MACTEC DESIGN CALCULATION OR ANALYSIS COVER SHEET

Project Name: PSEG ESP Application Project	Project Number: 6468-08-2251	Calc/Anls Number: 2251-ESP-REI-2047-ACR-040, Rev. 1	Sheet: 1 of 1

Nuclear Safety Classification: (SR) NSR AQ	Subject: Calculation of smooth vertical GMRS for the PSEG Site	Discipline: Seismology

Originator: Robin K. McGuire (RKM)	Origination Date: 11-02-09	Principal Professional: J. Allan Tice
Reviewer: Gabriel R. Toro (GRT)		

Comments: This calculation was prepared by Risk Engineering, a part of Fugro William Lettis Associates and is supported by electronic files in Record No. 2047-ACR-041. The Risk Engineering cover sheet documents their review and approval history. This MACTEC cover sheet addresses Revision 1 for REI Record No. 2047-ACR-040. Revision 1 is issued to change site name terminology from Hope Creek to PSEG Site. No changes in supporting documents were necessary. This cover sheet documents approval of Rev. 1 by MACTEC. Revision 1 was prepared by John Vlasity (JV) and reviewed by GRT.

As part of the response to MACTEC's Corrective Action Plan for Condition Report PSEG-22, a MACTEC Design Verification sheet has been completed and attached. The original design verification (designated as approval on the REI cover sheet) was reviewed by MACTEC personnel and the MACTEC Design Verification sheet was completed to indicate acceptance of the REI approval.

This calculation is one of five that were prepared for development of the Ground Motion Response Spectra (GMRS) as described in Work Instruction 129. A list of all the calculations associated with the GMRS is attached.

SJC 10/14/10

5/20/10

Rev #: 0	Reason: NA	By: RKM	Date: 5.20.10	Approved:
Rev #: 1	Reason: Change terminology from Hope Creek to PSEG Site	By: RKM	Date: 5.20.10	Approved: GRT 5/20/10
Rev #:	Reason:	By:	Date:	Approved:
Rev #:	Reason:	By:	Date:	Approved:

2047-COO-011

LISTING OF CALCULATIONS
PERFORMED UNDER WI 129
(GROUND MOTION RESPONSE SPECTRA)

REI CALCULATION RECORD NO.	SUBJECT	MACTEC CALCULATION NO. ASSIGNED
2047-ACR-032 Rev. 1	Artificial shear-wave velocity profiles for PSEG Site response calculations	2251-ESP-REI-2047-ACR-032 Rev. 1
2047-ACR-034 Rev. 1	Calculation of site response for the PSEG Site ESP	2251-ESP-REI-2047-ACR-034 Rev. 1
2047-ACR-038 Rev. 1	Calculation of smooth horizontal GMRs for the PSEG Site	2251-ESP-REI-2047-ACR-038 Rev. 1
2047-ACR-040 Rev. 1	Calculation of smooth vertical GMRs for the PSEG Site	2251-ESP-REI-2047-ACR-040 Rev. 1
2047-ACR-046 Rev. 1	Sensitivity of Site Amplification Factors for the PSEG Site ESP to Revisions in Degradation Curves	2251-ESP-REI-2047-ACR-046 Rev. 1

MACTEC 2251-ESP-REI-2047-ACR-040, Rev 1

DESIGN VERIFICATION CONTROL SHEET

Design Verification Checklist (excerpted from ANSI N.45.11 [1974 Edition] and ASME NQA-1-1994 Edition			
Yes	No	N/A	Design Verification Element Note: Any items checked "No" automatically imply the design is not verified.
		X	Is the person performing the design verification qualified to originate the document?
X			Is the design verification being performed by someone other than the supervisor of the originator?
X			Were the design inputs correctly selected and incorporated into design?
X			Are assumptions necessary to perform the design activity adequately described and reasonable? Where necessary, are assumptions identified for subsequent re-verifications when the detailed design activities are completed?
		X	Are the appropriate quality and quality assurance requirements specified?
X			Are the applicable codes, standards and regulatory requirements including issue and addenda properly identified, and their requirements for design met?
		X	Have applicable construction and operating experiences been considered?
		X	Have the design interface requirements been satisfied?
X			Were appropriate design methods and computer programs used?
X			Is the design output reasonable compared to design inputs?
		X	Are the specified parts, equipment, and processes suitable for the required application?
		X	Are the specified materials compatible with each other and the design environmental conditions to which the material will be exposed?
		X	Have adequate maintenance features and requirements been specified?
		X	Are accessibility and other design provisions adequate for performance of needed maintenance and repair?
		X	Have adequate accessibility been provided to perform the in-service inspection expected to be required during the plant life?
		X	Has the design properly considered radiation exposure to the public and plant personnel?
		X	Are the acceptance criteria incorporated in the design documents sufficient to allow verification that design requirements have been satisfactorily accomplished?
		X	Have adequate pre-operational and subsequent periodic test requirements been appropriately specified?
		X	Have adequate handling, storage, cleaning, and shipping requirements been specified?
		X	Are adequate identification requirements specified?
		X	Are requirements for record preparation review, acceptance, retention, etc., adequately specified?

Verified by: [signature] Date: 10/13/10 Approved by: [signature] Date: 10/14/10

S&L Acceptance Review : Name: Dan Kocunik Sign: [signature] Date: 10/11/11

MACTEC DESIGN CALCULATION OR ANALYSIS COVER SHEET

Project Name: PSEG ESP Application Project	Project Number: 6468-08-2251	Calc/Anls Number: 2251-ESP-REI-2047-ACR-040, Rev. 1	Sheet: 1 of 1

Nuclear Safety Classification: (SR) NSR AQ	Subject: Calculation of smooth vertical GMRS for the PSEG Site	Discipline: Seismology

Originator: Robin K. McGuire (RKM) Reviewer: Gabriel R. Toro (GRT)	Origination Date: 11-02-09	Principal Professional: J. Allan Tice

Comments: This calculation was prepared by Risk Engineering, a part of Fugro William Lettis Associates and is supported by electronic files in Record No. 2047-ACR-041. The Risk Engineering cover sheet documents their review and approval history. This MACTEC cover sheet addresses Revision 1 for REI Record No. 2047-ACR-040. Revision 1 is issued to change site name terminology from Hope Creek to PSEG Site. No changes in supporting documents were necessary. This cover sheet documents approval of Rev. 1 by MACTEC. Revision 1 was prepared by John Vlasity (JV) and reviewed by GRT.

5/20/10

Rev #: 0	Reason: NA	By: RKM	Date: 5.20.10	Approved:
Rev #: 1	Reason: Change terminology from Hope Creek to PSEG Site	By: RKM	Date: 5.20.10	Approved: CAJ 5/20/10
Rev #:	Reason:	By:	Date:	Approved:
Rev #:	Reason:	By:	Date:	Approved:

RISK ENGINEERING, INC.
V: PROJECT ANALYSIS AND CALCULATION RECORD

Title: ***Calculation of smooth vertical GMRS for the PSEG Site***

Record No. _2047_ -ACR- _040 **Rev. 1**_ (calcs)

Record No. _2047_ -ACR- _041_ (elec. files)

Rev.	Status	Date	Description	Prep. by	Rev. by	App.* by
0	Final	11-2-09	Initial release	RKM	GRT	RKM
1	Final	5-18-10	Clarification of site name	RV	GRT	RKM

*Approval for release of results

Reviewer
Description of work:
Initials

1.	Are objectives clearly stated?	GRT
2.	Are inputs correctly selected, stated, and referenced?	GRT
3.	Are literature searches and background information completely described?	GRT
4.	Are assumptions completely described and referenced?	GRT
5.	Is an appropriate computer program used for analysis?	N/A
6.	Are appropriate methods/equations used for hand calculations?	GRT
7.	Are the results reasonable, considering the input?	GRT
8.	Have mathematical checks been made to ensure the accuracy of the results?	GRT
9.	Have the accuracy and conclusions been confirmed?	GRT

All calculations shall fully describe:
1. Objectives of analysis.
2. Design inputs, sources, and references.
3. Literature searches and background information.
4. Assumptions, basis for assumptions, and references.
5. If computer calculations, program name and version name.
6. If hand calculations, equations used and outputs.

Calculation of smooth vertical GMRS for the PSEG Site

1. Objectives of analysis.

This calculation documents the smooth vertical GMRS for the **PSEG Site**.

2. Inputs.

Horizontal 10^{-5} UHRS and GMRS at 38 frequencies (Ref. 1).
Vertical/Horizontal (V/H) ratios (Ref. 2 and 3).
Western US ground motion equations (Ref. 4 and 5).

3. Literature search and background information.

Recommended V/H ratios for response spectra are given in Ref. 2 and 3. There is no reference that directly recommends V/H ratios for CEUS soil sites, so multiple V/H ratios are derived here from various sources, and a conservative envelope is used to bound those estimates to derived a recommended set of V/H ratios for the **PSEG Site**.

4. Assumptions and basis.

It is assumed that the horizontal 10^{-5} UHRS and GMRS from Ref. 1 are accurate. The basis is the separate QA review conducted for these calculations.

5. Computer calculations:

N/A.

6. Hand calculations:

Excel file **2047-ACR-041**.XLS in Ref. 8 calculates smooth vertical GMRS spectra at 38 frequencies for **the PSEG Site** and documents these in a plot and table. Spectra are calculated as follows:

(1) NUREG6728: This worksheet copies the V/H factors from Table 4-5 of Ref. 2. Note that these are for CEUS rock conditions.

(2) Campbell: This worksheet copies Table 5 and 6 from Ref. 5, and uses these to calculate spectral accelerations for horizontal and vertical motions for specified values of **M** and R. These motions are for the western US (WUS) for rock and soil. Note that **M** and R values in cells G1 and G2 are controlled in worksheet (7). Columns R and S show V/H ratios for rock and soil (the V/H ratios are the same).

(3) A&S-Table3: This worksheet copies the coefficients from Table 3 from Ref. 4, which are used to calculated horizontal amplitudes.

(4) A&S-Table5: This worksheet copies the coefficients from Table 5 from Ref. 4, which are used to calculated vertical amplitudes.

(5) A&S-vert amps: This worksheet uses the Table 5 coefficients from worksheet (4) to calculate vertical motions for the specified M and R values in cells F1 and F2 (these are controlled in worksheet (7)). Ground motions are calculated for both rock and soil conditions. Note that these motions are for WUS sites.

(6) A&S-horiz amps: This worksheet uses the Table 3 coefficients from worksheet (3) to calculate horizontal motions for the specified M and R values in cells F1 and F2 (these are controlled in worksheet (7)). Ground motions are calculated for both rock and soil conditions. Note that these motions are for WUS sites. Columns H and I calculated V/H ratios using ground motions from worksheets (5) and (6).

(7) VH_ratio: This worksheet copies V/H ratios from worksheets (2) and (6) and averages them for rock (column M) and soil (column P). Plots show the V/H ratios as a function of frequency. Column R shifts the frequency axis by a factor of 3 to approximate the difference between CEUS and WUS ground motion frequencies, and plots the V/H ratios with the shifted frequencies, as further background information. This worksheet also calculates V/H ratios from Reg. Guide 1.60 (Ref. 3). Recommended spectral amplitudes based on ground displacement for 0.25 Hz in Ref. 3 are converted to spectral accelerations as explained in notes in this worksheet.

This worksheet plots the V/H ratios for 7 cases as follows (this is included as Figure 1 below):

1. NUREG/CR-6728 (Ref. 2) labeled "CEUS rock", calculated in worksheet (1) for PGA<0.2g, which is the case for the horizontal GMRS.
2. "RG1.60", calculated in worksheet (7).
3. "WUS soil **M**=5.6, R 22". This is the average V/H ratio from WUS soil, column V of worksheet (7), for the dominant **M** and R values for the 1E-4 HF spectrum (Ref. 6). (Note that column V holds the "paste values" amplitudes from column P, for the appropriate **M** and R.)
4. "WUS soil (shifted) **M**=5.6, R 22". This is the average V/H ratio from WUS soil with frequencies shifted, similar to #3 above except that shifted frequencies are used from column R for plotting.
5. "WUS soil **M**=5.6, R 9.6". This is the average V/H ratio from WUS soil, column U of worksheet (7), for the dominant **M** and R values for the 1E-5 HF spectrum (Ref. 6). (Note that column V holds the "paste values" amplitudes from column P, for the appropriate **M** and R.)
6. "WUS soil (shifted) **M**=5.6, R 9.6". This is the average V/H ratio from WUS soil with frequencies shifted, similar to #5 above except that shifted frequencies are used from column R for plotting.
7. "Recommended V/H" is the V/H ratio of 1 for frequencies above 10 Hz, 0.75 for frequencies below 5 Hz, and a log-linear interpolation between 5 and 10 Hz.

The **M** and R values above are taken from the 1E-4 and 1E-5 HF deaggregations in Ref. 6 because the high frequencies above 10 Hz are where the V/H ratio is highest, and it is important to represent this frequency range accurately. The amplitude of the GMRS is below that of the 1E-5 UHRS, and the deaggregations at 1E-4 and 1E-5 are expected to bound the earthquakes that will control the GMRS. The CEUS rock spectrum demonstrates that V/H ratios in the CEUS have peaks at high frequencies (40 Hz and higher), which supports the frequency shift explained above for worksheet (7). The recommended V/H ratios envelop all other V/H ratios except the RG1.60 ratios, which are considered obsolete because they are based on ground motion records obtained primarily in California and all prior to 1973.

(7) H+V_GMRS: This worksheet copies the 1E-5 UHRS and GMRS from Ref. 1, applies the recommended H/V ratios described above, and calculates the vertical GMRS from the horizontal GMRS. This calculation is numerically identical to calculating a vertical 1E-5 UHRS and applying a factor of 0.45 to calculate the vertical GMRS from it.

Figure 2 plots the horizontal and vertical GMRS. Table 1 shows numerical values for the horizontal 1E-5 UHRS, the horizontal GMRS, the V/H ratios, and the vertical GMRS. All numerical results are documented in Ref. 8.

References

1. Risk Engineering, Inc. (**2010**). *Calculation of smooth horizontal GMRS for **the PSEG Site*** REI QA record 2047-ACR-038 **Rev. 1**.
2. Risk Engineering, Inc. (2001). *Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines,* US Nuc. Reg. Comm. Rept. NUREG/CR-6728.
3. US Atomic Energy Comm (1973). *Regulatory Guide 1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants,* Wash. DC, Dec.
4. Abrahamson, N.A., and W.J. Silva (1997). "Empirical response spectral attenuation relations for shallow crustal earthquakes," *Seism. Res. Ltrs,* 68, 1, 154-179.
5. Campbell, K.W. (1997). "Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity and pseudo-absolute acceleration response spectra", *Seism. Res. Ltrs,* 68, 1, 154-179.
6. Risk Engineering, Inc. (**2010**). *High- and low-frequency horizontal spectra for **the PSEG Site***, REI QA record 2047-ACR-024 **Rev. 1**.
7. Risk Engineering, Inc. (**2010**). *Electronic files for Calculation of soil hazard for **the PSEG Site***, REI QA record 2047-ACR-036 **Rev. 1**.
8. Risk Engineering, Inc. (**2010**). *Electronic files for Calculation of smooth vertical GMRS for **the PSEG Site***, REI QA record 2047-ACR-041.

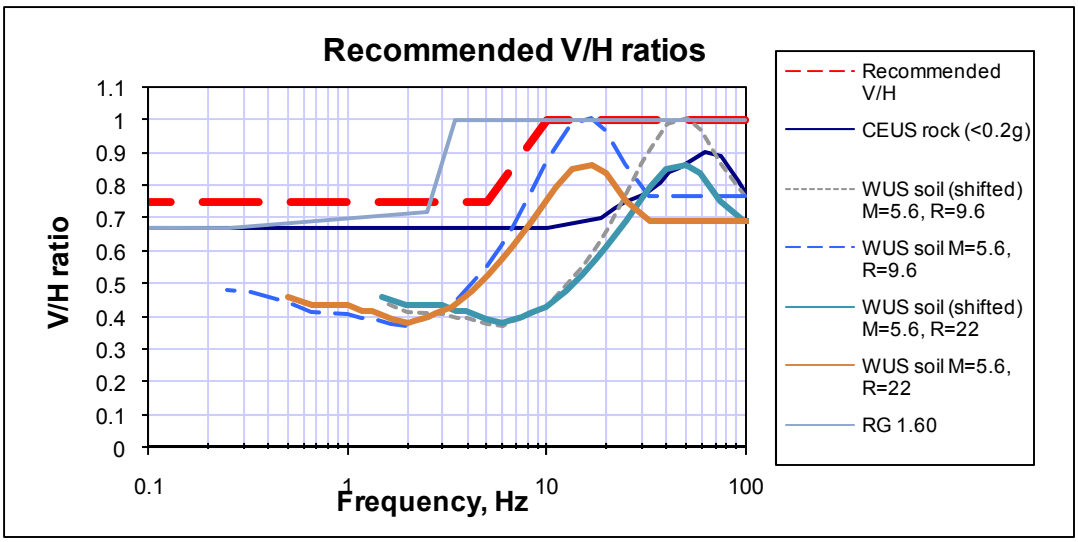

Figure 1: V/H ratios calculated by various methods.

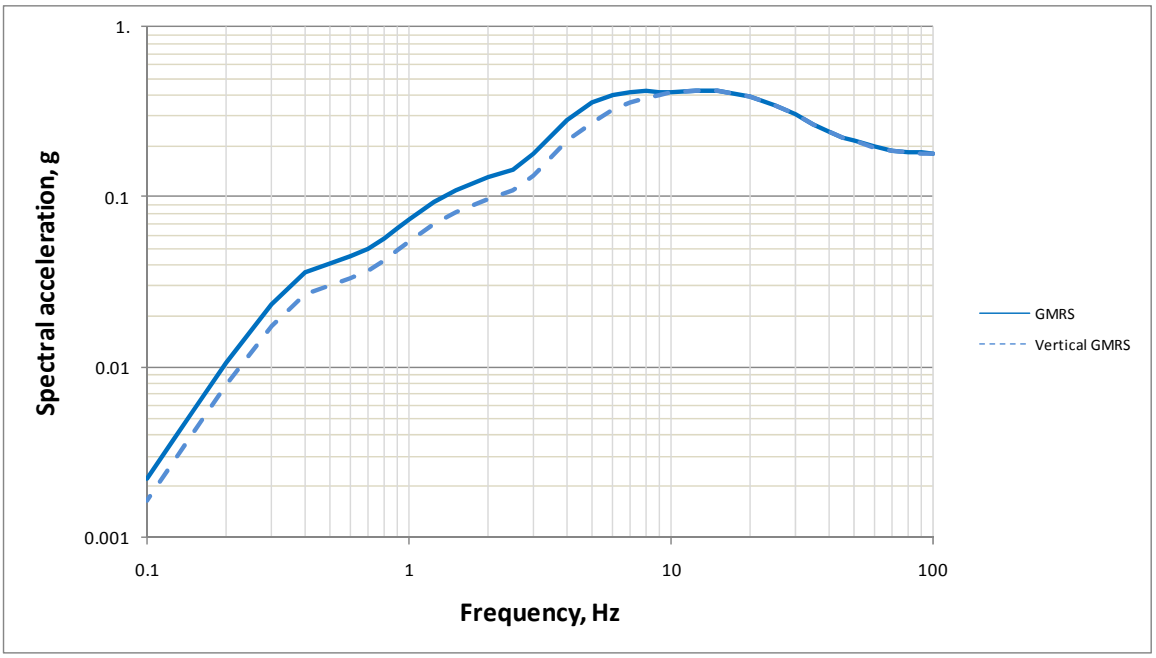

Figure 2: **PSEG Site** horizontal and vertical soil GMRS.

Table 1: Amplitudes for **PSEG Site** 10^{-5} horizontal soil UHRS and GMRS.

Freq.	1E-5 UHRS	GMRS	V/H ratio	Vertical GMRS
100	4.00E-01	1.80E-01	1	1.80E-01
90	4.03E-01	1.81E-01	1	1.81E-01
80	4.07E-01	1.83E-01	1	1.83E-01
70	4.16E-01	1.87E-01	1	1.87E-01
60	4.34E-01	1.96E-01	1	1.96E-01
50	4.72E-01	2.13E-01	1	2.13E-01
45	4.99E-01	2.25E-01	1	2.25E-01

40	5.40E-01	2.42E-01	1	2.42E-01
35	5.99E-01	2.69E-01	1	2.69E-01
30	6.71E-01	3.03E-01	1	3.03E-01
25	7.75E-01	3.48E-01	1	3.48E-01
20	8.79E-01	3.89E-01	1	3.89E-01
15	9.42E-01	4.20E-01	1	4.20E-01
12.5	9.36E-01	4.20E-01	1	4.20E-01
10	8.99E-01	4.10E-01	1	4.10E-01
9	9.22E-01	4.13E-01	0.96	3.97E-01
8	9.29E-01	4.17E-01	0.92	3.84E-01
7	9.23E-01	4.14E-01	0.87	3.61E-01
6	8.77E-01	3.96E-01	0.82	3.23E-01
5	8.17E-01	3.60E-01	0.75	2.70E-01
4	6.29E-01	2.84E-01	0.75	2.13E-01
3	3.96E-01	1.78E-01	0.75	1.33E-01
2.5	3.20E-01	1.45E-01	0.75	1.09E-01
2	2.91E-01	1.31E-01	0.75	9.79E-02
1.5	2.46E-01	1.09E-01	0.75	8.19E-02
1.25	2.07E-01	9.27E-02	0.75	6.95E-02
1	1.59E-01	7.34E-02	0.75	5.51E-02
0.9	1.44E-01	6.47E-02	0.75	4.85E-02
0.8	1.24E-01	5.63E-02	0.75	4.23E-02
0.7	1.09E-01	4.92E-02	0.75	3.69E-02
0.6	9.88E-02	4.44E-02	0.75	3.33E-02
0.5	9.05E-02	4.07E-02	0.75	3.05E-02
0.4	7.97E-02	3.58E-02	0.75	2.69E-02
0.3	5.15E-02	2.31E-02	0.75	1.73E-02
0.2	2.26E-02	1.05E-02	0.75	7.85E-03
0.15	1.24E-02	5.60E-03	0.75	4.20E-03
0.125	8.04E-03	3.63E-03	0.75	2.72E-03
0.1	4.90E-03	2.21E-03	0.75	1.65E-03