North Anna 3

North Anna Unit 3 COLA

Seismic Closure Plan

COLA Markup/RAI Revision Submission February 23, 2015

April 1st, 2015

Dominion

Agenda

- Introduction
- Review of RAI Responses
- NRC Meeting Questions
- Summary and Schedule
- Action Items

Introduction

- North Anna Unit 3 Seismic Closure Plan (SCP) submitted to NRC October 22, 2014
- Changes described in SCP:
  - Meet NRC requirements and guidance
  - Use methodologies for site-specific analyses specific to the NA3 site conditions
  - Increase consistency with DCD methodologies
  - Apply most current ground motion model (GMM) approved by NRC

RAI 02.05.02-3

TOPIC: 1-D Analysis Justification, Site Amp. Input Data and V_s Profile 1 and 2 Explanation

- The response is revised to reflect the EPRI 2013 updated GMM
  - Sensitivity site response analysis performed using each one of the B-901, B-907, and B-909 boreholes as a base profile
  - Comparison of the weighted average DRS from the sensitivity study with the FIRS and GMRS using 2013 updated GMM
- Other information previously provided by the RAI response remains unchanged.

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RAI 02.05.02-6

TOPIC: Vibratory Ground Motion

- The response is revised to reflect the EPRI 2013 updated GMM
  - Enveloped DRS from RB/FB and CB soil columns for calculation of GMRS at Elevation 224
  - Comparison with sensitivity site response analysis results performed using each one of the B-901, B-907, and B-909 boreholes as a base profile
  - Electronic data provided for the geologic outcrop site amplification functions for the RB/FB and CB for the GMRS horizon
- Other information previously provided by the RAI response remains unchanged.

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RAI 03.07.01-8

TOPIC: Development and Use of Companion Profiles

- The response is revised to reflect the EPRI 2013 updated GMM
  - Figure depicting the calculation of the design factor (DF) used in the DRS calculation for RB/FB
- Other information previously provided by the RAI response remains unchanged

RAI 03.07.01-11

TOPIC: FWSC Response Spectra Modeling Basis

- The response is revised to reflect the EPRI 2013 updated GMM
  - Comparisons provided between FWSC and CB UHRS and FIRS
  - Development of the SSI Input response spectra at Elevation 220 ft (bottom of concrete fill) for FWSC
- Other information previously provided by the RAI response remains unchanged.

RAI 03.07.01-12

TOPIC: Numerical Results of Spectral Matching and PSD Functions

- Presentation of the CSDRS spectrum which envelopes over the site specific spectra for frequencies less than 0.2 Hz
- Numerical results for statistical checks provided
- Scaling and baseline correction methodology sequence presented which ensures the time histories are baseline corrected and consistent with the statistical checks
- Digital values provided to NRC for response spectra, acceleration time histories and PSD functions at NRC request
- Acceptance of acceleration time histories and associated response spectra and PSD functions by NRC during meeting December 9, 2014

RAI 03.07.01-7

<u>TOPIC: Effects of Backfill on FIRS Development</u>

- Revision based on NRC comments from the 07/10/2014 public meeting.
- Added description of how fill material is represented in the models for SSI and SSSI.
- Includes technical basis for approach to address effects of variations in extent of horizontal fill on seismic response of SCI structures.
- RAI response describes extent of backfill and provides RAI sketches illustrating backfill for RB/FB, CB and FWSC.
- Related FSAR markups in 02/2015 submittal to Section 2.5.4.5.1 and Tables 3.7.1-201 through 3.7.1-206.

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RAI 03.07.02-11

TOPIC: SSI Input Control Motions

- Response is revised to reflect the EPRI 2013 updated GMM
  - Revised RAI response figures showing comparisons at two different elevations for Control Building (CB) horizontal full column profile design response spectra and CB horizontal partial column profile design response spectra
- Added information regarding addition of CB shear key (if needed) embedded in concrete fill to ensure sufficient lateral resistance of the subgrade to prevent CB sliding

NRC Meeting Question #1

Topic: Development of vertical FIRS and PBSRS for RB/FB, CB and FWSC from horizontal FIRS and PBSRS.

V/H: Implementation of NUREG/CR-6728

The following equation indicates an implementation of the NUREG procedure used in the FSAR:

$V/H_{CEUS,soil} = V/H_{CEUS,rock} \times f\,(\text{rock-to-soil}) \times f\,(\text{WUS-to-CEUS})$

where

$V/H_{CEUS,rock}$	appropriate hard rock CEUS V/H from the NUREG
f (rock-to-soil)	transfer function for converting rock V/H to soil V/H
f (WUS-to-CEUS)	transfer function converting WUS V/H to CEUS V/H

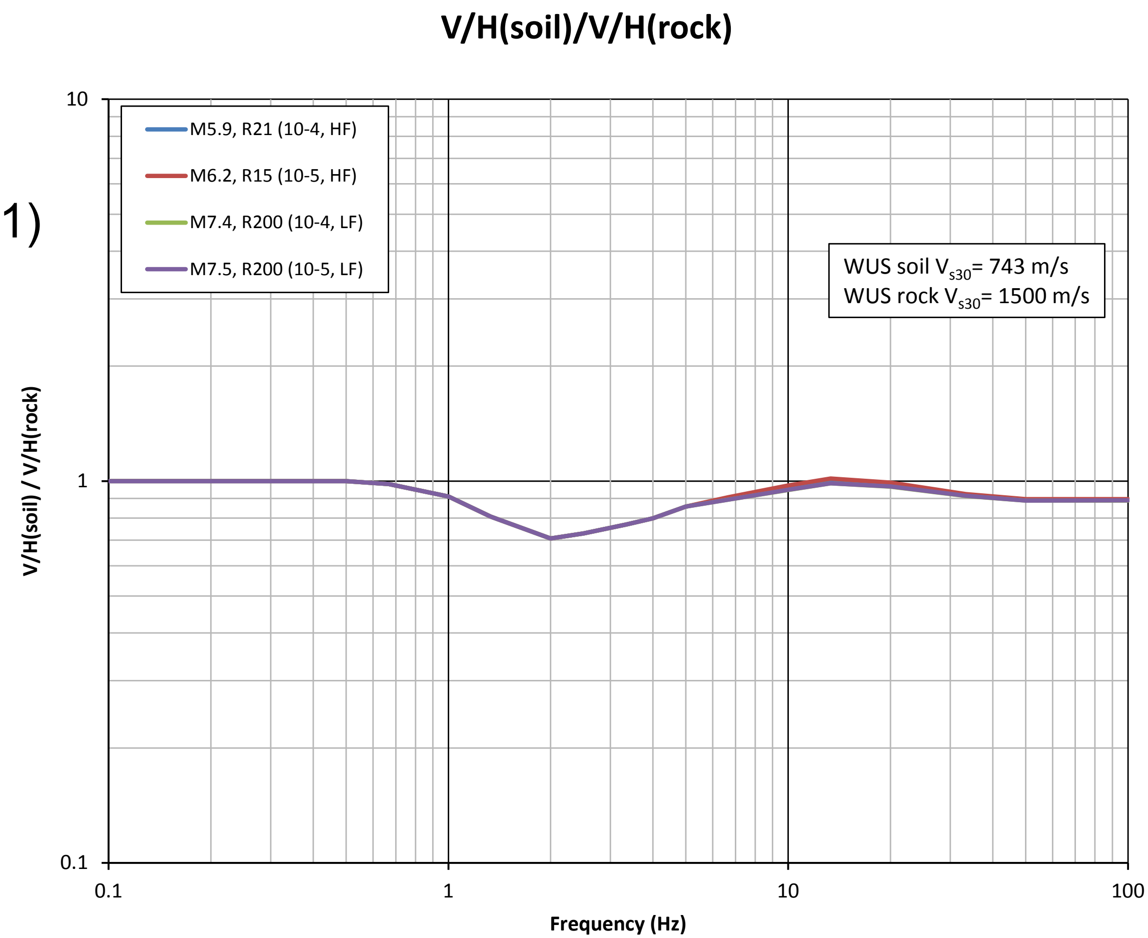
V/H: Implementation of NUREG/CR-6728

f (rock-to-soil)$_{WUS}$

Gülerce and Abrahamson (2011)

- Magnitude
- Distance
- V_{s30}

Deaggregation M, R



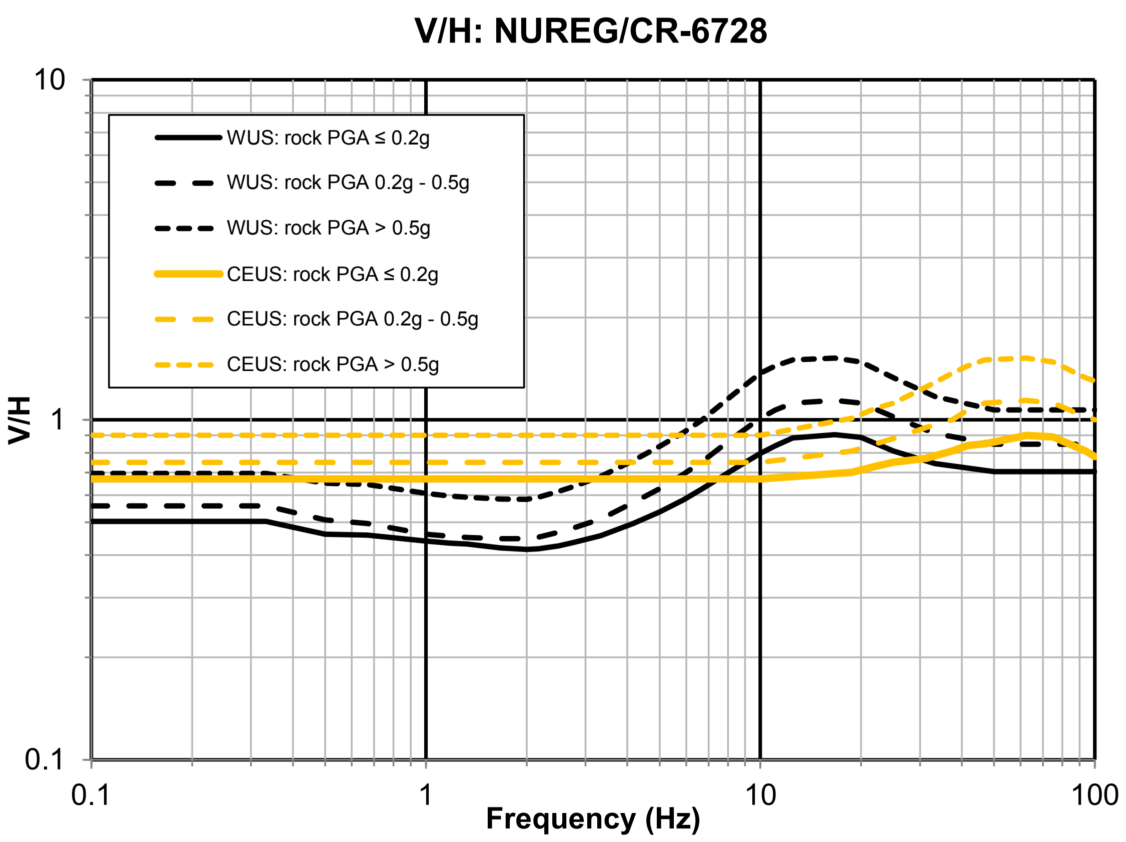
f (rock-to-soil)$_{WUS}$ = $V/H_{WUS,soil}$ / $V/H_{WUS,rock}$

V/H: Implementation of NUREG/CR-6728

f (WUS-to-CEUS)

As indicated in the NUREG, use well-defined, available information in WUS, and transform it to CEUS conditions.

Analogous to the first-order transformation from WUS to CEUS used in the NUREG for rock, perform a frequency shift of (62.5/16.7) to transform *f* (rock-to-soil)$_{WUS}$ to CEUS *f* (rock-to-soil)$_{CEUS}$



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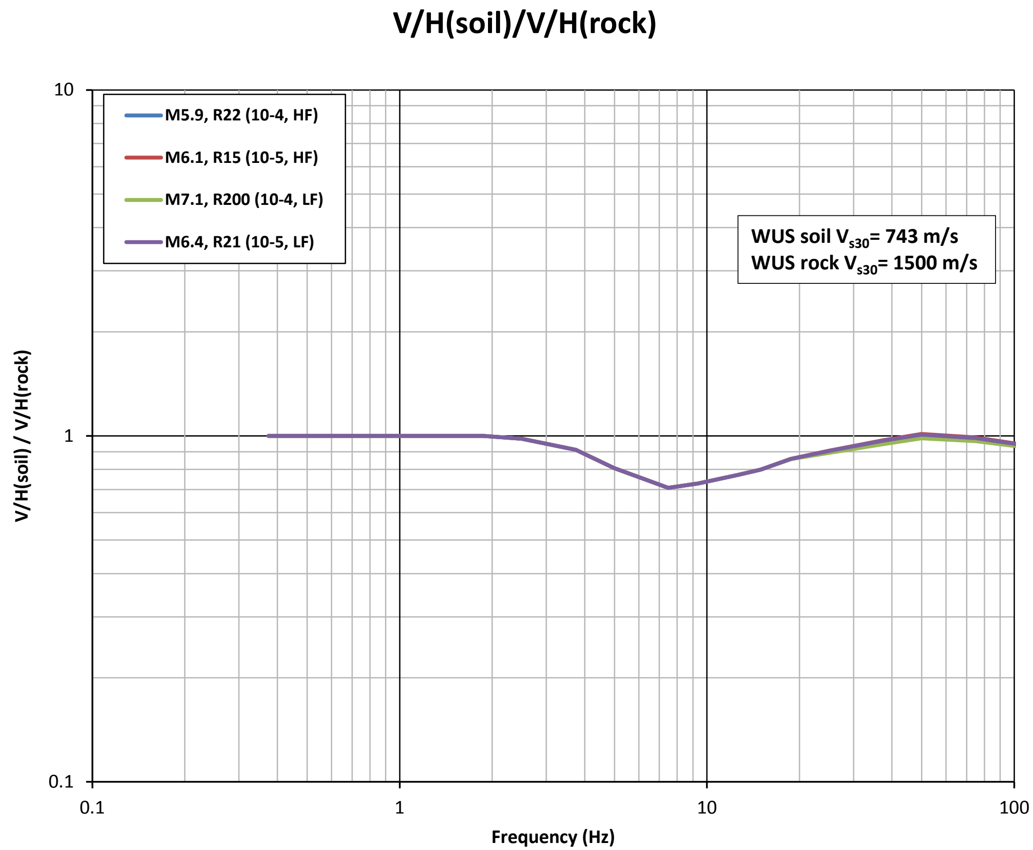
V/H: Implementation of NUREG/CR-6728

f (rock-to-soil)$_{CEUS}$

or

$(V/H_{WUS,soil} / V/H_{WUS,rock})_{frequency\text{-}shifted}$

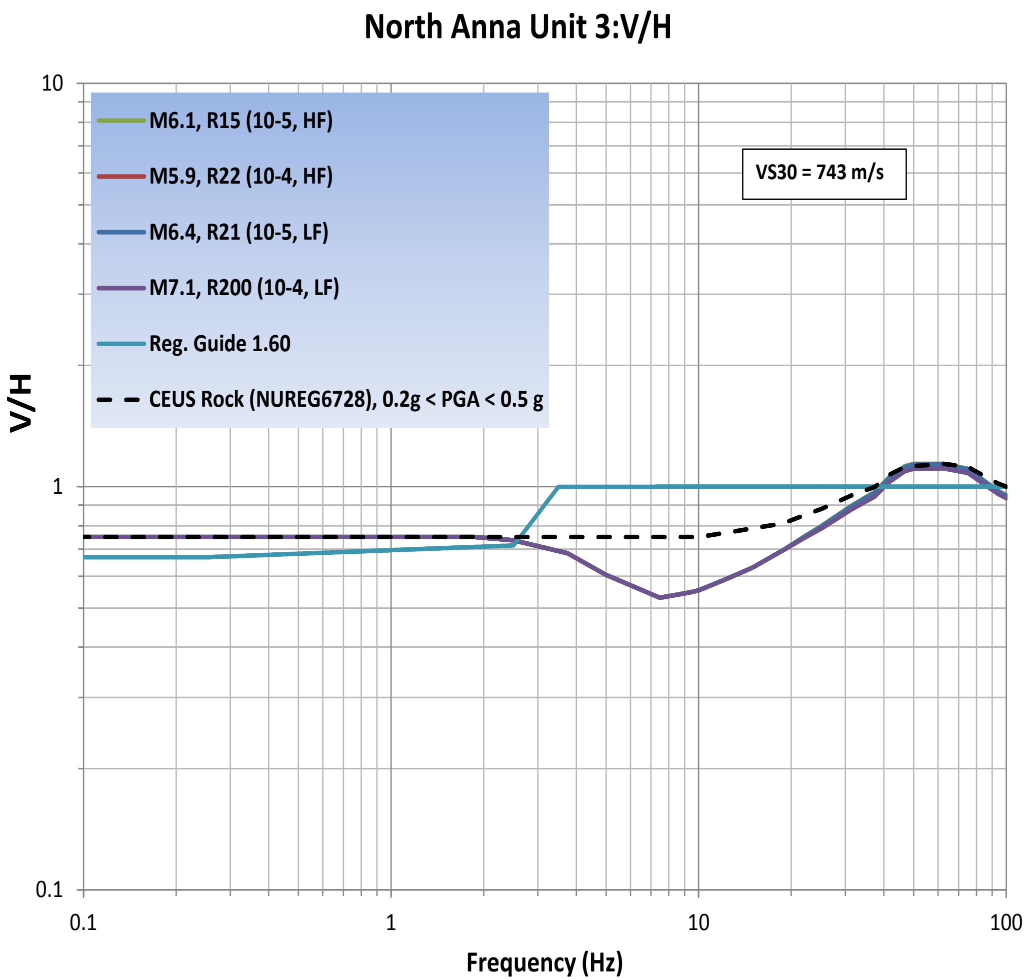


V/H: Implementation of NUREG/CR-6728

$V/H_{CEUS,soil}$

$= V/H_{CEUS,rock} \times (V/H_{WUS,soil} / V/H_{WUS,rock})_{frequency\text{-}shifted}$

The dip [low values] in the V/H ratios in the frequencies between about 2 and 20 Hz may be considered, by some, to be an unconservative or WUS-biased character, so the CEUS rock V/H is used as a "floor" to prevent the dip.



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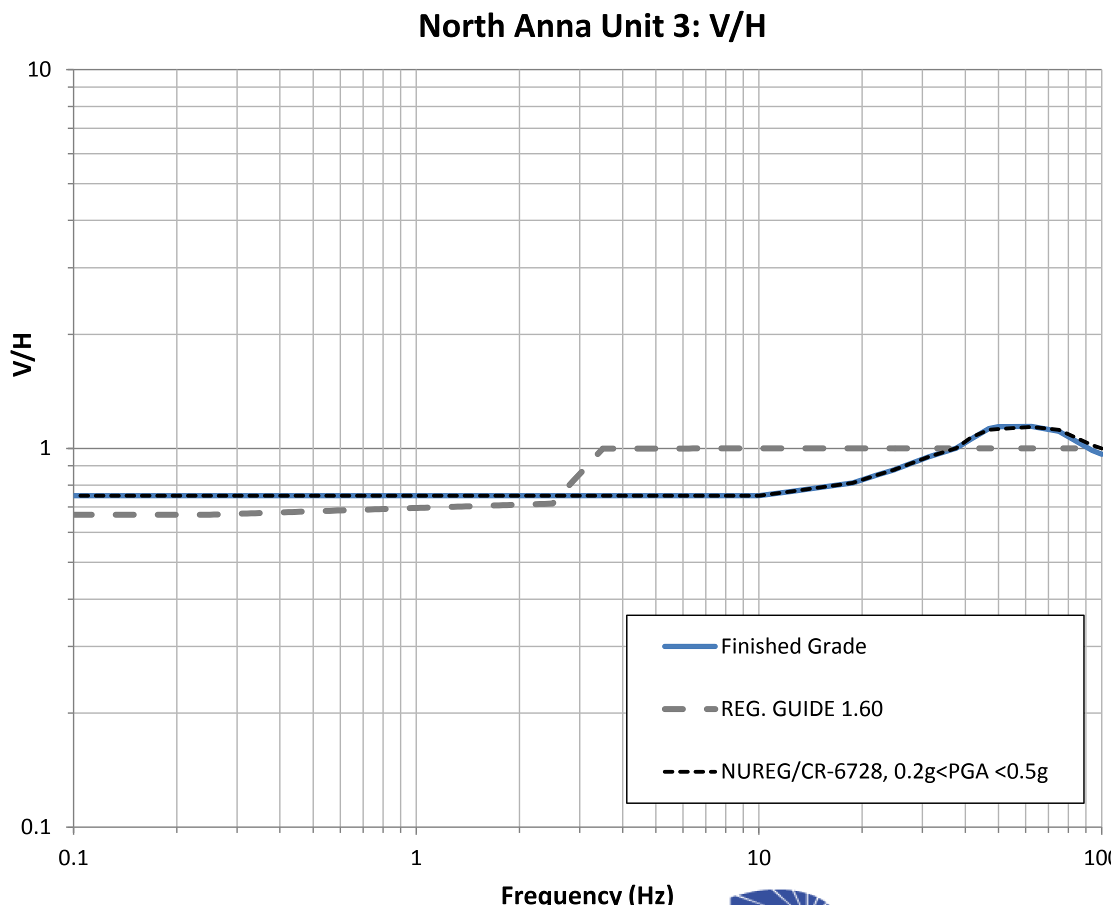
V/H: Implementation of NUREG/CR-6728

$V/H_{CEUS,soil}$

Note: The NUREG procedure is not explicitly prescriptive, as evidenced in the various ways in which it has been used in various ESPs and COLAs.

The beneficial aspect of the procedure used here is that as V_{S30} approaches the higher rock values, the ratio $V/H_{WUS,soil}$ / $V/H_{WUS,rock}$ goes to 1.0 at all frequencies, giving the $V/H_{CEUS,rock}$ as given in the NUREG.



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NRC Meeting Question #2

TOPIC: Digital format of FWSC SSI models for (1) SASSI soil profiles, (2) FWSC in-column input time histories and (3) FWSC structural and concrete fill properties.

- The requested information will be provided (digitally) with the RAI 03.07.01-11 Supplement 3 response. Supplement 3 will provide analyses results with FIRS at base of concrete fill based on 2013 GMM. Supplement 3 response will be provided in July 2015 per the Seismic Closure Plan.

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NRC Meeting Question #3

TOPIC: Digital format of:

(1) 60 strain-compatible soil profiles for LF4, HF4, LF5, HF5,

(2) Log-mean and log-SD [of the strain compatible soil profiles] for hazard levels 10-4 and 10-5,

(3) Log-mean and log-SD [of the strain compatible soil profiles consistent with] FIRS; and

(4) LB, BE and UB soil profiles.

[The bracketed text was added for clarification]

- Is the information requested for a specific building?
- The requested information will be provided (digitally) in April 2015.

NRC Meeting Question #4

TOPIC: FSAR Section 3.7.1.1.5.1.1 revision

- Revision to FSAR text submitted by Dominion Letter NA3-14-030A, dated 7/18/14.
  - Contained deletion of PSD comparison discussion (see next slide).
- Revision to FSAR text carried over by Dominion Letter NA3-14-030D, dated 10/13/14 (see excerpt).
- February, 23th 2015 submittal included only pages of FSAR that were revised subsequent to Dominion Letter NA3-14-030D.

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NRC Meeting Question #4 (cont)

- Non-stationary phasing consistent with seismological principals.
- Uniform normalized Arias intensity curves

Following these selection guidelines, the strong ground motion time history from the 1984 **M**6.2 Morgan Hill earthquake recorded at the station Gilroy–Gavilan College was selected as the seed input time history set for the spectral matching presented here. This selected time history from the CEUS magnitude-distance database bin of NUREG/CR-6728 is based on the original empirical recording from the Morgan Hill earthquake at the Gilroy–Gavilan College station with the additional modification of the empirical time history to adjust for more CEUS hard rock conditions.

3.7.1.1.5.1.1 **SSI Input Acceleration Time Histories for the RB/FB**

Two sets of three statistically independent acceleration time histories of motions (i.e., two horizontal and one vertical component) are developed for the full column and partial column final SSI input motion spectra. These time histories are modified to be spectrum compatible following Option 1, Approach 2 of SRP 3.7.1. Additionally, the power spectrum density (PSD) of the spectrum matched time histories are ~~compared to reference PSDs developed consistent with the target response spectra using the site response analysis, the methodology and data provided in Appendix B of SRP 3.7.1, and the deaggregation information from the probabilistic seismic hazard analysis for the site. For each spectrum matched time history, it is confirmed that its PSD does not fall below 80 percent of its corresponding reference PSD~~ computed to allow for the conclusion that these spectrum compatible time histories do not contain any significant gaps in energy over the SRP 3.7.1 defined frequency range.

The input seed time histories are modified to be spectrum compatible using the computer program RSPM. The baseline correction program BLINE, a component program of RSPM, is also used in the process after each iteration of RSPM.

For each time history, the average ratio between the acceleration time history response spectrum and the corresponding target acceleration response spectrum (both at a spectral damping of 5 percent) was greater than 1.0. In addition, the spectral matching criteria given in SRP 3.7.1 for Option 1, Approach 2 were satisfied in each spectral matching case.

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NRC Meeting Question #4 (cont)

results are a magnitude of **M**7.4 and a distance of 540 km for the 10^{-4} and **M**7.5 and a distance of 480 km for the 10^{-5} hazard levels (Section 2.5.2.4). Based on the large distance associated with the low frequency controlling event, the selected seed input acceleration time history for the spectral matching procedure was governed by the high frequency controlling events.

In selecting a candidate acceleration time history set from the applicable magnitude-distance bin from NUREG/CR-6728, the following aspects of a given time history set were considered:

- Similarity between the spectral shape of the candidate acceleration time history and the target spectrum
- Total time history duration of at least 20 seconds
- Zero-lag cross correlation coefficient between any two components of acceleration time histories should be less than 0.16
- Appropriate magnitude and distance values relative to the controlling event values
- Non-stationary phasing consistent with seismological principals.
- Uniform normalized Arias intensity curves

Following these selection guidelines, the strong ground motion time history from the 1984 **M**6.2 Morgan Hill earthquake recorded at the station Gilroy–Gavilan College was selected as the seed input time history set for the spectral matching presented here. This selected time history from the CEUS magnitude-distance database bin of NUREG/CR-6728 is based on the original empirical recording from the Morgan Hill earthquake at the Gilroy–Gavilan College station with the additional modification of the empirical time history to adjust for more CEUS hard rock conditions.

3.7.1.1.5.1.1 **SSI Input Acceleration Time Histories for the RB/FB**

Two sets of three statistically independent acceleration time histories of motions (i.e., two horizontal and one vertical component) are developed for the full column and partial column final SSI input motion spectra. These time histories are modified to be spectrum compatible following Option 1, Approach 2 of SRP 3.7.1. Additionally, the power spectrum density (PSD) of the spectrum matched time histories are computed to allow for the conclusion that these spectrum compatible time histories do

not contain any significant gaps in energy over the SRP 3.7.1 defined frequency range.

The input seed time histories are modified to be spectrum compatible using the computer program RSPM. The baseline correction program BLINE, a component program of RSPM, is also used in the process after each iteration of RSPM.

For each time history, the average ratio between the acceleration time history response spectrum and the corresponding target acceleration response spectrum (both at a spectral damping of 5 percent) was greater than 1.0. In addition, the spectral matching criteria given in SRP 3.7.1 for Option 1, Approach 2 were satisfied in each spectral matching case.

For the RB/FB partial column spectrally matched time histories, the comparisons between the scaled spectrum compatible acceleration response spectra and the target spectra and boundary range are plotted in Figures 3.7.1-235 through 3.7.1-237 for the first horizontal direction (H1), second horizontal direction (H2) and the vertical direction (UP), respectively. Similar plots for the RB/FB full column spectrally matched time histories are presented in Figures 3.7.1-238 through 3.7.1-240.

The zero-lag cross-correlation for each three component sets of spectrum compatible acceleration time histories are computed to verify the acceptability of the acceleration time histories. The zero-lag cross-correlations for the partial column and full column RB/FB cases are listed in Table 3.7.1-210. These computed values are all less than the required minimum value of 0.16.

In addition to the cross-correlation values, the peak ground motion parameters and associated ratios are listed in Table 3.7.1-211. Based on the target spectra used in the spectral matching procedure being a composite of both the high frequency and low frequency cases (i.e., the deaggregation values are bi-modal), the resulting PGV/PGA and $PGA*PGD/PGV^2$ ratios do not fall within the bin values reported in NUREG/CR-6728. The PGA, PGV, and PGD refer to the peak ground acceleration, peak ground velocity, and peak ground displacement, respectively. This observed deviation from the reported bin values is caused by the relatively large PGA value from the high frequency case (i.e., small magnitude event at relative close distances) compared to the intermediate and longer spectral period range PGV and PGD which is controlled by the low frequency case (i.e., large magnitude event at a

Schedule: COLA Markups and RAIs

Submittal Date	Revised COLA/FSAR Sections	RAI Responses		Status
Submitted previously		02.05.02-7 02.05.05-4 03.07.01-9 03.07.01-10 03.07.01-11 and S01 03.07.01-12 and S01 03.07.02-10 03.07.02-11 03.07.02-12	03.07.02-15 03.07.02-19 03.07.02-22 03.07.02-23 03.07.02-24 03.07.02-25 03.07.03-1 03.08.05-7 03.09.02-3	Submitted
02/2015	FSAR Section 2.0, Site Intro. FSAR Section 2.5.2 **<u>FSAR Section 2.5.4</u>** **<u>FSAR Section 2.5.5</u>** FSAR Section 3.7.1	**<u>02.05.02-3 (revised)</u>** 02.05.02-6 (revised) **<u>03.07.01-7 (revised)</u>** 03.07.01-8 (revised)	03.07.01-11 S02 03.07.01-12 S02 **<u>03.07.02-11 (revised)</u>**	Submitted
07/2015	FSAR Section 3.7.2 FSAR Section 3.8.2 FSAR Section 3.8.4 FSAR Section 3.8.5 FSAR Section 3G-S.1.5	03.07.01-11 S03 03.07.02-13 03.07.02-14 03.07.02-15 (revised)	03.07.02-16 03.07.02-23 (revised) **<u>03.07.02-26</u>** 03.08.05-6	On Schedule
12/2015	FSAR Section 1.6 FSAR Section 3.7.2 FSAR Section 3.8.2 FSAR Section 3.8.3 FSAR Section 3.8.4 FSAR Section 3.8.5 FSAR Section 3G-3 FSAR Section 4.2 FSAR Section 9.1 FSAR Section 19.2 COLA Part 7	03.07.02-17 03.07.02-18 03.07.02-19 (revised) 03.07.02-20 03.07.02-21 03.08.04-37 03.08.05-7 (revised) 04.02-1 19.02-1		On Schedule

<u>Bold and Underline:</u> Differs from SCP submitted to NRC October 22, 2014

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Summary

- February 23, 2015 transmittal content consistent with SCP, with following exceptions:
  - Revisions to RAIs 02.05.02-3 and 03.07.01-7 were also included. The revisions were identified as required during a review of FSAR Sections 2.5 and 3.7, respectively
- Next Meeting – April 15th, 2015
  - Preview of July 2015 transmittal
- Questions?
- Actions?

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Acronyms

- GMM – Ground Motion Model
- GMPE – Ground Motion Prediction Equation
- FIRS – Foundation Input Response Spectra
- DRS – Design Response Spectra
- PSHA – Probabilistic Seismic Hazard Analysis
- TSCR – Truncated Soil Column Response
- GMRS – Ground Motion Response Spectra
- SCP – Seismic Closure Plan
- CEUS – Central Eastern United States
- UHRS – Uniform Hazard Response Spectra
- OBE – Operating Basis Earthquake
- SSE – Safe Shutdown Earthquake
- SSI – Soil-Structural Interaction
- SSSI – Seismic Structure-Soil-Structure Interaction
- BE – Best Estimate
- LF – Low Frequency
- DF – Design Factor
- HF – High Frequency
- V/H – Vertical to Horizontal Spectral Acceleration Ratio
- TH – Time History
- PBSRS – Performance-based surface response spectra
- CSDRS – Certified Seismic Design Response spectra
- PSD – Power Spectral Density
- V_{s30} – Shear Wave Velocity for 30 meters

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