding the borehole by using a lower-frequency surface energy source with a geophone clamped at depth. Two different types of energy sources were used at the surface for the downhole measurements—an impulsive source that produces a single, unambiguous signal, and a vibratory source, which is more difficult to interpret but has the greater energy required to reach the depths of these boreholes. The first source was either a sledgehammer or small mechanical device. The second source was a large truck-mounted electro-hydraulic vibrator. A description of the techniques, equipment, and detailed results of these studies are available elsewhere [5-8].

Systematic differences were found between the suspension and downhole logging measurements. Suspension logging gives a very high-resolution measurement, but the signal frequencies of the downhole method are similar to those of earthquakes important in ground-motion response modeling. The suspension logging measurements gave velocities significantly greater than the downhole measurements in the basalts for both shear and compression waves. Downhole logging shear wave velocity data from the three boreholes and the core hole were combined statistically to produce an average velocity model of the WTP site. Suspension logging results were used to shape the downhole velocity profiles to address details of velocity reductions in the basalt flow tops that were not modeled previously.

Figure 5 presents results of shear wave travel-time measurements and interpreted velocity (Vs) results using the impulsive sources in borehole C4993, and includes data collected in the suprabasalt sediments as well as two uppermost basalt units (Elephant Mountain and Pomona) and sedimentary interbeds (Rattlesnake Ridge and Selah) before and after installation of stainless steel casing. Overall, very similar results were obtained in boreholes C4996 and C4997/C4998 (not shown), with variability across the boreholes generally less than 30%. However, borehole C4993 indicated a reduction in Vs from the lower region of the Hanford formation (H3 unit) to the upper region of the Ringold Formation (Cold Creek Unit [CCU]), whereas measurements in the other two boreholes indicated either a much smaller reduction or slight increase in Vs.

Figure 6 presents results of shear wave travel-time measurements and interpreted Vs results using the vibratory source in borehole C4993, and includes data collected through all of the basalt and sedimentary

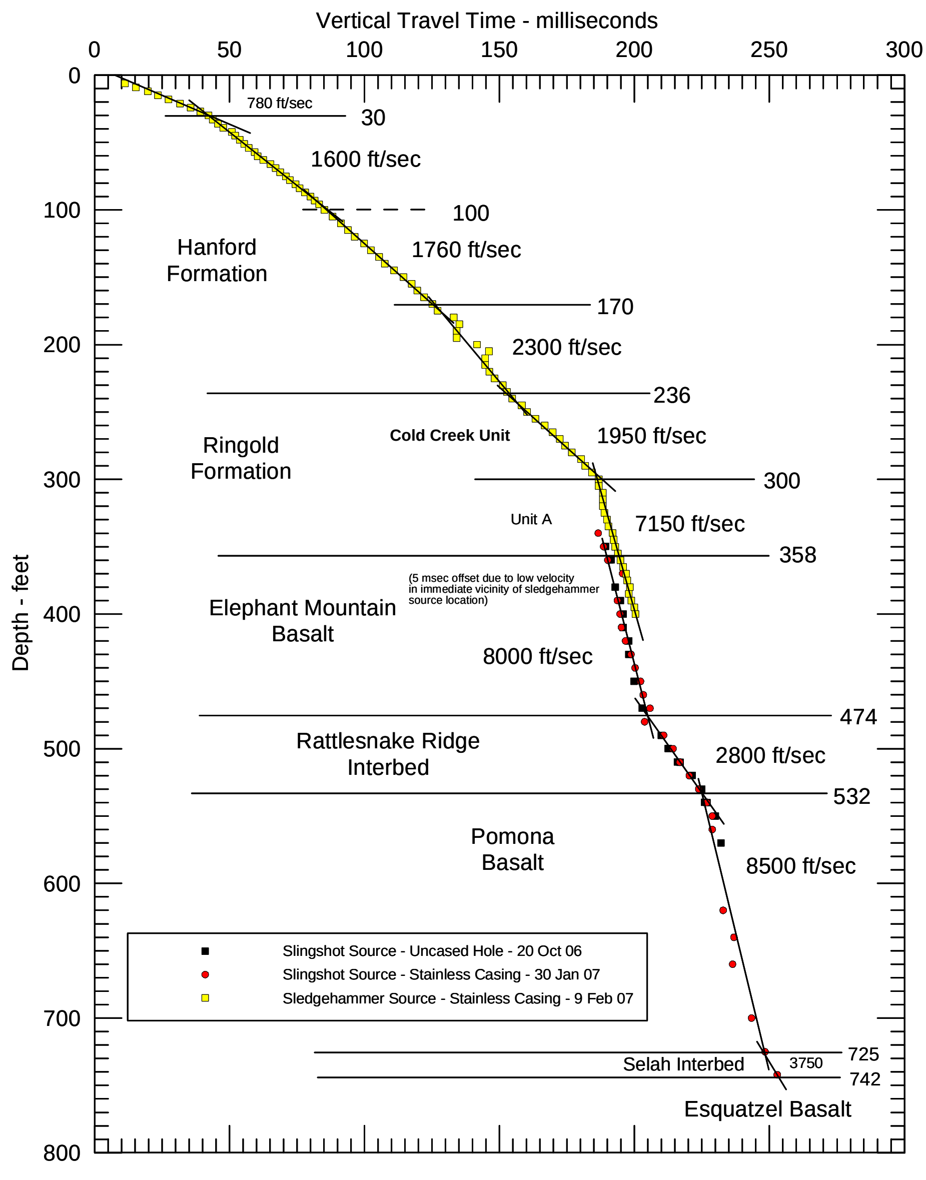


Fig. 5. Shear wave velocity measurements in borehole C4993 using an impulsive seismic source (adapted from Redpath [5])

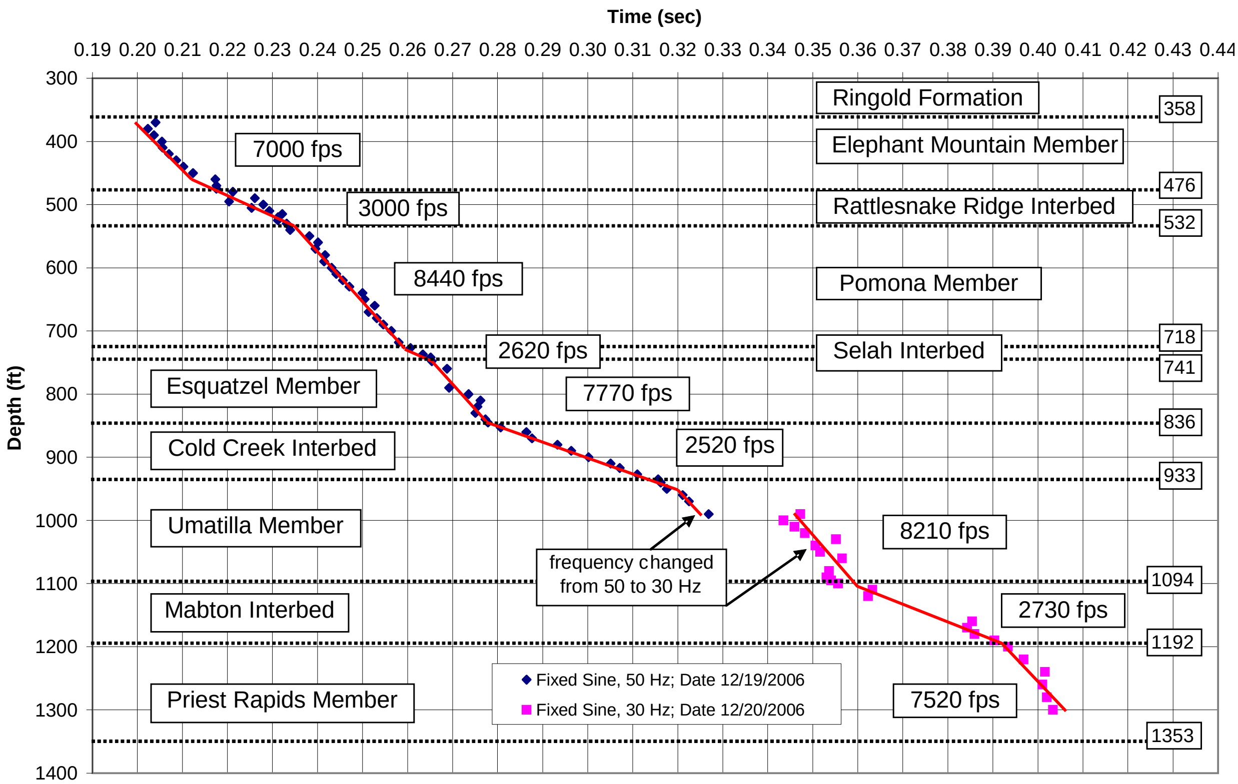


Fig. 6. Shear wave velocity measurements in borehole C4993 using a vibratory seismic source. Velocities reported in ft/sec (fps) (from Stokoe et al. [6]).

interbed units. Overall, very similar results were obtained in boreholes C4996 and C4997 (not shown). Variability across boreholes was generally less than 20%.

Density measurements were also made using two different methods. A standard geophysical logging method measured density at the borehole wall. A second method using a borehole gravity meter measured density far from the borehole wall. The second method is not affected by drill fluid invasion, cement, or metal casing in the borehole. Comparison of the two density measurements gave good agreement except where borehole irregularities or steel casing were present.

The shear wave velocity and density data from the three boreholes and the core hole were combined statistically to produce an average velocity and density model of the WTP site. The final set of profiles integrated data from the new boreholes and previous studies and provided a set of updated input parameters for subsequent use in evaluating the seismic site response of the WTP site. The statistical analysis also provided bounds on the variability and uncertainty of the profiles. Figure 7 depicts the 2007 velocity model for the suprabasalt sediments along with the 2005 velocity model for comparison. The 2007 model was produced by integrating and averaging the new borehole Vs data with prior seismic cone penetrometer and downhole data, and used geologists' logs to define the range of geologic unit thicknesses. The 2007 models for the suprabasalt sediments are comparable to the 2005 models except for a sharp Vs contrast from Hanford sand to gravel (H2/H3), a sharp Vs contrast from Cold Creek Unit to lower Ringold Unit A, and a high Vs in Ringold Unit A that is comparable to Vs in basalt flow top.

Figure 8 depicts the 2007 velocity model for the basalts and interbeds along with the 2005 velocity model for comparison. The 2007 model was produced by integrating and averaging the new borehole Vs data

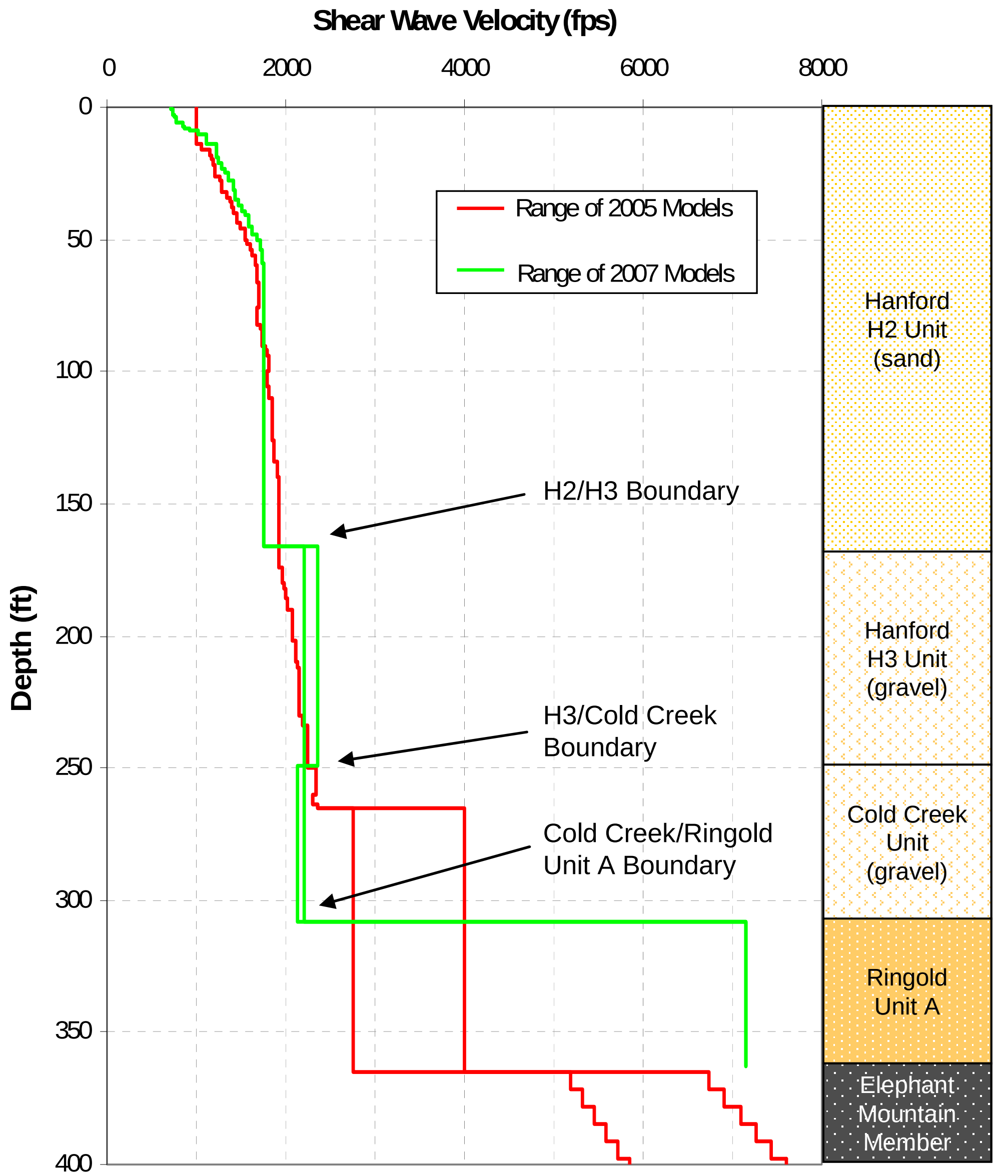


Fig. 7. Comparison of 2007 Vs models to 2005 Vs models for suprabasalt sediments.

collected using downhole logging with the vibratory source for all basalts and interbeds and the impulsive source for the upper basalts and interbeds. As with the suprabasalt sediments, geologists' logs were used to define the range of geologic unit thicknesses. Significant differences can be seen between the 2007 and 2005 models for the basalts and interbeds. The basalt Vs values for 2007 are comparable to the upper limit of the 2005 analyses, and the interbed Vs values are significantly less than the upper limit of the 2005 analyses. The measured results and corresponding 2007 model represents significantly greater contrast in Vs between the basalt and interbed units. The flow top gradients are also noticeably different. The velocity profiles for these flow top gradients were estimated using density and suspension logging Vs data, which enabled unit-specific gradients to be developed for 2007 which have a gradual rise from a much smaller Vs value than estimated in 2005. Finally, the 2007 profile represents the interflow features

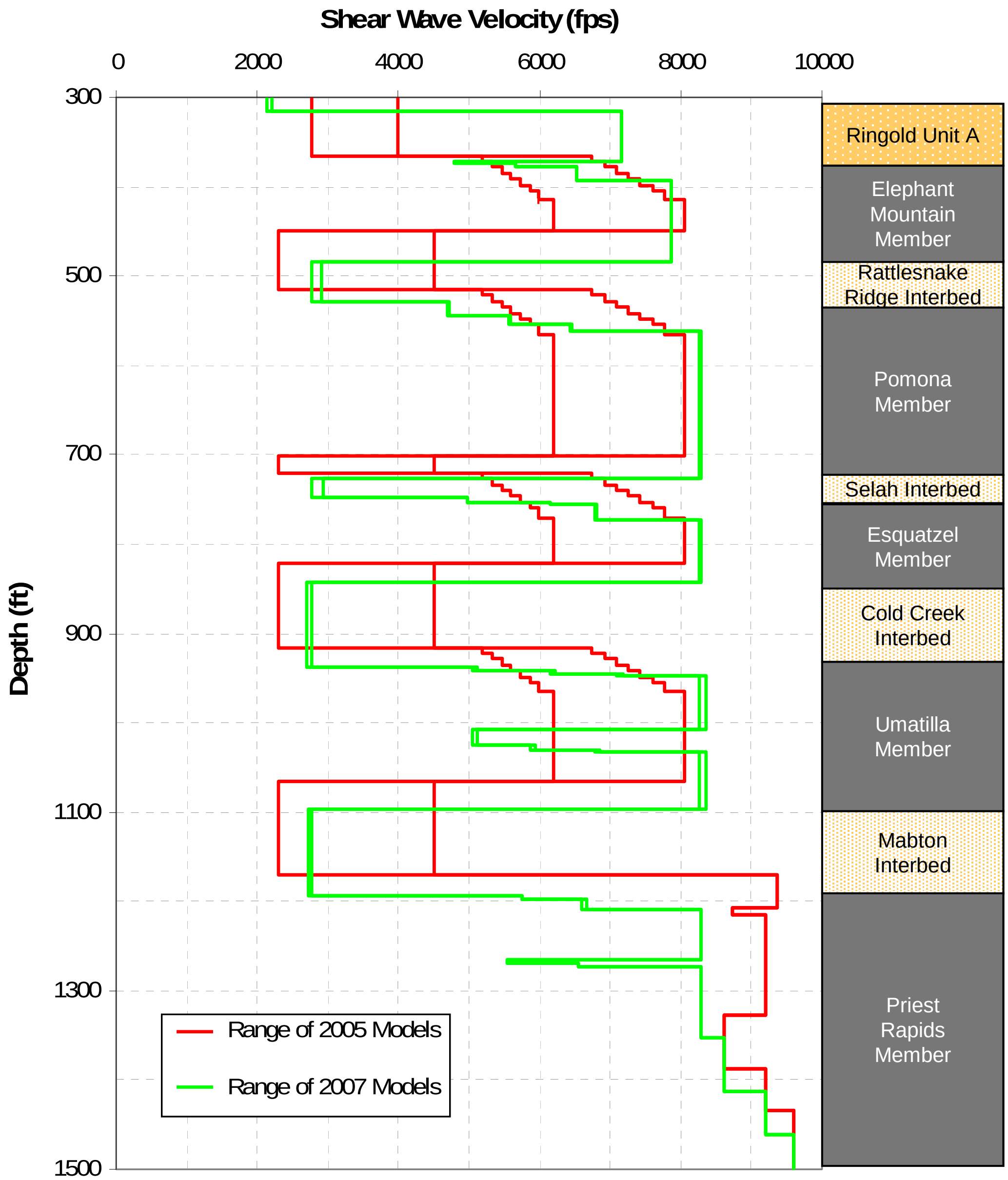


Fig. 8. Comparison of 2007 Vs models to 2005 Vs models for basalts and interbeds.

that are present in the Umatilla and Priest Rapids members, introducing flow top gradients between specific basalt flows.

The final velocity and density profiles are represented by a set of input parameters required for seismic site response analyses that include densities of all stratigraphic units, stratigraphic unit thicknesses, basalt flow top thicknesses, Vs of all stratigraphic units, and basalt flow top velocity gradients (as depicted in Figures 7-8).

SITE RESPONSE ANALYSIS RESULTS AND DISCUSSION

An updated site response model for the WTP site was developed by PNNL and Geomatrix. This effort was supported by an expert panel that provided guidance on the interpretation of the data and recommendations on formulating the updated site response model.

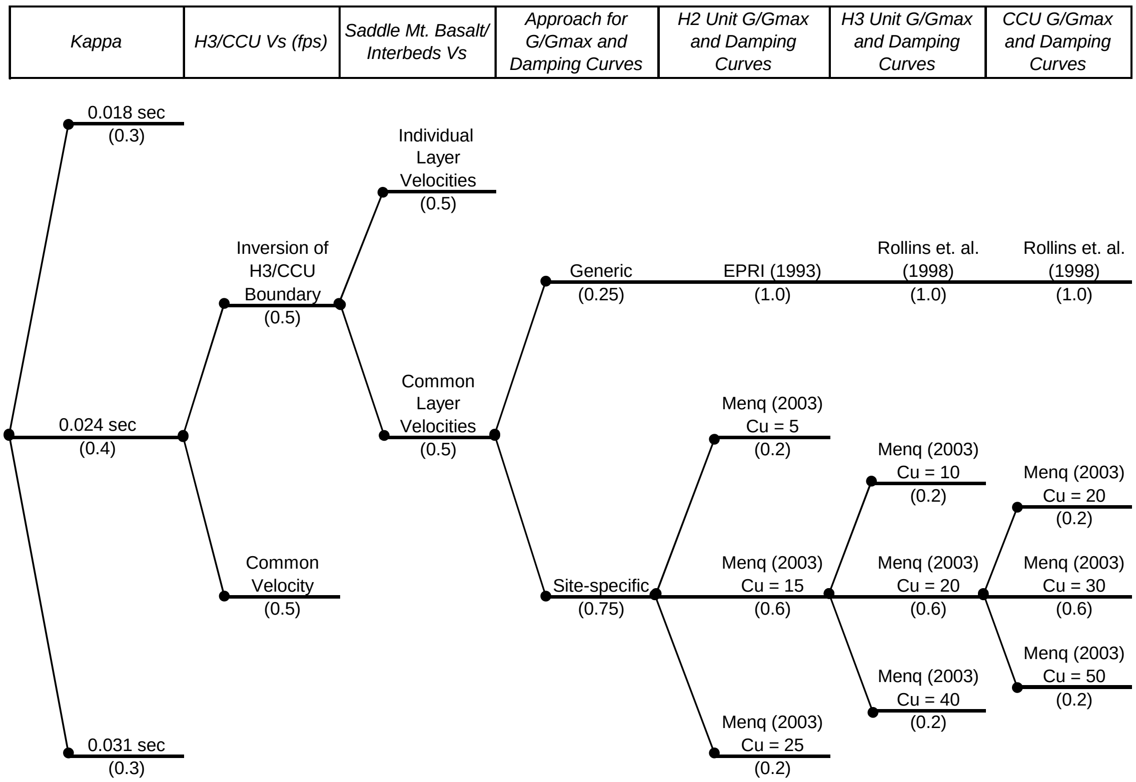
Model Input Parameters

Input parameters for the site response model are listed in Table II along with the relative (qualitative) uncertainty and impact on overall site response (i.e., spectral acceleration) for both the 2005 and 2007 calculations. For model parameters with significant uncertainty, a range of alternative parameter values and weights/probabilities was used and agreed to by expert panel members. Figure 9 shows the site response model logic tree developed to represent the uncertainties in the site dynamic properties. A few points should be made to assist the reader in understanding the structure of the logic tree. For the sake of visual clarity, the logic tree figure does not display all of the branches that exist in the actual logic tree used in the analysis. Those branches that are repeated at multiple nodes of the tree are not shown. For example, note that at the first node for the value of "kappa" there are three branches for alternative values. The next level (node) of the logic tree indicates alternative models for H3/CCU sediment velocities. The alternative H3/CCU velocity models are only shown for a single kappa branch. This is only for the sake of keeping the figure uncomplicated. In the site response calculation, *all* nodes of the logic tree are assigned the relevant branches such that all possible sets of site parameters are used.

Overall damping is represented by the "kappa" value in the site response model. Uncertainties in kappa are represented by three alternatives which were described previously by Rohay and Reidel [2]. The alternative models used in the 2007 site response model are consistent with those used in 2005. No new data have been collected that would warrant change to the alternatives used previously.

Table II. Model Inputs to 2005 and 2007 Site Response Analyses and Relative Uncertainties and Impact

Model Inputs	2005		2007	
	Uncertainty	Impact	Uncertainty	Impact
Sediment velocities	**Med**	Med	**Low**	Med
Basalt and interbed velocities	**High**	High	**Low**	High
Sediment modulus reduction and damping curves	**Low**	Low	**Med**	Med
Kappa (overall damping)	**Med**	Med	**Med**	Med
Geometry of contact (depths/thicknesses)	**Low**	Med	**Low**	Med
Densities	**Low**	Low	**Low**	Low



Terminology
Kappa - Overall Damping; (#.#) - weight/probability; Vs - shear wave velocity in ft/sec; G/Gmax - Modulus Reduction; Cu - Coefficient of Uniformity; H3 - Hanford formation, H3 unit; H2 - Hanford formation, H2 unit; CCU - Ringold Formation, Cold Creek Unit

Fig. 9. Updated site response model logic tree for the WTP. (Numbers in parentheses below branches indicate assigned weight.)

The velocities of sediments and basalts used in the 2007 site response model were as depicted in the velocity model Figures 7 and 8. Two alternative models for the H3 and CCU sediment velocities were used to represent uncertainty in measured values for these specific units. For the basalt and interbed velocity model, two alternative models were used. One was based on the individual unit velocities as depicted in Figure 8. The other alternative used a single mean or common value for all basalt units and another mean value for all interbed units.

Uncertainties in the sediment modulus reduction and damping curves were represented by two main alternatives – generic soil curves from the literature, and site-specific curves. Rohay and Reidel [2,3] used published generic modulus reduction and damping relationships from the Electric Power Research Institute (EPRI) [9] and Rollins et al. (1998) [10] to represent the non-linear behavior of the suprabasalt sediments in the 2005 site response model. During the field investigation conducted in 2006, bulk samples of these sediments were obtained. Dynamic resonant column/torsional shear (RCTS) tests were performed on reconstituted samples by the University of Texas at Austin (UTA). The bulk samples obtained by UTA were scalped to remove large particle sizes before testing. Results of this UTA testing showed that a Menq [11] model provided a reasonably good match to the scalped test data, and that the model could be used to develop appropriate modulus reduction (G/Gmax) and damping relationships for the in-situ grain size distributions of the H2, H3, and CCU sediment layers. Therefore, two modeling approaches for specification of the G/Gmax and damping relationships for the sediments were incorporated into the site response model, one based on the use of generic curves and one based on development of a range of site-specific curves using the model developed by Menq.

Site Response Model and Design Response Spectra

A site response analysis was performed to compute the relative response of Hanford site profiles and California soil site profiles to ground motions representative of the site hazard at the specified return period. These site response analyses were performed using outcropping motions back-propagated to the crustal depth where the California and Hanford sites have similar shear wave velocities, which is at a depth of 3 km [1]. These rock motions were then propagated upward through randomized California soil site profiles and randomized Hanford profiles. Geometric mean (mean log) response spectra for the computed surface motions were used to compute the ratio of Hanford surface motions to California soil site motions. This ratio, termed the relative amplification function (RAF) was used by Rohay and Reidel [2] to adjust the original horizontal design response spectrum developed using California-based empirical ground motion models to reflect the ground motions representative of the response of the Hanford WTP site to similar levels of shaking. The same approach was followed in this study. The site response model logic tree is used in the full probabilistic analysis to produce a distribution of RAF curves.

Rohay and Reidel developed the 2005 revised horizontal ground motion design response spectrum (RGM) for the WTP site by multiplying the original WTP horizontal design response spectrum (based on the 1996 PSHA results) by the RAF derived from relative site response analyses. For conservatism in the final design recommendation, the 84th percentile relative amplifications from the full logic tree analysis were used to develop the RGM. Figure 10 shows the original 1996 design response spectrum (1996 DRS); the 1996 DRS multiplied by the 2005 84th percentile RAF, and the resulting RGM.

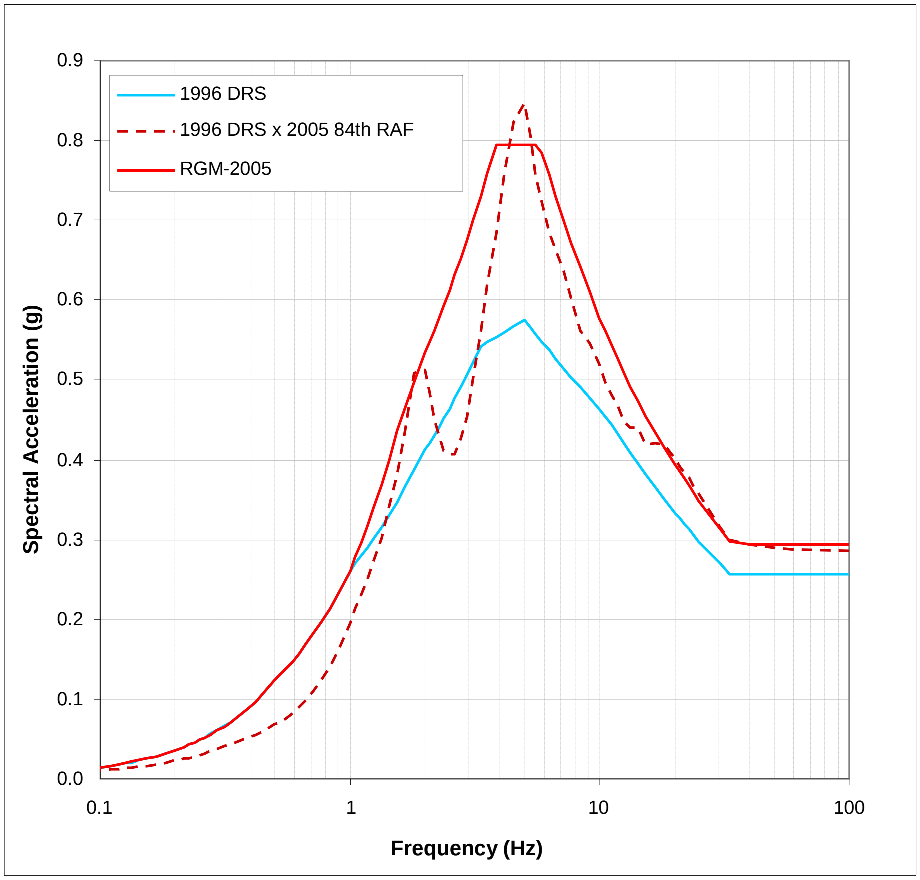


Fig. 10. Development of 2005 interim WTP horizontal design response spectrum (RGM-2005) compared to the original horizontal design response spectrum (1996 DRS)

The RGM was developed by smoothly enveloping and broadening the peak of the 1996 DRS x 2005 84th RAF curve. The resulting RGM-2005 increased peak horizontal ground motion by up to 40% over the original 1996 design criteria.

Figure 11 shows the same three curves as Figure 10 along with two new curves representing the 2007 site response analysis (1996 DRS x 2007 84th RAF) and updated WTP site-specific horizontal ground motion design response spectra (WSGM–2007). The 84th percentile RAF was again used in 2007 for conservatism, and the resulting WSGM was developed by smoothly enveloping and broadening the peak of the 1996 DRS x 2007 84th RAF curve. The resulting WSGM-2007 decreased the peak horizontal ground motion by approximately 25% from the 2005 RGM design criteria. This significant reduction in peak ground motion is attributed to significantly smaller uncertainty of median shear wave velocities for the basalts and interbeds based on direct measurements, significantly greater contrast between basalts and interbeds velocities, and more non-linear and greater damping based on site-specific data.

The final results of this study, including a description of the geology, an updated velocity and density model, updated site response analysis, and updated design response spectra, were formally documented in May and June of 2007 [12-14]. These results confirmed that the RGM-2005 used as the basis for design of the WTP was conservative. In August 2007, the Secretary of Energy certified to Congress that the ground motion design criteria for the WTP were final, and restart of construction of the pretreatment and HLW vitrification facilities was authorized.

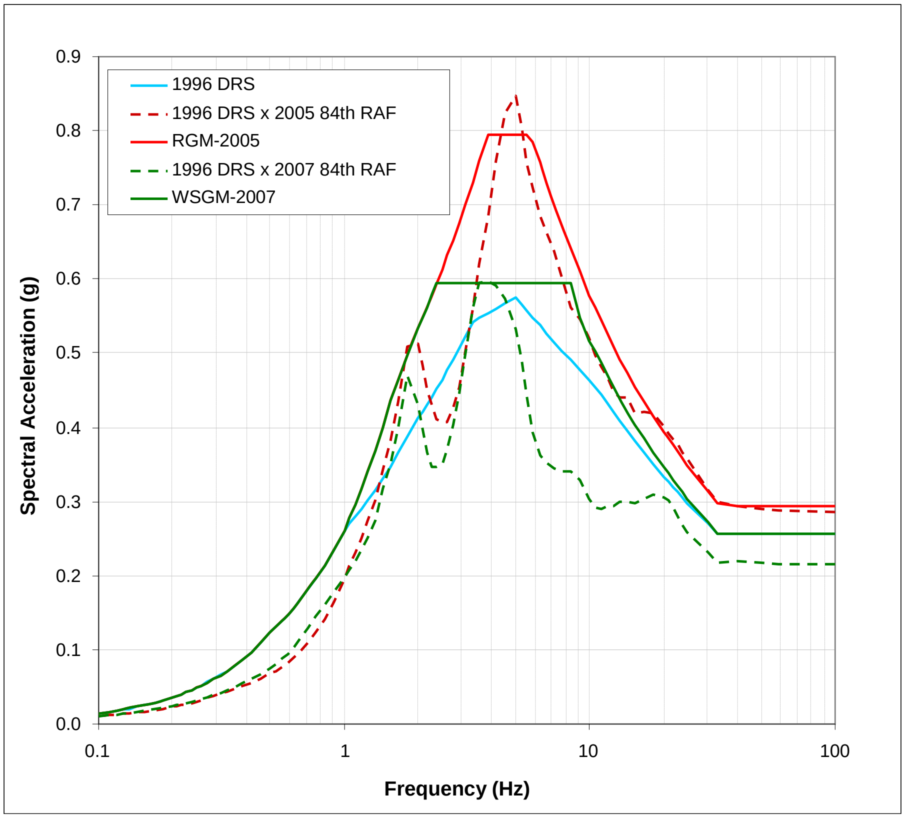


Fig. 11. Development of WSGM-2007 horizontal design response spectrum. Also shown are the original design response spectrum (1996 DRS), the original design response spectrum multiplied by the 2005 84th-percentile RAF, and the RGM-2005

SUMMARY AND CONCLUSIONS

One of the Department of Energy's top priorities and toughest technical challenges has been resolving seismic issues for Hanford's Waste Treatment and Immobilization Plant (WTP). Construction of the two performance category three (PC-3) facilities was halted until the Secretary of Energy could certify the final seismic and ground motion criteria to Congress. The Seismic Boreholes Project was initiated by DOE to address uncertainties in the ground motion criteria for WTP. In 2006, DOE-ORP assigned PNNL the responsibility of managing the effort to drill four deep boreholes to depths of approximately 1,400 feet directly on the WTP construction site and collect the needed seismic data. PNNL led the team of local and national industry and university experts in deep borehole drilling, geologic and seismic data collection, and seismic response analysis.

The project team completed all project deliverables within 15 months of the first drilling services request for proposal. The project required seventeen contractors, many of them working round-the-clock during drilling operations to install boreholes, collect geophysical data and samples, and perform ground motion response modeling. The project was completed safely, within budget, and within schedule expectations. Only one lost-time injury was experienced during the more than 170,000 work hours.

The end result was the scientifically defensible resolution of critical seismic safety issues that enabled the Secretary of Energy to certify seismic design criteria and authorize WTP construction to resume at the site. The resulting WSGM-2007 confirmed that the existing design criteria are conservative. Use of the updated WSGM-2007 criteria will be limited, but will assure substantial design margin for the WTP and may be used by DOE as needed on a case-by case basis.

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