REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**182-8160**
SRP Section:	**03.07.01 – Seismic Design Parameters**
Application Section:	**3.7.1**
Date of RAI Issue:	**08/31/2015**

Question No. 03.07.01-2

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. In accordance with 10 CFR 50 Appendix S, the staff reviewed the adequacy of the synthetic acceleration time histories used for seismic analysis of the SSCs. The APR1400 DCD indicates that a single set of time histories were developed in the three orthogonal directions for both the certified seismic design response spectra (CSDRS) and the hard rock high frequency (HRHF) response spectra (RS), following SRP 3.7.1 Option 1 Approach 1. In order for the staff to understand whether the method and parameters associated with the time history generation are consistent with the guidance of SRP Acceptance Criteria 3.7.1 II.1.B, the applicant is requested to provide additional information related to the fallowing aspects of the development of the synthetic acceleration time histories.

a) Justification of seed recorded time histories

Section 3.7.1.1.2 of the DCD, “Design Ground Motion Time History,” indicates that the initial seed motions for the development of the design ground motions are recorded ground motions from the Northridge earthquake. The DCD does not provide justification for the selection of these Northridge ground motions as seed motions. The staff recognizes that some discussion on the choice of the Northridge time histories is provided in APR1400-E-S-NR-14001-P, Rev. 0, “Seismic Design Bases.” Since this report is not incorporated by reference, the applicant is requested to provide appropriate justification for the seed motions in the DCD.

As described in Section 3.2.2 of APR1400-E-S-NR-14001-P, Rev. 0, the recorded seed time histories, from the M6.7 Northridge earthquake, has a time increment of 0.02 s, which corresponds to a Nyquist frequency of 25 Hz. Furthermore, Figures 3-4 and 3-5 of this technical report show that the frequency contents are only up to about 8~9 Hz for the two horizontal directions. However, Section 3.2.3 of this technical report

indicates that the applicant re- digitized the time histories to 0.005 s. Therefore, the applicant is requested to (1) provide a description and a justification of the method used for the re-digitization of the seed recorded time histories, and (2) provide an explanation why the seed recorded motions for the two horizontal directions are considered acceptable given that they have power only up to 8~9 Hz (not to 50 Hz).

b) Provide numerical values to demonstrate that the synthetic acceleration time histories meet the SRP 3.7.1 Option 1 Approach 1 spectral matching criteria

Section 3.7.1.1.2 of the DCD provides some numerical information on the design time histories, such as time increment (0.005 s), correlation coefficients (<0.16), and duration (20.48 s). However, it does not provide the necessary numerical values for the design time histories that show how they meet the SRP 3.7.1 Option 1, Approach 1 criteria, although the DCD generally concludes that those criteria are met. Some of the information is provided in graphical form but is difficult to extract/interpret from the figures. Therefore, the applicant is requested to provide, preferable in a tabular format, the following additional information of the design time histories for both the CSDRS and the HRHF RS and revise the DCD and the HRHF report, as appropriate:

(1) Strong motion durations for all three directions

(2) Peak values (A, V, D)

(3) How many points of the response spectra were below each DRS

(4) The lowest percentage below the DRS

c) Provide the time histories for staff's confirmatory analyses

In light of the different ways to develop target PSD, normalize Fourier spectra, and estimate PSDs from time histories, the staff decided to perform a confirmatory analysis of the APR1400 design time histories. As such, please provide the following information in digital format (e.g., text files):

(1) The CSDRS and HRHF RS

(2) The target PSDs

(3) The PSDs estimated from the time histories

(4) The six synthetic acceleration time histories

Response – (Rev. 1)

(a) The 1994 M6.7 Northridge earthquake recorded time histories at the West Covina recording station are selected as the seed motions for the development of the CSDRS-compatible time histories because these recorded motions are selected from the NRC time history library in Page B-52 of NUREG/CR-6728, Appendix B, as appropriate recorded motions for representing earthquake motions for CEUS rock sites for Magnitude range from 6 to 7 and source-to-site distance range from 50 to 100 km.

Although these recorded motions are recorded motion for WUS and have a time increment (Δt) of 0.02 seconds, which corresponds to a Nyquist frequency of 25 Hz, they can be used for response spectrum matching for response spectra with a cutoff frequency higher than 25 Hz. This is discussed in NUREG/CR-6728, Section 3.4 - Matching WUS Time History to CEUS Spectrum, in which it states in the second to the last sentence on Page 3-6 that "Overall, these comparisons indicate that WUS motions can be used as inputs to matching CEUS spectra provided the sample interval reflects a Nyquist frequency ($f_N = [2\,\Delta t\,]^{-1}$) of at least 100 Hz." Thus, to make the selected seed motions suitable for inputs to match CSDRS, which has spectral cutoff frequency at 50 Hz, the recorded seed motions need be re-digitized to have a time increment (Δt) of 0.005 seconds so that the Nyquist frequency is 100 Hz, as discussed in NUREG/CR-6728, Section 3.4 - Matching WUS Time History to CEUS Spectrum, mentioned above. The re-digitization of time histories with a time increment of 0.005 seconds is performed using linear interpolation of the time histories recorded at 0.02 second intervals. The comparison of time histories digitized in time increment of 0.02 seconds and 0.005 seconds is shown below in Figures 1 through 3.

Even though the selected recorded seed motions for the two horizontal components have major power up to approximately 8 to 9 Hz, spectrum-matching time-history adjustments add higher-frequency motion contents to the recorded seed motions so that the resulting spectrum-matched modified time histories for the two horizontal components have response spectrum amplitudes that conservatively match the CSDRS up to 50 Hz, as indicated in Figures 3-15 through 3-20 and Figures 3-22 through 3-27 in APR1400-E-S-NR-14001-P, Rev. 0. The Fourier spectra (amplitude and phase spectra) of the re-digitized seed time histories using time increments of 0.005 seconds have been calculated and are shown in Figures 4 through 15, below. The phase spectra for the re-digitized time histories are plotted to show that the phase spectra in the higher frequency range are sufficiently random.

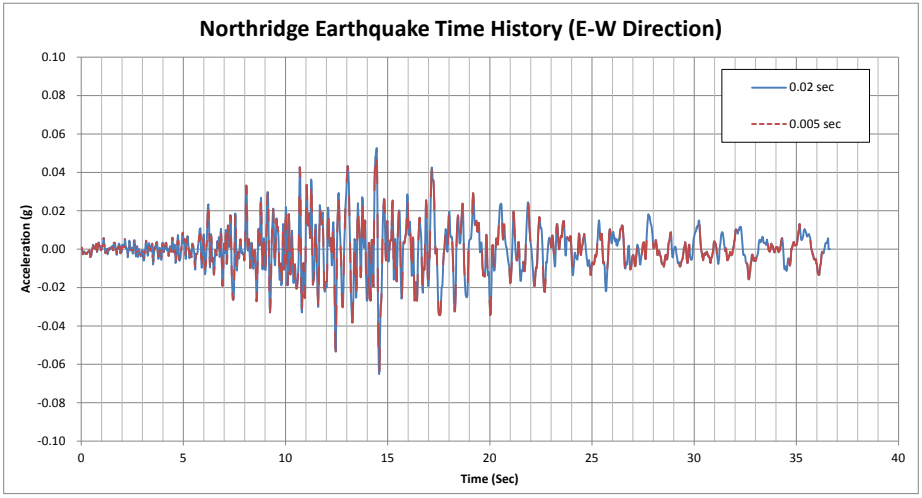

Figure 1 Northridge Earthquake Time History, E-W Direction

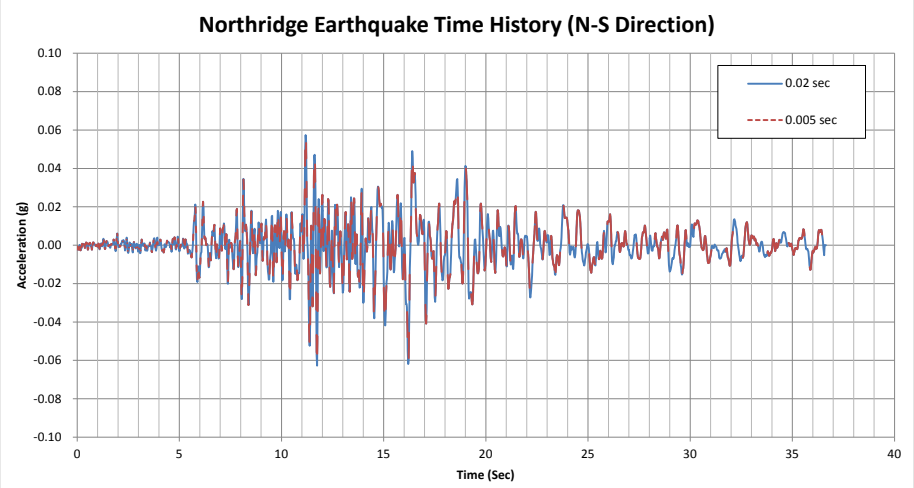

Figure 2 Northridge Earthquake Time History, N-S Direction

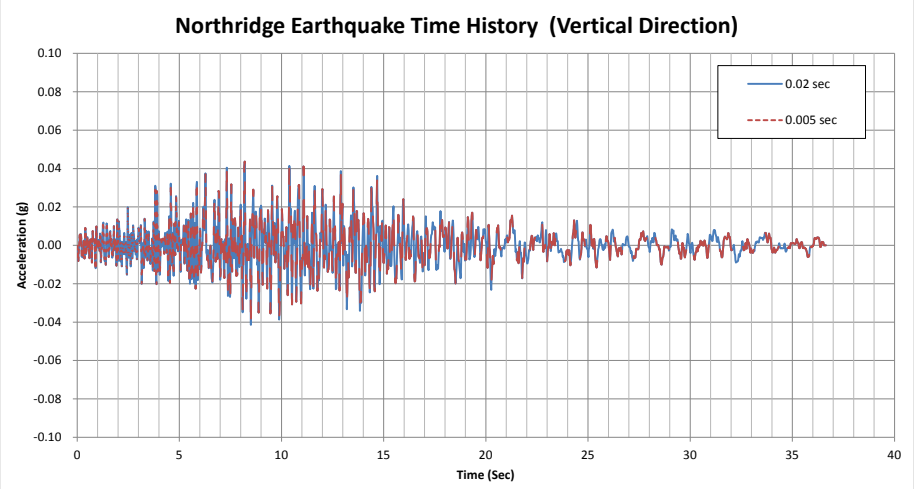

Figure 3 Northridge Earthquake Time History, Vertical Direction

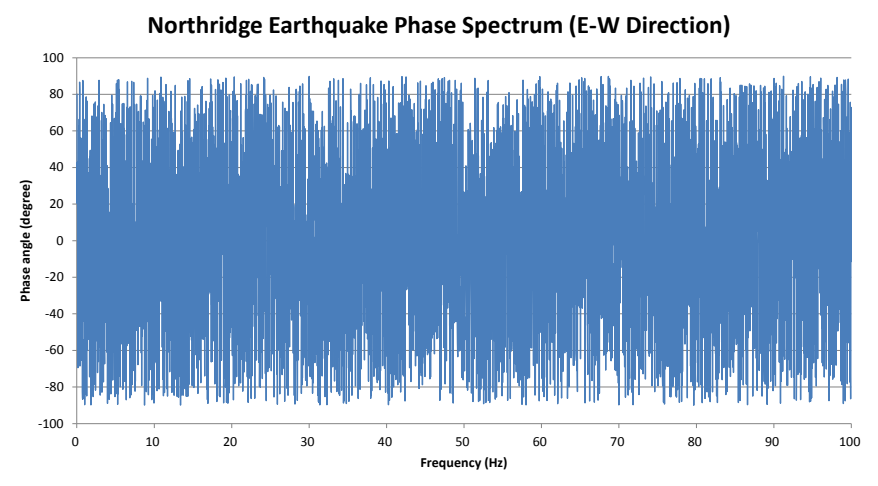

Figure 4 Northridge Earthquake Phase Spectrum, E-W Direction

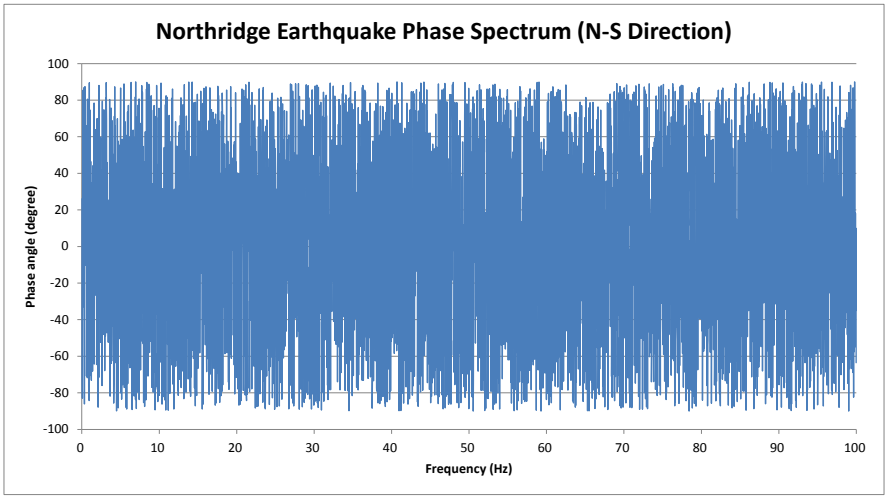

Figure 5 Northridge Earthquake Phase Spectrum, N-S Direction

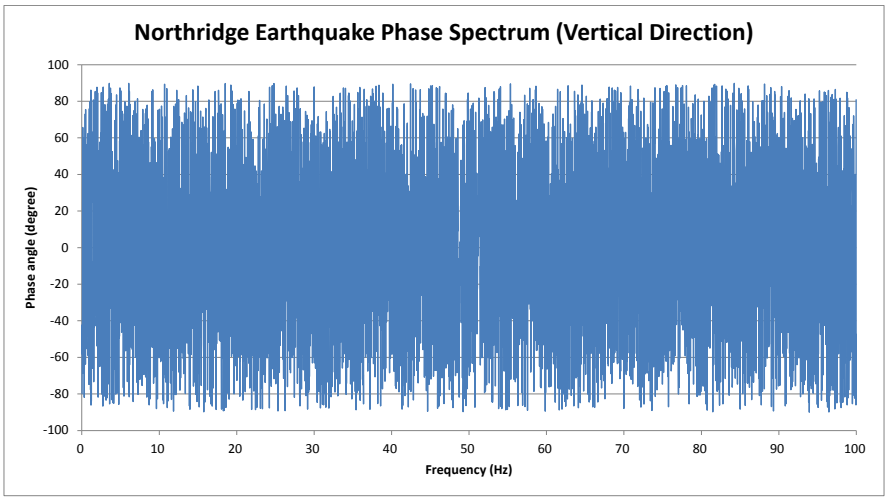

Figure 6 Northridge Earthquake Phase Spectrum, Vertical Direction

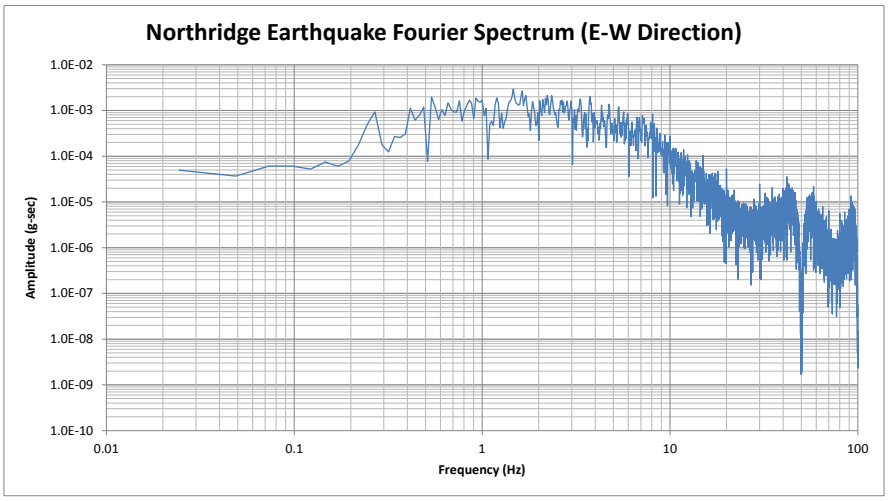

Figure 7 Northridge Earthquake Fourier Spectrum, E-W Direction

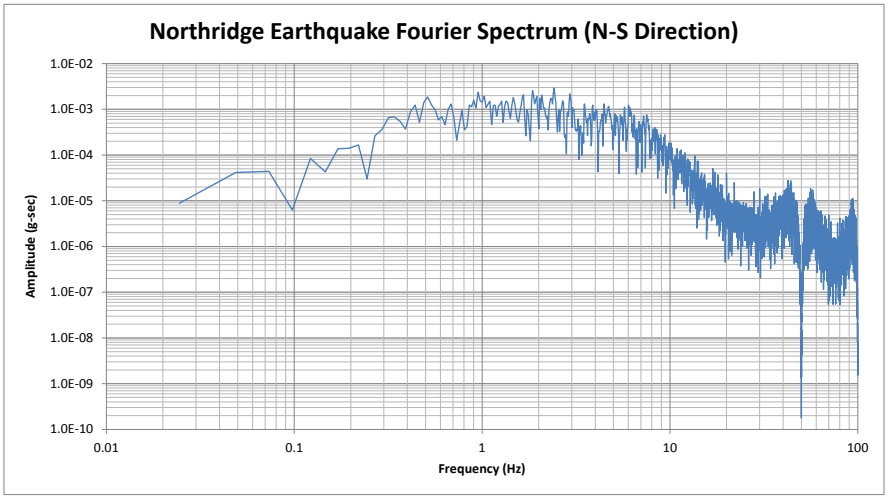

Figure 8 Northridge Earthquake Fourier Spectrum, N-S Direction

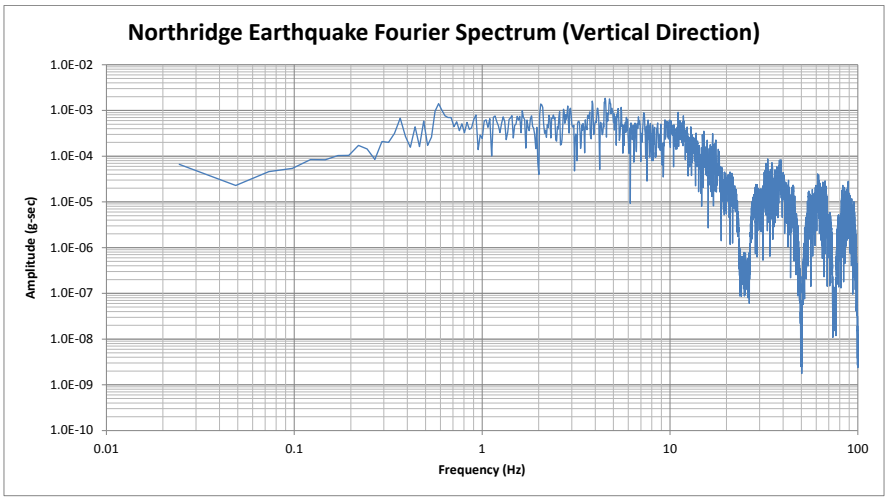

Figure 9 Northridge Earthquake Fourier Spectrum, Vertical Direction

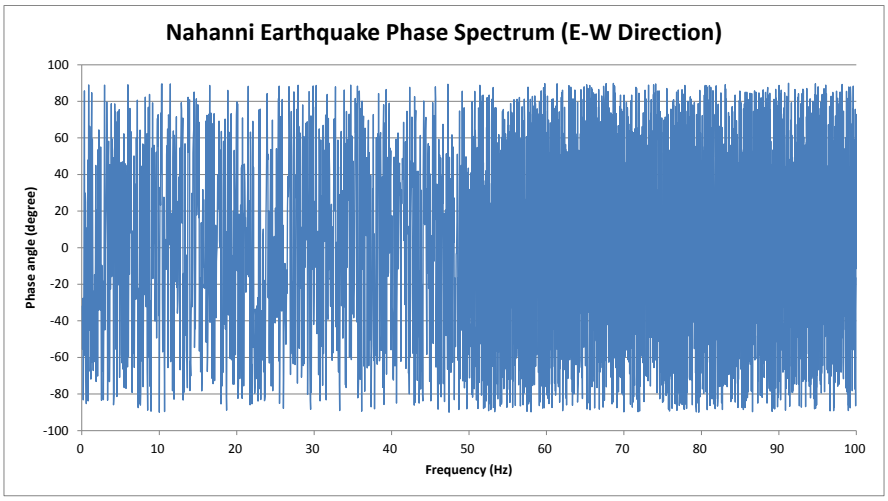

Figure 10 Nahanni Earthquake Phase Spectrum, E-W Direction

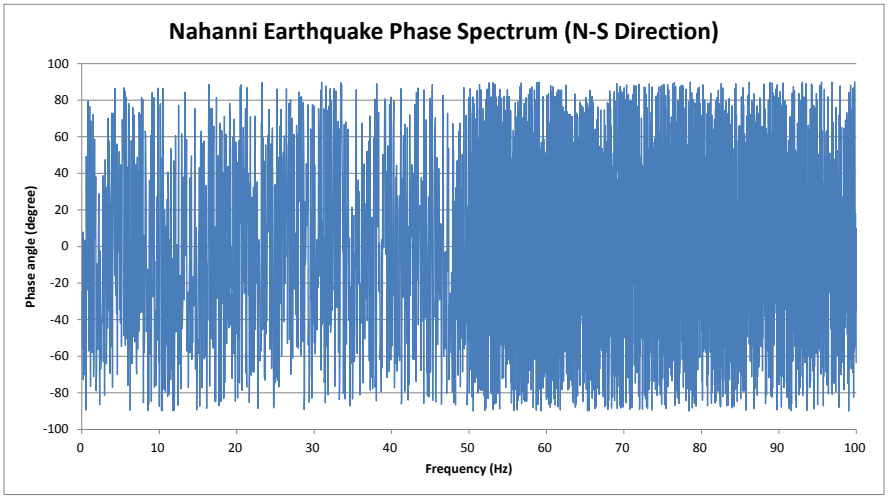

Figure 11 Nahanni Earthquake Phase Spectrum, N-S Direction

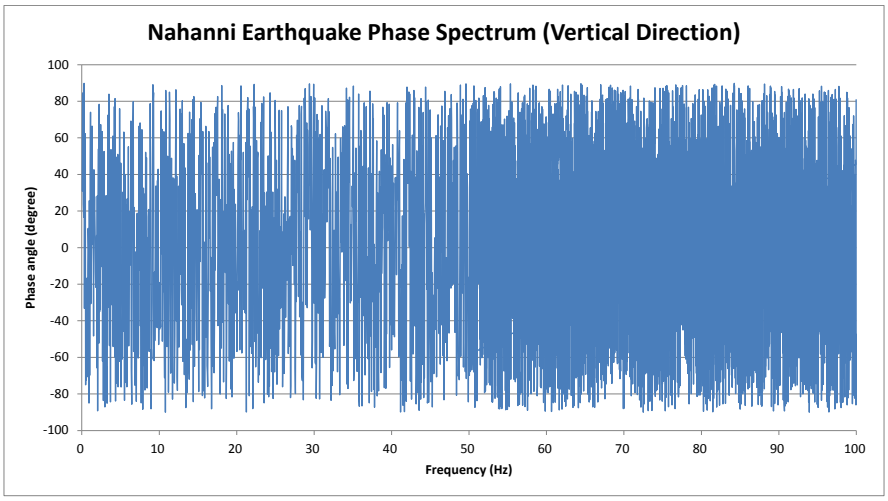

Figure 12 Nahanni Earthquake Phase Spectrum, Vertical Direction

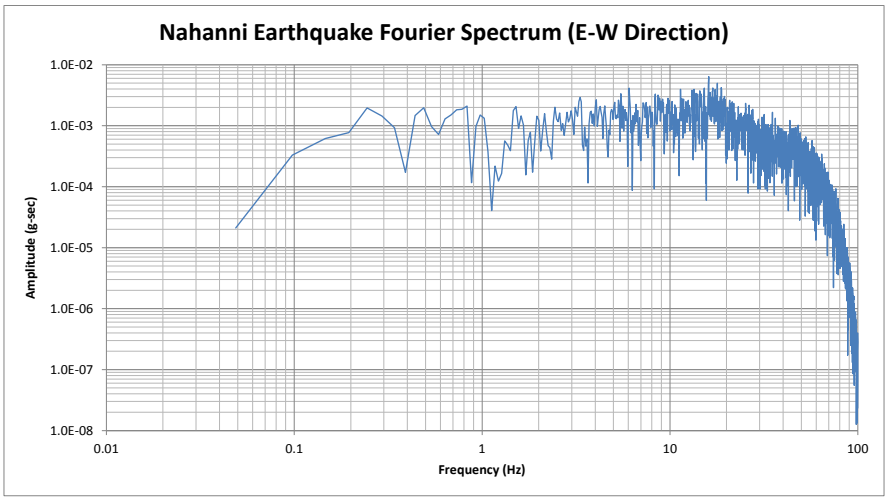

Figure 13 Nahanni Earthquake Fourier Spectrum, E-W Direction

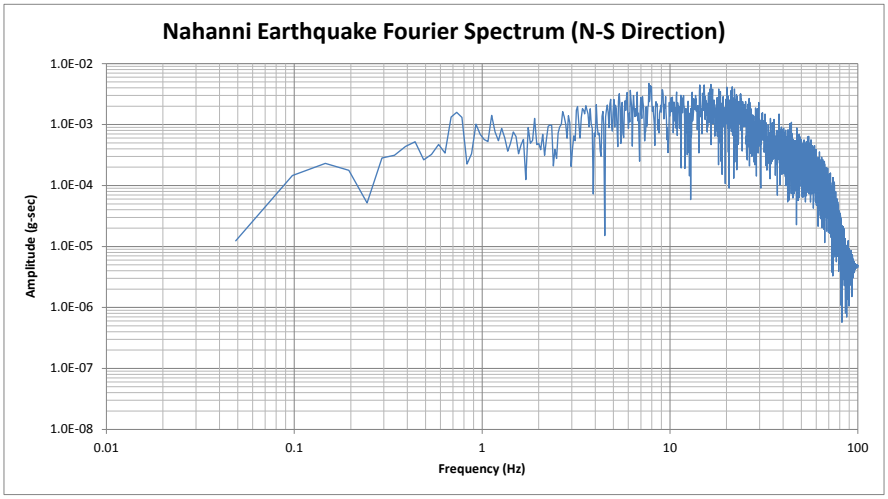

Figure 14 Nahanni Earthquake Fourier Spectrum, N-S Direction

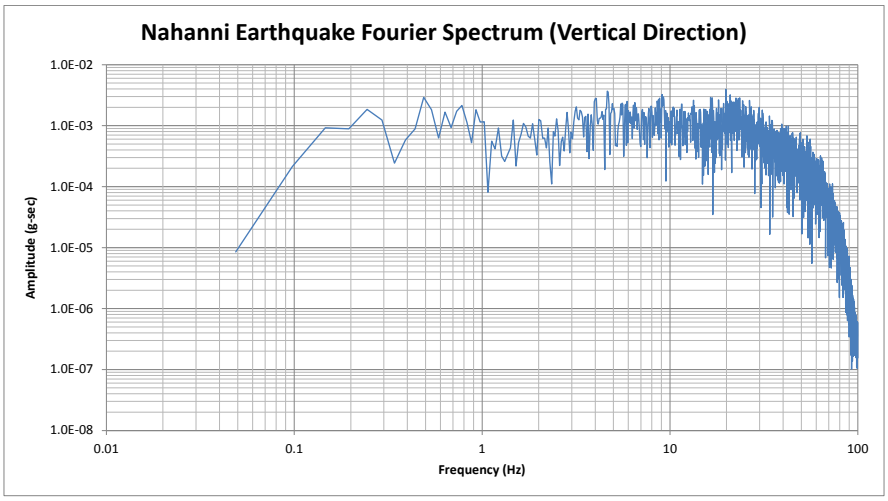

Figure 15 Nahanni Earthquake Fourier Spectrum, Vertical Direction

(b) The requested four items are described in Tables 1 through 4.

Table 1 Strong motion duration for all three directions

Direction	CSDRS (sec)	HRHF (sec)
EW	9.2	6.090
NS	10.3	6.400
VT	8.4	6.505

Table 2 Peak values (A, V, and D)

Direction	CSDRS			HRHF		
	A (g)	V (in/sec)	D (in)	A (g)	V (in/sec)	D (in)
EW	0.300	17.5	16.5	0.463	8.86	3.63
NS	0.300	17.9	16.1	0.463	10.50	3.51
VT	0.300	18.9	13.0	0.463	9.94	4.16

Table 3 Number of points of the response spectra below each DRS

Damping	CSDRS			HRHF		
	EW	NS	VT	EW	NS	VT
2%	4	4	2	0	1	3
3%	1	3	2	2	4	1
4%	4	3	2	1	5	2
5%	5	2	1	0	4	3
7%	4	2	1	0	0	2
10%	1	2	1	4	3	2

Table 4 The lowest percentage below the DRS

Damping	CSDRS			HRHF		
	EW (%)	NS (%)	VT (%)	EW (%)	NS (%)	VT (%)
2%	-6.66	-4.53	-0.48	1.02	-0.77	-2.94
3%	-4.72	-1.69	-2.99	-1.85	-4.02	-1.49
4%	-4.58	-5.89	-2.94	-0.67	-1.84	-1.61
5%	-3.61	-4.15	-1.00	1.56	-3.02	-2.01
7%	-6.11	-5.51	-0.62	0.76	0.33	-0.89
10%	-6.02	-2.40	-1.43	-1.94	-1.09	-4.40

DCD Table 3.7-2, Table 3.7-4, Table 3-8 through Table 3-10 of Technical Report APR1400-E-S-NR-14001-P/NP, Rev. 0 and Tables 3-11 through 3-14 of Technical Report APR1400-E-S-NR-14004-P/NP, Rev. 1 will be revised as indicated in the attachments.

(c) The requested files are attached in digital format.

The CSDRS and HRHF RS are provided on the enclosed CD.
(6 text files in "01_CSDRS and HRHF" folder)

A. CSDRS_RS_EW.txt

B. CSDRS_RS_NS.txt

C. CSDRS_RS_VT.txt

D. HRHF_RS_EW.txt

E. HRHF_RS_NS.txt

F. HRHF_RS_VT.txt

The target PSDs are provided on the enclosed CD.
(4 text files in "02_Target PSDs" folder)

G. CSDRS_Horizontal PSD.txt

H. CSDRS_Vertical PSD.txt

I. HRHF_Horizontal PSD.txt

J. HRHF_Vertical PSD.txt

The PSDs estimated from the time histories are provided on the enclosed CD.
(6 text files in "03_The PSDs estimated from the time histories" folder)

K. CSDRS_PSD_EW.txt

L. CSDRS_PSD_NS.txt

M. CSDRS_PSD_VT.txt

N. HRHF_PSD_EW.txt

O. HRHF_PSD_NS.txt

P. HRHF_PSD_VT.txt

The six synthetic acceleration time histories are provided on the enclosed CD.
(6 text files in "04_The six synthetic acceleration time histories" folder)

Q. CSDRS_TH_EW.txt

R. CSDRS_TH_NS.txt

S. CSDRS_TH_VT.txt

T. HRHF_TH_EW.txt

U. HRHF_TH_NS.txt

V. HRHF_TH_VT.txt

Impact on DCD

DCD Table 3.7-2 and Table 3.7-4 will be revised, as indicated on the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Technical Report APR1400-E-S-NR-14001-P/NP, Rev. 0, Tables 3-8 through 3-10 and Technical R eport APR1400-E-S-NR-14004-P/NP, Rev. 1, Tables 3-11 through 3-14 will be added, as indicated on the attachment associated with this response.

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Table 3.7-2

Numerical Information of CSDRS

a) Strong motion duration for all three directions (sec)

H1	H2	VT
9.2	10.3	8.4

b) Peak values (A, V and D)

	A (g)	V (in/sec)	D (in)
H1	0.300	17.5	16.5
H2	0.300	17.9	16.1
VT	0.300	18.9	13.0

c) Number of points of the response spectra below CSDRS

	H1	H2	VT
2%	4	4	2
3%	1	3	2
4%	4	3	2
5%	5	2	1
7%	4	2	1
10%	1	2	1

d) The lowest percentage below CSDRS (%)

	H1	H2	VT
2%	-6.66	-4.53	-0.48
3%	-4.72	-1.69	-2.99
4%	-4.58	-5.89	-2.94
5%	-3.61	-4.15	-1.00
7%	-6.11	-5.51	-0.62
10%	-6.02	-2.40	-1.43

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Table 3.7-4

Numerical Information of HRHF RS

a) Strong motion duration for all three directions (sec)

H1H	H2H	VTH
6.090	6.400	6.505

b) Peak values (A, V and D)

	A (g)	V (in/sec)	D (in)
H1H	0.463	8.86	3.63
H2H	0.463	10.50	3.51
VTH	0.463	9.94	4.16

c) Number of points of the response spectra below CSDRS

	H1H	H2H	VTH
2%	0	1	3
3%	2	4	1
4%	1	5	2
5%	0	4	3
7%	0	0	2
10%	4	3	2

d) The lowest percentage below CSDRS (%)

	H1H	H2H	VTH
2%	1.02	-0.77	-2.94
3%	-1.85	-4.02	-1.49
4%	-0.67	-1.84	-1.61
5%	1.56	-3.02	-2.01
7%	0.76	0.33	-0.89
10%	-1.94	-1.09	-4.40

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Table 3-8

Maximum Acceleration (A), Velocity (V), and Displacement (D) of Generated Time Histories

Component	A (g)	V (in/sec)	D (in)
H1	0.3	17.5	16.5
H2	0.3	17.9	16.1
VT	0.3	18.9	13.0

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Table 3-9

Number of Points of the Response Spectra Below each CSDRS

Damping	Component		
	H1	H2	VT
2%	4	4	2
3%	1	3	2
4%	4	3	2
5%	5	2	1
7%	4	2	1
10%	1	2	1

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Table 3-10

The Lowest Percentage below the CSDRS

Damping	Component		
	H1 (%)	H2 (%)	VT (%)
2%	-6.66	-4.53	-0.48
3%	-4.72	-1.69	-2.99
4%	-4.58	-5.89	-2.94
5%	-3.61	-4.15	-1.00
7%	-6.11	-5.51	-0.62
10%	-6.02	-2.40	-1.43

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Table 3-11

Stationary Duration of Generated Time Histories

Component	Ts^i (5-75%) (sec)
H1H	6.090
H2H	6.400
VTH	6.505

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Table 3-12

Maximum Acceleration (A), Velocity (V), and Displacement (D) of Generated Time Histories

Component	A (g)	V (in/sec)	D (in)
H1H	0.463	8.86	3.63
H2H	0.463	10.50	3.51
VTH	0.463	9.94	4.16

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Table 3-13

Number of Points of the Response Spectra Below each HRHF DRS

Damping	Component		
	H1H	H2H	VTH
2%	0	1	3
3%	2	4	1
4%	1	5	2
5%	0	4	3
7%	0	0	2
10%	4	3	2

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Table 3-14
The Lowest Percentage below the HRHF DRS

Damping	Component		
	H1H (%)	H2H (%)	VTH (%)
2%	1.02	-0.77	-2.94
3%	-1.85	-4.02	-1.49
4%	-0.67	-1.84	-1.61
5%	1.56	-3.02	-2.01
7%	0.76	0.33	-0.89
10%	-1.94	-1.09	-4.40