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Holtec International Generic Report

REGULATORY GUIDE 1.60 TIME HISTORIES USING EZ-FRISK

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DOCUMENT CATEGORIZATION

In accordance with the Holtec Quality Assurance Manual and associated Holtec Quality Procedures (HQPs), this document is categorized as a:

☑ Calculation Package[3] (Per HQP 3.2)
☐ Technical Report (Per HQP 3.2) (Such as a Licensing Report)
☐ Design Criterion Document (Per HQP 3.4)
☐ Design Specification (Per HQP 3.4)
☐ Other (Specify):

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2. A revision to this document will be ordered by the Project Manager and carried out if any of its contents including revisions to references is materially affected during evolution of this project. The determination as to the need for revision will be made by the Project Manager with input from others, as deemed necessary by him.

3. Revisions to this document may be made by adding supplements to the document and replacing the "Table of Contents", this page and the "Revision Log".

SUMMARY OF REVISIONS

Revision 0: Initial Issue.

Revision 1: Revised to add additional sets of time histories with shorter duration to reduce analysis time and/or improve response spectra matching in the Appendix.

Revision 2: Revised the report to include Appendix B to document a single time history set that envelops Regulatory Guide 1.60 response spectra in all three directions and satisfies the requirements for single set of modified real recorded time histories in SRP 3.7.1 [1]. All changes made to the report in this revision are indicated by revision bars in the right hand margin.

TABLE OF CONTENTS

1 INTRODUCTION

The purpose of this report is to provide information on five sets of three directional time histories generated for 5% damped Regulatory Guide (RG) 1.60 design response spectra [7]. The target design response spectra are scaled to 0.26 g's in all three directions. For Plants that have RG 1.60 earthquake as their design basis spectra but with different intensities, the generated time histories and the corresponding response spectra can be linearly scaled to the applicable g-value.

Note that the response spectrum corresponding to each time history need not envelop the target response spectrum. The modified real acceleration time histories are required to meet the applicable requirements specified in NUREG-0800, SRP 3.7.1 [1], including the spectra enveloping and the statistical independence.

A new time history set satisfying the requirements of SRP 3.7.1 [1] for a modified real recorded single set of time histories is documented in Appendix B. This time history set is generated for 5% damped RG 1.60 spectra scaled to 0.25g's in all three directions.

2 METHODOLOGY

Following are the steps involved in the development of the real time histories corresponding to the design spectra.

1. Obtain the target response spectra over a frequency range of 0.1 Hz to 50 Hz from [7] and scale them to 0.26 g's in all three directions. The target spectrum in both horizontal directions will be identical. For single time history set documented in Appendix B, the target response spectra are scaled to 0.25 g's in all three directions.

2. Select at least five sets of the real recorded ground motions that match reasonably well with the shape of design response spectra in three directions. This is accomplished using EZ-FRISK™ ([2] and [11]) seismic analysis software program. The response spectra and the corresponding acceleration time histories in three directions are obtained for the seed real recorded ground motions. For single time history set documented in Appendix B, at least one set of real recorded ground motions that match reasonably well with the shape of design response spectra in three directions is selected.

3. Use matching technique in EZ-FRISK™ (based on RspMatch2009 method) to scale the selected real recorded ground motions to match with the target response spectra in all three directions. The response spectra and the corresponding acceleration time histories in three directions are then obtained for the generated time histories.

The second and third steps in the process are accomplished using the seismic analysis software program EZ-FRISK™. EZ-FRISK™ (an NRC recommended program) is a software package used by engineers and seismologists to perform site-specific earthquake hazard analysis. In the current work, Spectral Matching module in EZ-FRISK™ is used to select and match the real recorded ground motions that reasonably match the shape of design response spectra while maintaining a total duration of at least 20.0 seconds, a strong motion duration of at least 6.0 seconds, and a time step size less than or equal to 0.01 seconds [1].

Spectral matching makes adjustments to an input accelerogram so that its response spectrum matches a target response spectrum. Spectral matching can be performed as a stand-alone task by directly providing the target spectrum, or in conjunction with a probabilistic seismic hazard analysis.

The spectral matching technique used in the current work is based on the well known RspMatch2009 spectral matching algorithm. It is based on the time domain method of Tseng and Lilanand (1988) ([2] and [11]), with modifications to preserve non-stationarity at long periods by using different functional forms for the modified time history.

A key benefit of using EZ-FRISK™ for spectral matching is that it has a powerful search feature which quickly provides key information in choosing an appropriate initial accelerogram. It contains a scoring feature to select the best accelerograms based on the initial response spectrum's match to the target spectrum, the degree of scaling required for the accelerogram, and the duration of the event. The search gives immediate feedback in the form of thumbnails of the unscaled and scaled accelerograms, as well as the response spectrum.

EZ-FRISK™ is a useful tool that allows users to search through more than ten thousand records in the PEER NGA database [3] and about a thousand records in the Central Eastern United States (CEUS) database [4] using built-in selection criteria and user-defined filters. The records can be filtered out based on more than one hundred record attributes defined in EZ-FRISK™ such as:

- Faulting Mechanism
- Earthquake Name
- Magnitude
- Distance

Based on the scoring importance defined by the user for each of the selection criteria, EZ-FRISK™ selects real recorded ground motions and sorts them accordingly. The following selection criteria are available in EZ-FRISK™:

- Magnitude
- Distance
- Arias Duration
- RMS (Target – Scaled response)
- Scaling Factor

It is noted that some of the time histories generated using EZ-FRISK™ are linearly scaled to meet all the enveloping requirements of SRP 3.7.1 [1]. More than five sets of time histories were generated as some of the time histories did not meet the strong motion duration and the statistical independence requirements of [1]. All criteria, except for one, from [1] are satisfied as noted in Section 3.

The modified scaled acceleration time histories are adjusted in EZ-FRISK™ to have zero final displacements and velocities using a third order baseline correction technique.

3 ACCEPTANCE CRITERIA

The multiple sets of real acceleration-time histories can be generated in accordance with Section II.1.B, Option 2 of [1]. Specifically, the following criteria must be met when using multiple real time histories for a non-linear analysis:

1. The minimum number of time histories must be greater than four.

2. The total duration of the ground motion time histories should be long enough such that adequate representation of the Fourier components at low frequency is included in the time history. The strong motion duration is defined as the time required for the Arias Intensity to rise from 5% to 75%. The minimum acceptable strong motion duration is six seconds.

3. Multiple sets of real ground motion time histories should be used to represent the design spectra. Each set of time histories shall be selected from real recorded ground motions appropriate for the characteristic low and high frequency events.

4. The multiple time histories are acceptable if the average calculated response spectra generated from these times histories envelope the design response spectra of the plant.

5. An acceptable method to demonstrate the adequacy of a set of multiple time histories, in terms of enveloping requirements and having sufficient power over the frequency range of interest, is to follow the procedures described below (restated from Option I, Approach II of [1]):

   (a) The time history shall have a sufficiently small time increment and sufficiently long duration. Records shall have a Nyquist frequency of at least 50 Hz (e.g., a time increment of at most 0.01 seconds) and a total duration of at least 20 seconds.

(b) Spectral acceleration shall be computed at a minimum of 100 points per frequency decade, uniformly spaced over the log frequency scale from 0.1 Hz to 50 Hz or the Nyquist frequency. The comparison of the response spectrum obtained from the scaled ground motion time history with the target response spectrum shall be made at each frequency computed in the frequency range of interest.

(c) The average of the computed response spectrum of the accelerogram shall not fall more than 10% below the target response spectrum at any one frequency. To prevent response spectra in large frequency windows from falling below the target response spectrum, the response spectra within a frequency window of no larger than ±10% centered on the frequency shall be allowed to fall below the target response spectrum. This corresponds to response spectra at no more than 9 adjacent frequency points defined in (b) above from falling below the target response spectrum.

(d) In lieu of the power spectrum density requirement of Approach 1 of [1], the computed response spectrum of the modified real recorded ground motion time history shall not exceed the target response spectrum at any frequency by more than 30% (a factor of 1.3) in the frequency range of interest. If the response spectrum for the accelerogram exceeds the target response spectrum by more than 30% at any frequency range, the power spectrum density of the accelerogram needs to be computed and shown to not have significant gaps in energy at any frequency over this frequency range. The power spectrum density function represents the energy distribution at the frequencies of interest.

SRP 3.7.1 [1] requires Criteria 5(a) and 5(b) to be satisfied for each time histories. However, Criteria 5(c) and 5(d) can be satisfied by utilizing the results for the average of the time histories.

6. The time history set (2 horizontal and 1 vertical) must be statistically independent. This is demonstrated by calculating the cross correlation coefficient for each time history with each of the other two components. The absolute value of each of the three correlation coefficients must be less than 0.16.

7. The amplitude of the real recorded ground motions may be scaled but the phasing of Fourier components should be maintained to the maximum extent practical (i.e., minor distortion of the phase angle spectrum due to baseline correction is permissible [5] and [12]).

8. Additionally, consistent with well-established industry practice (but not stated in [1]), it is required that the acceleration time histories be baseline corrected to have final acceleration, final velocity and final displacement approaching zero.

The higher order baseline correction process invariably eliminates strict adherence to the phase angle separation between the harmonics that exist in the seed earthquake. The Criteria 1 through 6 are set down as inviolable requirements. Criterion 8 is well founded in industry practice but is omitted in [1] and Criterion 7 is at odds with Criterion 8.

In the case of spectra with broadened peaks like the RG 1.60 earthquake, maintaining the phasing of Fourier components is often extremely tedious, if not impossible. Even if a Herculean effort is made to preserve it by delicately adjusting amplitudes in the frequency domain, the subsequent baseline correction operation ends up corrupting it. Thus, higher order baseline correction and phase angle preservation are mutually incompatible requirements.

In the time history sets developed herein, five sets of time histories are generated using the public domain code, EZ-FRISK™ (NRC recommended), which operates in the time domain, thus the phasing of Fourier components may be affected during scaling of time histories as well. As a result, while the higher order baseline correction is performed and all of the above mentioned Criteria 1 through 6 are followed, the phase angle correspondence with the real recorded seed earthquake is not assured.

All criteria above except for 1, 3 and 4 are applicable for single time history set documented in Appendix B.

4 ASSUMPTIONS

Assumptions used in the report are listed wherever applicable.

5 INPUT DATA

Input data is defined in Section 11.

6 COMPUTER CODES AND FILES

The time history generation is performed in Windows 7 environment. The analytical software program EZ-FRISK™ ([2], [9] and [11]) is used to scale and modify the real recorded ground motions (acceleration time histories) to meet the acceptance criteria in Section 3.0. The program EZ-FRISK™ Version 7.62, Build 001 [2] and EZ-FRISK™ Version 7.65, Build 004 [11] is run on Computers 1187 and 1188 which are on the Holtec Approved Computer Program List (ACPL) [10]. The analytical software program MATLAB [6] is used to perform data and graphical processing.

All computer files relevant to the sets of acceleration time histories are saved on the Holtec network under the following directory:

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7 GENERATION OF TIME HISTORIES

EZ-FRISK™ is used to modify the real recorded ground motions (acceleration time histories). One set of acceleration time histories consists of three component directions. EZ-FRISK™ employs a target response spectrum as input and enables expansion of the digitized target response spectra to a number of equally spaced frequency intervals on a logarithmic scale. The total number of frequency points (frequency intervals) used in EZ-FRISK™ for the current work is 500. Specific data for the time histories is contained in Section 11 and the Appendices.

8 RESULTS

The time history results are presented in Section 11 and Appendix A for the 5% damped RG 1.60 earthquake scaled to 0.26 g's in all three directions. Section 11 provides information on 5 sets of time histories. In addition, Appendix A provides information on alternate Set 3 and Set 5 which provide shorter duration and/or improve response spectra match. The alternate Set 3 and Set 5 can be used in conjunction with Sets 1, 2, and 4 time histories of Section 11 to form a complete 5 sets of time histories which meet the criteria listed in Section 3.

The single time history set results are presented in Appendix B for the 5% damped RG 1.60 earthquake scaled to 0.25 g's in all three directions.

9 CONCLUSIONS

The acceleration time histories, generated using EZ-FRISK™, presented in Section 11 and the Appendices, demonstrate adherence to acceptance criteria defined in Section 3. The data presented in Section 11 and Appendices, and saved on the network location given in Section 6 is suitable for use as input data for subsequent analyses.

10 REFERENCES

[1] U.S. Nuclear Regulatory Commission, "Standard Review Plan Chapter 3.7.1 - Seismic Design Parameters", Revision 3, March 2007.

[2] Risk Engineering, Inc., "EZ-FRISK™ 7.62 Build 001, Software for Earthquake Ground Motion Estimation", 2011.

[3] PEER, "The Pacific Earthquake Engineering Research Center Ground Motion Database", http://peer.berkeley.edu/peer_ground_motion_database.

[4] CEUS-SSC, "The Central and Eastern United States Seismic Source Characterization for Nuclear Facilities Database", http://www.ceus-ssc.com/.

[5] Division of Spent Fuel Storage and Transportation, Office of Nuclear Material Safety and Safeguards, "Summary of May 30, 2013, Meeting with Holtec International, Potential Re-Submittal of the Topical Report on a Freestanding Stack-up", Docket No. 72-1014, June 28, 2013.

[6] MathWorks, Inc., "MATLAB Release 2011b".

[7] U.S. Nuclear Regulatory Commission, Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants", Revision 1, 1973.

[8] Risk Engineering, Inc., "NUREG/CR-6728, Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk - Consistent Ground Motion Spectra Guidelines", 2001.

[9] Holtec Report HI-2135536, "Validation of EZ-FRISK Computer Code", Revision 2.

[10] Holtec Approved Computer Program List (ACPL), Revision 342, March 6, 2017.

[11] Risk Engineering, Inc., "EZ-FRISK™ 7.65 Build 004, Software for Earthquake Ground Motion Estimation", 2015.

[12] US NRC Regulatory Issue Summary 2015-13, "Seismic Stability Analysis Methodologies for Spent Fuel Dry Cask Loading Stack-up Configuration", November 12, 2015.

11 TIME HISTORY INFORMATION FOR RG 1.60 EARTHQUAKE

11.1 Target Response Spectra

The design 5% damped RG 1.60 response spectra [7], scaled to 0.26 g's in horizontal and vertical directions, are used as the target. The spectra over 0.1 Hz to 50 Hz are used as the input. The input response spectra for horizontal and vertical directions (slightly conservative) are presented in Tables 11-1 and 11-2. It is noted that for frequencies in between the values given in Tables 11-1 and 11-2, the spectral accelerations are interpolated on log/log scale within EZ-FRISK™. Also, the time step size of the generated time histories is interpolated to 0.005 seconds (wherever applicable) to provide a consistent time step size for all five sets.

The target response spectra for single set of time histories in Appendix B are obtained by scaling the input spectral accelerations in Tables 11-1 and 11-2 by a factor of 0.25/0.26.

Table 11-1: Horizontal Design Response Spectrum

Freq (Hz)	HOR Accel (g's)
0.1	0.02
0.25	0.123
2.5	0.8138
9	0.6786
33	0.26
50	0.26

Table 11-2: Vertical Design Response Spectrum

Freq (Hz)	VT Accel (g's)
0.1	0.014
0.25	0.088
3.5	0.7748
9	0.6786
33	0.26
50	0.26

11.2 Average Response Spectra vs. Target Response Spectra

A total of 500 digitized response spectrum points, uniformly spaced over the log frequency scale from 0.1 Hz to 50 Hz, are used in all three directions. The plots for average response spectra vs. target response spectra are included in Figures 11-1 to 11-3 below for all three directions. Table 11-3 provides a summary of the checking of criteria 5 (c) and 5 (d) of Section 3.

Table 11-3: Summary of Response Spectrum Checks for 5-Set Average

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The target response spectra for E-W (or X) and N-S (or Y) directions is the horizontal response spectrum from Table 11-1, and the response spectrum for VT (or Z) direction is the vertical response spectrum from Table 11-2.

All results for single set of time histories scaled to 5% damped RG 1.60 earthquake with a ZPA of 0.25g in all three directions are presented in Appendix B.

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Figure 11-1: Five-Set Average Response Spectrum vs. Target Response Spectrum - E-W

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Figure 11-2: Five-Set Average Response Spectrum vs. Target Response Spectrum – N-S

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Figure 11-3: Five-Set Average Response Spectrum vs. Target Response Spectrum - VT

11.3 Seed Time History Selections

The following five sets of real recorded ground motions (Table 11-4) are chosen for the current work. For each set, the three orthogonal component motions are obtained from the same earthquake. Table 11-5 provides the scale factors used on seed time histories to match target PGA.

Table 11-4: Seed Time History Information

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Table 11-5: Scale Factors on Seed Time Histories to Match Target Spectra PGA

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The seed earthquakes are selected based on their magnitude, RMS scale spectra score, as well as other criteria listed in Section 2.

Section II.1.B of SRP 3.7.1 [1] requires the selected earthquakes to be appropriate for the characteristic low and high frequency events. Per Section 5.6 (page 5-13) of NUREG/CR-6728 [8], the low frequency deaggregated event is typically defined as a large magnitude, and large distance earthquake while the high frequency deaggregated event is typically a small magnitude and small distance earthquake. The selected earthquakes envelope the small distance to large distance criterion, and have a magnitude greater than 6.50 approaching 8.0.

The generated time history sets output from EZ-FRISK™ are amplified slightly to ensure that the average response spectra of the modified time histories envelope the target spectra as described in Section 3.0 of this report. The scale factors used to satisfy the enveloping requirement are shown in Table 11-6.

Table 11-6: Summary of Scale Factors for Response Spectra Enveloping

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11.4 Time History Results

Sections 11.5 through 11.9 provide the summary tables and graphs for five sets of time histories. The tables in those sections include Summary of Durations and Summary of Correlation Coefficients. The figures in those sections provide information on the seed and the generated time histories including acceleration, velocity and displacement plots. They also provide information on the percentage of Arias intensity, and the response spectra for the seed and generated time histories.

For each direction (N-S, E-W, and VT), the values of PGV/PGA and PGA×PGD/PGV^2 from the five time history sets are calculated to obtain the representative values for the seismic input motion (Table 11-8) where PGA is the maximum ground acceleration, PGV is the maximum ground velocity, and PGD is the maximum ground displacement. In the expression PGV/PGA, PGA is in g's and PGV is in inches/sec. In the PGA x PGD/PGV^2, PGA is in inches/sec^2, PGV is in inches/sec, and PGD is in inches. The purpose of these ratios is to show that the generated time histories are consistent with characteristic values for the magnitude and distance of the appropriate controlling events defining the target spectra. The information for a particular site may be used to judge the applicability of generated time histories.

In addition, the PGA, PGV and PGD values for all five sets of time histories are presented in Table 11-7.

Table 11-9 shows the PGV/PGA mean ± one standard deviation values, PGA×PGD/PGV^2 mean (x) ± one standard deviation (σ) values, and PGA×PGD/PGV^2 mean ± two standard deviations values for the earthquakes of magnitude bins of M6.41+ with distance bins from 0 to 200 km at soil sites, using data provided in NUREG/CR-6728 [8], Table 3-6.

Table 11-7: Summary of Peak Values for Generated Time Histories

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Table 11-8: Generated Time History PGV/PGA and PGA x PGD /PGV^2

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Table 11-9: PGV/PGA and PGA×PGD /PGV^2 Mean ± Standard Deviation(s) Values
(Obtained from Table 3-6 of NUREG/CR-6728 [8])

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From Tables 11-8 and 11-9, the average value of PGV/PGA from the modified time histories is within the mean ratio ± one standard deviation values for 0-100 km distance bin.

The average value of $PGA \times PGD/PGV^2$ from the modified time histories is greater than the mean ratio – one standard deviation for all components. However, the average value of $PGA \times PGD/PGV^2$ in VT direction exceeds the mean + one standard deviation value for 0-10 km and 50-100 km distance bins. This is judged to be acceptable because NUREG/CR-6728 [8] states that there is a high degree of scatter associated with the $PGA \times PGD/PGV^2$ ratios, and the $PGA \times PGD/PGV^2$ ratios for all components are well below the mean ratio + two standard deviations value.

11.5 Set 1 Time Histories (THs)

Table 11-10: Summary of Duration for Set 1

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Table 11-11: Summary of Correlation Coefficients for Set 1

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11.5.1 Seed 1 Time History Graphs

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Figure 11-4: E-W Seed Time Histories Set 1: Acceleration, Velocity, and Displacement

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Figure 11-5: N-S Seed Time Histories Set 1: Acceleration, Velocity, and Displacement

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Figure 11-6: VT Seed Time Histories Set 1: Acceleration, Velocity, and Displacement

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Figure 11-7: E-W Scaled Seed Spectrum Set 1 vs. Target Spectrum

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Figure 11-8: N-S Scaled Seed Spectrum Set 1 vs. Target Spectrum

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Figure 11-9: VT Scaled Seed Spectrum Set 1 vs. Target Spectrum

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Figure 11-10: Percentage Arias Intensity for Seed THs Set 1

11.5.2 Generated Set 1 Time History Graphs

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Figure 11-11: E-W Generated THs Set 1: Acceleration, Velocity, and Displacement

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Figure 11-12: N-S Generated THs Set 1: Acceleration, Velocity, and Displacement

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Figure 11-13: VT Generated THs Set 1: Acceleration, Velocity, and Displacement

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Figure 11-14: E-W Generated TH Set 1 Response Spectrum

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Figure 11-15: N-S Generated TH Set 1 Response Spectrum

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Figure 11-16: VT Generated TH Set 1 Response Spectrum

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Figure 11-17: Percentage Arias Intensity for Generated THs Set 1

11.6 Set 2 Time Histories

Table 11-12: Summary of Duration for Set 2

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Table 11-13: Summary of Correlation Coefficients for Set 2

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11.6.1 Seed 2 Time History Graphs

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Figure 11-18: E-W Seed Time Histories Set 2: Acceleration, Velocity, and Displacement

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Figure 11-19: N-S Seed Time Histories Set 2: Acceleration, Velocity, and Displacement

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Figure 11-20: VT Seed Time Histories Set 2: Acceleration, Velocity, and Displacement

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Figure 11-21: E-W Scaled Seed Spectrum Set 2 vs. Target Spectrum

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Figure 11-22: N-S Scaled Seed Spectrum Set 2 vs. Target Spectrum

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Figure 11-23: VT Scaled Seed Spectrum Set 2 vs. Target Spectrum

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Figure 11-24: Percentage Arias Intensity for Seed THs Set 2

11.6.2 Generated Set 2 Time History Graphs

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Figure 11-25: E-W Generated THs Set 2: Acceleration, Velocity, and Displacement

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Figure 11-26: N-S Generated THs Set 2: Acceleration, Velocity, and Displacement

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Figure 11-27: VT Generated THs Set 2: Acceleration, Velocity, and Displacement

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Figure 11-28: E-W Generated TH Set 2 Response Spectrum

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Figure 11-29: N-S Generated TH Set 2 Response Spectrum

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Figure 11-30: VT Generated TH Set 2 Response Spectrum

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Figure 11-31: Percentage Arias Intensity for Generated THs Set 2

11.7 Set 3 Time Histories

Table 11-14: Summary of Duration for Set 3

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Table 11-15: Summary of Correlation Coefficients for Set 3

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11.7.1 Seed 3 Time History Graphs

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Figure 11-32: E-W Seed Time Histories Set 3: Acceleration, Velocity, and Displacement

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Figure 11-33: N-S Seed Time Histories Set 3: Acceleration, Velocity, and Displacement

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Figure 11-34: VT Seed Time Histories Set 3: Acceleration, Velocity, and Displacement

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Figure 11-35: E-W Scaled Seed Spectrum Set 3 vs. Target Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-36: N-S Scaled Seed Spectrum Set 3 vs. Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-37: VT Scaled Seed Spectrum Set 3 vs. Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-38: Percentage Arias Intensity for Seed THs Set 3

11.7.2 Generated Set 3 Time History Graphs

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-39: E-W Generated THs Set 3: Acceleration, Velocity, and Displacement

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-40: N-S Generated THs Set 3: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure 11-41: VT Generated THs Set 3: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-42: E-W Generated TH Set 3 Response Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-43: N-S Generated TH Set 3 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure 11-44: VT Generated TH Set 3 Response Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-45: Percentage Arias Intensity for Generated THs Set 3

11.8 Set 4 Time Histories

Table 11-16: Summary of Duration for Set 4

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table 11-17: Summary of Correlation Coefficients for Set 4

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

11.8.1 Seed 4 Time History Graphs

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-46: E-W Seed Time Histories Set 4: Acceleration, Velocity, and Displacement

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-47: N-S Seed Time Histories Set 4: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-48: VT Seed Time Histories Set 4: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-49: E-W Scaled Seed Spectrum Set 4 vs. Target Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-50: N-S Scaled Seed Spectrum Set 4 vs. Target Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-51: VT Scaled Seed Spectrum Set 4 vs. Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-52: Percentage Arias Intensity for Seed THs Set 4

11.8.2 Generated Set 4 Time History Graphs

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-53: E-W Generated THs Set 4: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-54: N-S Generated THs Set 4: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure 11-55: VT Generated THs Set 4: Acceleration, Velocity, and Displacement

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-56: E-W Generated TH Set 4 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-57: N-S Generated TH Set 4 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-58: VT Generated TH Set 4 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-59: Percentage Arias Intensity for Generated THs Set 4

11.9 Set 5 Time Histories

Table 11-18: Summary of Duration for Set 5

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table 11-19: Summary of Correlation Coefficients for Set 5

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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11.9.1 Seed 5 Time History Graphs

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-60: E-W Seed Time Histories Set 5: Acceleration, Velocity, and Displacement

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-61: N-S Seed Time Histories Set 5: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-62: VT Seed Time Histories Set 5: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-63: E-W Scaled Seed Spectrum Set 5 vs. Target Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-64: N-S Scaled Seed Spectrum Set 5 vs. Target Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-65: VT Scaled Seed Spectrum Set 5 vs. Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-66: Percentage Arias Intensity for Seed THs Set 5

11.9.2 Generated Set 5 Time History Graphs

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-67: E-W Generated THs Set 5: Acceleration, Velocity, and Displacement

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-68: N-S Generated THs Set 5: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-69: VT Generated THs Set 5: Acceleration, Velocity, and Displacement

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-70: E-W Generated TH Set 5 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-71: N-S Generated TH Set 5 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-72: VT Generated TH Set 5 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 11-73: Percentage Arias Intensity for Generated THs Set 5

12 APPENDICES

Appendix A – Time History Information for Alternate Sets 3 and 5

Appendix B – Single Time History Set Information

APPENDIX A – TIME HISTORY INFORMATION FOR ALTERNATE SETS 3 AND 5

This appendix provides information on alternate Set 3 and Set 5 which provide shorter duration time and/or improve response spectra match. The alternate Set 3 and Set 5 can be used in conjunction with Sets 1, 2, and 4 time histories of Section 11 to form a complete 5 sets of time histories. This appendix also present the checking of Section 3 criteria of the 5 sets of time histories composed of Sets 1, 2, and 4 from Section 11 and Sets 3 and 5 from this Appendix.

A.1. Target Response Spectra

The target response spectra used for the 5 set of time history containing alternate Sets 3 and 5 are the same as the target response spectra in Section 11.1

A.2. Average Response Spectra vs. Target Response Spectra

A total of 500 digitized response spectrum points, uniformly spaced over the log frequency scale from 0.1 Hz to 50 Hz, are used in all three directions. The plots for average response spectra vs. target response spectra are included in Figures A-1 to A-3 below for all three directions. Table A-1 provides a summary of the checking of criteria 5 (c) and 5 (d) of Section 3.

Table A-1: Summary of Response Spectrum Checks for 5-Set Average

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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The target response spectra for E-W (or X) and N-S (or Y) directions is the horizontal response spectrum from Table 11-1, and the response spectrum for VT (or Z) direction is the vertical response spectrum from Table 11-2.

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-1 - Five-Set Average Response Spectra vs Target Response Spectra - E-W

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-2 - Five-Set Average Response Spectra vs Target Response Spectra - N-S

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-3 - Five-Set Average Response Spectra vs Target Response Spectra - VT

A.3. Seed Time History Selections

The following five sets of real recorded ground motions (Table A-2) are chosen for the current work. For each set, the three orthogonal component motions are obtained from the same earthquake. Table A-3 provides the scale factors used on seed time histories to match target PGA. As noted previously, Sets 1, 2, and 4 are the same sets in Section 11.

Table A-2: Seed Time History Information

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table A-3: Scale Factors on Seed Time Histories to Match Target Spectra PGA

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

The seed earthquakes are selected based on their magnitude, RMS scale spectra score, as well as other criteria listed in Section 2.

Section II.1.B of SRP 3.7.1 [1] requires the selected earthquakes to be appropriate for the characteristic low and high frequency events. Per Section 5.6 (page 5-13) of NUREG/CR-6728 [8], the low frequency deaggregated event is typically defined as a large magnitude, and large distance earthquake while the high frequency deaggregated event is typically a small magnitude and small distance earthquake. The selected earthquakes envelope the small distance to large distance criterion, and have a magnitude greater than 6.50 approaching 8.0.

Some of the generated time history sets output from EZ-FRISK™ are amplified slightly to ensure that the average response spectra of the modified time histories envelope the target spectra as described in Section 3.0 of this report. The scale factors used to satisfy the enveloping requirement are shown in Table A-4.

Table A-4: Summary of Scale Factors for Response Spectra Enveloping

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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A.4. Time History Results

Sections A.5 and A.6 provide the summary tables and graphs for the alternate Sets 3 and 5 of time histories. The tables in those sections include Summary of Durations and Summary of Correlation Coefficients. The figures in those sections provide information on the seed and the generated time histories including acceleration, velocity and displacement plots. They also provide information on the percentage of Arias intensity, and the response spectra for the seed and generated time histories.

For each direction (N-S, E-W, and VT), the values of PGV/PGA and PGA×PGD/PGV^2 from the five time history sets are calculated to obtain the representative values for the seismic input motion (Table A-6) where PGA is the maximum ground acceleration, PGV is the maximum ground velocity, and PGD is the maximum ground displacement. In the expression PGV/PGA, PGA is in g's and PGV is in inches/sec. In the PGA x PGD/PGV^2, PGA is in inches/sec^2, PGV is in inches/sec, and PGD is in inches. The purpose of these ratios is to show that the generated time histories are consistent with characteristic values for the magnitude and distance of the appropriate controlling events defining the target spectra. The information for a particular site may be used to judge the applicability of generated time histories.

In addition, the PGA, PGV and PGD values for all five sets of time histories are presented in Table A-5.

Table A-5: Summary of Peak Values for Generated Time Histories

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table A-6: Generated Time History PGV/PGA and PGA x PGD /PGV^2

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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From Tables A-6 and 11-9, the average value of PGV/PGA from the modified time histories is within the mean ratio ± one standard deviation values for 0-100 km distance bin.

The average value of PGA×PGD/PGV^2 from the modified time histories is greater than the mean ratio – one standard deviation for all components. However, the average value of PGA×PGD/PGV^2 in VT direction exceeds the mean + one standard deviation value for 0-10 km and 50-100 km distance bins. This is judged to be acceptable because NUREG/CR-6728 [8] states that there is a high degree of scatter associated with the PGA×PGD/PGV^2 ratios, and the PGA×PGD/PGV^2 ratios for all components are well below the mean ratio + two standard deviations value.

A.5. Alternate Set 3 Time Histories

Table A-7 - Summary of Duration for Set 3

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table A-8 - Summary of Correlation Coefficients for Set 3

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-4 - E-W Dir. Acceleration Time History Set 3

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-5 - N-S Dir. Acceleration Time History Set 3

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-6 - VT Dir. Acceleration Time History Set 3

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-7 - E-W Dir. Generated THs Set 3 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-8 - N-S Dir. Generated THs Set 3 Response Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-9 - VT Dir. Generated THs Set 3 Response Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-10 - E-W Dir. Generated vs Seed Time Histories (Velocity and Displacement) Set 3

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-11 - N-S Dir. Generated vs Seed Time Histories (Velocity and Displacement) Set 3

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-12 - VT Dir. Generated vs Seed Time Histories (Velocity and Displacement) Set 3

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-13 - E-W Scaled Seed Spectrum Set 3 vs Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-14 - N-S Scaled Seed Spectrum Set 3 vs Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-15 - VT Scaled Seed Spectrum Set 3 vs Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure A-16 - Percentage Arias Intensity for Seed THs Set 3

A.6. Alternate Set 5 Time Histories

Table A-9 - Summary of Duration for Set 5

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table A-10 - Summary of Correlation Coefficients for Set 5

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-17 - E-W Dir. Acceleration Time History Set 5

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-18 - N-S Dir. Acceleration Time History Set 5

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-19 - VT Dir. Acceleration Time History Set 5

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-20 - E-W Dir. Generated THs Set 5 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-21 - N-S Dir. Generated THs Set 5 Response Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-22 - VT Dir. Generated THs Set 5 Response Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure A-23 - E-W Dir. Generated vs Seed Time Histories (Velocity and Displacement) Set 5

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-24 - N-S Dir. Generated vs Seed Time Histories (Velocity and Displacement) Set 5

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-25 - VT Dir. Generated vs Seed Time Histories (Velocity and Displacement) Set 5

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-26 - E-W Scaled Seed Spectrum Set 5 vs Target Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure A-27 - N-S Scaled Seed Spectrum Set 5 vs Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-28 - VT Scaled Seed Spectrum Set 5 vs Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure A-29 - Percentage Arias Intensity for Seed THs Set 5

APPENDIX B – SINGLE TIME HISTORY SET INFORMATION

This appendix provides information on single set of time histories developed to match 5% damped RG 1.60 earthquake scaled to 0.25 g's in all three directions. The time history set satisfies the requirements of Approach 2 of Option 1 in Section II of SRP 3.7.1 [1]. The methodology and acceptance criteria are also defined in Sections 2 and 3, respectively, of main body of this report.

B.1 Target Response Spectra

The target response spectrum for E-W (or X) and N-S (or Y) directions is the horizontal response spectrum from Table 11-1 scaled by a factor of 0.25/0.26, and the response spectrum for VT (or Z) direction is the vertical response spectrum from Table 11-2 scaled by a factor of 0.25/0.26.

B.2 Scaled Response Spectra vs. Target Response Spectra

A total of 500 digitized response spectrum points, uniformly spaced over the log frequency scale from 0.1 Hz to 50 Hz, are used in all three directions. The plots for scaled response spectrum vs. target response spectrum are included in Figures B-1 to B-3 below for all three directions. Table B-1 provides a summary of the checking of criteria 5 (c) and 5 (d) of Section 3.

Table B-1: Summary of Response Spectra Checks

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-1 - Scaled Response Spectrum vs. Target Response Spectrum - E-W

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure B-2 - Scaled Response Spectrum vs. Target Response Spectrum - N-S

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure B-3 - Scaled Response Spectrum vs. Target Response Spectrum - VT

B.3 Seed Time History Set Selection

The below set of real recorded ground motion (Table B-2) is chosen for the current work. The three orthogonal component motions are obtained from the same earthquake. Table B-3 provides the scale factors used on seed time histories to match target PGA.

Table B-2: Seed Time History Set Information

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table B-3: Scale Factors on Seed Time Histories to Match Target Spectra PGA

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

The seed earthquake is selected based on its magnitude, RMS scale spectra score, as well as other criteria listed in Section 2. The generated time history sets output from EZ-FRISK™ are amplified slightly to ensure that the response spectra of the modified time histories envelope the target spectra as described in Section 3.0 of this report. The scale factors used to satisfy the enveloping requirement are shown in Table B-4.

Table B-4: Summary of Scale Factors for Response Spectra Enveloping

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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B.4 Time History Results

Section B.5 provides the summary tables and graphs for the single time history set. The tables in Section B.5 include Summary of Durations and Summary of Correlation Coefficients. The figures in Section B.5 provide information on the seed and the generated time histories including acceleration, velocity and displacement plots. They also provide information on the percentage of Arias intensity, and the response spectra for the seed time histories.

For each direction (N-S, E-W, and VT), the values of PGV/PGA and PGA×PGD/PGV^2 are calculated to obtain the representative values for the seismic input motion (Table B-6) where PGA is the maximum ground acceleration, PGV is the maximum ground velocity, and PGD is the maximum ground displacement. In the expression PGV/PGA, PGA is in g's and PGV is in inches/sec. In the PGA x PGD/PGV^2, PGA is in inches/sec^2, PGV is in inches/sec, and PGD is in inches. The purpose of these ratios is to show that the generated time histories are consistent with characteristic values for the magnitude and distance of the appropriate controlling events defining the target spectra. The information for a site may be used to judge the applicability of generated time histories.

In addition, the PGA, PGV and PGD values for all three directions are presented in Table B-5.

Table B-5: Summary of Peak Values for Generated Time Histories

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table B-6: Generated Time History PGV/PGA and PGA x PGD /PGV^2

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

From Tables B-6 and 11-9, the value of PGV/PGA from the modified time histories is within the mean ratio ± one standard deviation values for 0-100 km distance bin.

The value of $PGA \times PGD/PGV^2$ from the modified/scaled time histories is slightly beyond the range of mean ratio – one standard deviation to mean + one standard deviation but well within two standard deviations. This is judged to be acceptable because NUREG/CR-6728 [8] states that there is a high degree of scatter associated with the $PGA \times PGD/PGV^2$ ratios.

B.5 Generated Time Histories

Table B-7 - Summary of Durations

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Table B-8 - Summary of Correlation Coefficients

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-4 - E-W Seed and Scaled Acceleration Time Histories

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-5 - N-S Seed and Scaled Acceleration Time Histories

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

Figure B-6 - VT Seed and Scaled Acceleration Time Histories

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-7 - E-W Scaled vs. Seed Time Histories (Velocity and Displacement)

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-8 – N-S Scaled vs. Seed Time Histories (Velocity and Displacement)

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-9 - VT Scaled vs. Seed Time Histories (Velocity and Displacement)

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-10 - E-W Scaled Seed Spectrum vs. Target Spectrum

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-11 - N-S Scaled Seed Spectrum vs. Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-12 - VT Scaled Seed Spectrum vs. Target Spectrum

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure B-13 - Percentage Arias Intensity for Scaled THs