August 16, 1984

Docket No.: 50-206
LS05-84-08-020

Mr. Kenneth P. Baskin, Vice President
Nuclear Engineering
Licensing and Safety Department
Southern California Edison Company
2244 Walnut Grove Avenue
Post Office Box 800
Rosemead, California 91770

Dear Mr. Baskin:

SUBJECT: SEISMIC GROUND MOTION - SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1

In a letter dated September 16, 1982, the NRC staff issued a Safety Evaluation Report which described a free-field ground motion to be used in the seismic reevaluation of San Onofre Unit 1 under the Systematic Evaluation Program Topic III-6. Subsequently, in a letter dated April 2, 1983, the staff requested additional information concerning vertical ground motion for the San Onofre Unit 1 site. SCE responded in letters dated August 3, 1983 and February 7, 1984.

As described in the enclosed Safety Evaluation Report, the staff concludes that the original estimate for the free-field ground motion in our September 16, 1982 letter, applied at the foundation, is appropriate for the San Onofre Unit 1 seismic reevaluation.

Sincerely,

Gary M Holahan for

Dennis M. Crutchfield, Assistant Director
for Safety Assessment
Division of Licensing

Enclosure:
As stated

cc w/enclosure:
See next page

*PREVIOUS CONCURRENCES OBTAINED

ORB#5:PM	SEPB:DL	SEPB:DL		ORB#5:AC	AD:SA:DL
*EMcKenna:dk	*TCheng	CGrimes	LReiter	WPaulson	DCrutchfield
8/15/84	8/15/84	8/16/84	8/16/84	8/16/84	8/16/84

SE04
1/1
(EX-08)

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Mr. Kenneth P. Baskin

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SAFETY EVALUATION REPORT

VERTICAL GROUND MOTION

SAN ONOFRE NUCLEAR GENERATING STATION, UNIT 1

In a letter dated September 16, 1982, the staff issued its Safety Evaluation Report entitled "Seismic Input for the Reevaluation of San Onofre Nuclear Generating Station Unit 1" to Southern California Edison Company. That review placed much reliance on the extensive operating license review carried out by the staff for the adjacent San Onofre Nuclear Generating Station Unit 2 and 3 (SONGS 2&3) as well as on the reports submitted by Southern California Edison (SCE) in the period between February 1982 to August 1982. In that report, the staff approved the use of the Housner spectrum for reanalysis with some exceptions: the staff concluded that the best estimate of the 84th percentile spectrum from the controlling earthquake (magnitude $M_s = 7$ at 8 kilometers distance) would exceed, for horizontal motion, the Housner spectrum (anchored at 0.67g) by up to 10% in the 0.07 to 0.25 second period range, and for the vertical motion, the Housner spectrum (anchored at 0.44g) by up to 10% in the 0.05 to 0.15 second period range. The staff's estimate of the vertical response spectrum was based primarily on the results of theoretical modeling studies performed for SCE (Del Mar Technical Associates, 1979; Del Mar Technical Associates, 1980).

Subsequent to the staff's report, Campbell (1982) published the results of a study on the near-source behavior of peak vertical acceleration. A conclusion of this study was that for large earthquakes the ratio of the peak-vertical to peak-horizontal acceleration was found to exceed a value of two-thirds for fault distances less than 10 to 25 kilometers. As a result, the staff asked SCE (letter April 2, 1983; to R. Dietch from D. Crutchfield) to address the adequacy of the SONGS 1 vertical ground motion estimates in light of Campbell's (1982) study. SCE responded to the staff's question in a letter of August 3, 1983 (to D. M. Crutchfield from K. P. Baskin) which provided a chronology of the development of information prepared for SCE regarding vertical ground motion relative to the San Onofre site and a description of the development of the paper by K. W. Campbell regarding vertical peak ground acceleration.

SCE further responded to the staff on February 7, 1984, with a report by one of its consultants (Sierra Geophysics) entitled "84th Percentile Vertical Response Spectrum San Onofre Nuclear Generating Station, Unit 1." To develop the vertical response spectrum, Sierra Geophysics decomposed the problem into two parts: (1) development of an 84th percentile peak vertical ground acceleration value; and (2) development of a vertical ground motion spectral shape. Sierra Geophysics took the position that Campbell's study did not take into account site-conditions in performing the regression analysis for peak vertical acceleration, that the data set is dominated by soft soil sites, that the peak horizontal acceleration for both soil and rock sites are essentially the same, that recent modeling studies show that site conditions significantly affect vertical ground acceleration and that SONGS 1 is an intermediate or "average soil" site. To illustrate the effect of site conditions, Sierra

Geophysics provided the results of a recent theoretical modeling study (Apsel and others, 1983) in which the spectral ratios of soft-soil to average-soil sites were estimated. The vertical spectral ratios, estimated in the near field of magnitude 5.5 earthquakes, exceed unity at high frequencies.

Sierra Geophysics used a multiple-method approach to estimate the 84th percentile peak vertical ground acceleration for SONGS 1. In this approach, seven estimates of the 84th percentile peak vertical acceleration (PVA) were made and the average of these was proposed as the appropriate value to be used as a spectral high frequency anchor. A copy of Sierra Geophysics' Table 2.1 which outlines each of the seven methods is attached. The following is a discussion of the seven methods used, including the relative merits and limitations of each.

Method 1 used the regression equation developed by Campbell (1982) and the magnitude and the distance appropriate for SONGS 1. The resulting PVA is 0.43g. This method is the most direct method of estimating PVA, other than actually recording at the site, in that it is based on the regression analysis of real earthquake ground motion data. However, the regression analysis did not take into account the site geological considerations. The licensee has argued that the data set used is dominated by deep soft-soil sites, the deep soil amplifies PVA with respect to peak horizontal acceleration (PHA) and, therefore, predicts a higher PVA than is appropriate for the SONGS 1 site. The staff has discussed with Campbell the data set he used in his study. He indicated that it is dominated by deep soft-soil site recordings and that he had not made any analysis of the effect of the site condition on the prediction of peak vertical acceleration. Both the information provided from the theoretical modeling study (Apsel and others, 1983) and the empirical data from the 1979 Coyote Lake earthquake lend credence to the theory that the ratio of the PVA to PHA is subject to site conditions.

Method 2 used the PVA/PHA from the 1979 Imperial Valley earthquake at a distance of 8 kilometers and 0.50g, which is the mean of the three 84th percentile PHA's presented for SONGS 1 in the June 1982 report (Woodward-Clyde Consultants, 1982), to estimate a PVA value for SONGS 1 of 0.37g. Campbell (1983) estimates an 84 percentile PHA of 0.46g for an $M_s = 7$ at 8 kilometers. Method 2 uses the vertical to horizontal ratio from an earthquake of about the same magnitude as the SONGS safe shutdown earthquake (SSE); however, the data were recorded under site conditions different than those at SONGS.

Method 3 used the results of a theoretical modeling study (Apsel and others, 1983) to obtain a ratio of the PVA of an average soil site to the PVA of a soft soil site at 8 kilometers. This ratio was then used to scale Campbell's value of PVA which was dominated by data from soft soil site conditions to approximate a PVA for SONGS site conditions. The value obtained is 0.28g. This method attempted to compensate for the difference in site conditions between SONGS 1 and the locations where the data was obtained. However, the modeling study on which the scaling ratio is based was performed for magnitude 5.5 earthquakes. This adds some uncertainty to the estimate as there may be a magnitude effect to consider in applying this to a magnitude 7 earthquake.

Method 4 used the 84th percentile PVA from the Imperial Valley earthquake at 8 kilometers scaled up from magnitude 6.9 to magnitude 7, modified to take into account the results of Apsel and other (1983) used in method 2. The resulting PVA was 0.26g. This method is based on data from only one earthquake and the magnitude scaling is only an approximation.

Method 5 relied on the results of the Del Mar Technical Associates (1979, 1980) estimates of PVA. These are the same studies upon which the staff based its estimates of the SONGS 1 vertical ground motion in its September 1982 report. The 1979 Del Mar study (Supplement I) results in an 84th percentile estimate which is about 63% of the 84th percentile PVA estimate obtained from the Del Mar 1980 study (Supplement III). In using these results the Sierra Geophysics report weights the Supplement I PVA and the Supplement III results in a manner similar to that used by the staff in its September 1982 report. One advantage of these theoretical studies is that they attempt to model the site conditions, the earthquake magnitude, and the source distance for the SONGS site.

In Method 6, the results of both theoretical modeling and the analysis of empirical data were used to make an estimate of the 84th percentile PVA. The ratio of the vertical to horizontal ground motion from Supplement III was used in conjunction with the 84th percentile PHA for SONGS 1 to estimate a PVA value. The merit of this method is that the data it uses are taken from studies specific to the SONGS site conditions. The resulting PVA was 0.28g.

Method 7 used the average PVA to PHA ratio obtained for stations 2, 5, 8, 12 and Temblor of the Cholame strong motion array from the 1966 Parkfield earthquake and the 84th percentile PHA estimate for SONGS 1 to estimate the SONGS 1 PVA. There are several limitations to this method. Among them are: the Parkfield earthquake was magnitude 6.4 while the SONGS 1 SSE is 7.0, SONGS 1 is 8 kilometers from the causative fault while the distance range for the Cholame array is 0.08 to 12 kilometers. Most important, however, is that the site foundation at SONGS 1 has been characterized by SCE as average soil while the conditions at the Cholame array vary from rock through shallow soil to deep soil. The resulting PVA was 0.21g.

To further support the hypothesis that PVA/PHA is a function of site condition Sierra Geophysics presented the strong ground motion data from the 1979 Coyote Lake magnitude 5.9 earthquake. Of the six strong motion stations which recorded the earthquake, three (Gilroy Array 1 and 6, and San Martin) were located on rock and the other three stations (Gilroy Array 2, 3 and 4) were located on soft alluvium. The average PVA/PHA for the rock sites is 0.55 whereas the average PVA/PHA for the soft soil sites is 0.95. If the assumption is made that the horizontal value of peak ground acceleration is insensitive to soil conditions, these results imply that the vertical component of motion on a rock site is about 60 percent of that recorded on a soil site. The estimates made for the SONGS 1 PVA using the seven methods range from 0.19g to 0.43g with an average of 0.28g. This wide range of values (over a factor of two) illustrates the large uncertainty in the estimations.

To develop a site specific vertical response spectral shape for SONGS 1, Sierra Geophysics examined the character of the vertical to horizontal response spectral ratio as a function of site conditions. They concluded that the shape of the vertical response spectra is site dependent and that it is appropriate to use the response ratio of the normalized vertical and horizontal spectra as developed by Del Mar Technical Associates Supplement III (1980) for determining a SONGS 1 site specific spectral ratio. It appears that the shape of the vertical response spectrum is site and distance dependent and it is, therefore, appropriate to use the spectral shape obtained from the modeling study which used SONGS 1 site specific conditions. The shape of the vertical response spectrum for SONGS 1 was estimated by multiplying the values of the Supplement III vertical to horizontal spectral ratio, at each period, by the horizontal spectral values presented for SONGS 1 in the June 1982 report by Woodward-Clyde Consultants. The estimate of the 84th percentile vertical response spectrum was obtained by anchoring the vertical spectral shape, thus obtained, to a peak acceleration of 0.28g. The peak acceleration of 0.28g is the average of the seven estimates discussed above.

In its September 1982 report, the staff estimated that the 84th percentile vertical spectrum for SONGS 1 would exceed the Housner spectrum anchored at 0.44g by up to 10% in the period range 0.05 to 0.15 seconds. A comparison of the Sierra Geophysics vertical response spectrum with the September 1982 staff estimate indicates that at its highest value, at 0.07 seconds period, the Sierra Geophysics spectrum is 14% below the staff's estimate. The Sierra Geophysics spectral shape would have to be anchored at about 0.33g for its highest value to equal the staff's estimate. The staff's September 1982 estimate is, thus, above the mean of the range of estimates made by Sierra Geophysics using the seven methods and is only exceeded in any significant manner by Method 1 which did not take site conditions into account. The staff, therefore, concludes that there is no reason to alter the original estimate. As discussed above, there are many uncertainties in estimating the vertical near field ground motion and these uncertainties result in a wide range of values, none of which can stand alone. Determination of vertical ground motion parameters is not at the same stage of development as that of horizontal ground motion.

Because of the uncertainties inherent in this estimation of ground motion, the staff concludes that the estimate of the 84th percentile spectrum for SONGS 1 in the September 1982 report should not be reduced based on these studies. Moreover, the staff concludes that the response spectrum in the September 1982 report adequately reflects the applicable uncertainties and, therefore, is appropriate for use in the SONGS 1 seismic reevaluation when applied at the foundation.

References

1. Apsel, R. J., D. M. Hadley and R. S. Hart, 1983, Effects of Earthquake Rupture Shallowness and Local Soil Conditions on Simulated Ground Motions, NUREG/CR-3102, p. 123.

2. Campbell, K. W., 1982, A Study of the Near-Source Behavior of Peak Vertical Acceleration (Abstract), EOS V. 63, p. 1037.

3. Campbell, K. W., 1983, The Effects of Site Conditions on Near-Source Recordings of Strong Ground Motion, Proceedings of Workshop on Site-Specific Effects of Soil and Rock on Ground Motion and Their Implications for Earthquake Resistant Design, Santa Fe, NM, July 26-28, 1983.

4. Del Mar Technical Associates, 1979, Simulation of Earthquake Ground Motions for San Onofre Nuclear Generating Station, Unit 1, Supplement 1.

5. Del Mar Technical Associates, 1980, Simulation of Earthquake Ground Motions for San Onofre Nuclear Generating Station, Unit 1, Supplement III.

6. Sierra Geophysics, 1984, 84th Percentile Vertical Response Spectrum San Onofre Nuclear Generating Station Unit 1. SGI-R-84-103.

7. Woodward-Clyde Consultants, 1982, Development of Instrumental Response Spectra for the San Onofre site.

TABLE 2.1

SONGS - UNIT 1

MULTI-METHOD APPROACH TO 84th PERCENTILE PGA VERTICAL

1. CAMPBELL = 0.43g

2. [IV79 RATIO VERTICAL/HORIZONTAL] X
[SONGS 84TH HORIZONTAL] X

   [0.74] X [0.50] = 0.37

3. [CAMPBELL - 84TH VERT] X
[EUSGCS2/EUSGCS3 - (NUREG/CR-3102)]

   [0.43] X [0.67] = 0.28

4. [IV79 84TH VERTICAL] X
[EUSGCS2/EUSGCS3 - (NUREG/CR-3102)] X
[PGA M = 7.0/PGA M = 6.9]

   [0.37] X [0.67] X [1.08] = 0.26

5. A) [SUPPLEMENT I] X [1σ]
[.11] X [1.5] = 0.17

   B) [(SUPPLEMENT I + III)/2] X [1σ]
[(.11 + .18)/2] X [1.5] = 0.21

   AVERAGE - A & B = 0.19

6. [SUPPLEMENT III VERT/HORIZ] X
[SONGS 84TH HORIZONTAL]

   [0.57] X [0.50] = 0.28

7. [PARKFIELD - STA. 2, 5, 8, 12 & TEMBLOR - VERT/HORIZ] X
[SONGS 84TH HORIZONTAL]

   [0.42] X [0.50] = 0.21

AVERAGE = 0.28