Southern California Edison Company

P. O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

K. P. BASKIN
MANAGER, NUCLEAR ENGINEERING
AND LICENSING

TELEPHONE
(213) 572-1401

July 1, 1980

Director, Office of Nuclear Reactor Regulation
Attention: Mr. Albert Schwencer, Acting Branch Chief
Licensing Projects Branch 3
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket Nos. 50-361 and 50-362
San Onofre Nuclear Generating Station
Units 2 and 3

The NRC's letters of March 20, 1980, and May 23, 1980, forwarded several requests for additional information including NRC Questions 361.63, 361.64 and 361.65 in the geosciences area. SCE's letter of June 11, 1980, transmitted sixty-three copies of the responses to NRC Questions 361.63 and 361.64. This letter forwards sixty-three copies of the response to NRC Question 361.65. These responses will be incorporated in Amendment 19 to the Final Safety Analysis Report (FSAR) which is scheduled for transmittal in July, 1980.

As indicated in the June 11, 1980 letter, direct distribution of these responses will be made as part of the Amendment 19 distribution and will be in accordance with the service list provided by SCE's letter of October 29, 1979 to the Commission. An affidavit attesting to the fact that distribution has been completed will be provided within ten days of docketing of Amendment 19.

Also enclosed are seven copies of the logs from six vibratory core holes taken offshore of the San Onofre site. The holes ranged between 25.5 feet and 44 feet deep and were done in an effort to provide an age of the submerged terrace platform underlying the sediments. Organic samples were collected at selected intervals in the cores for age dating. The results of the age dating will be provided at a later date as soon as they are available.

If you have any questions or comments concerning this information, please contact me.

Very truly yours,

K P Baskin

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cc: USGS, Menlo Park, CA (Dr. J. Andrews)
USGS, Reston, VA (J. F. DeVine)
California Division of Mines and Geology (P. Amimoto)
D. B. Slemmons

QUESTION 361.65

The estimation of free field earthquake ground motion to be used in the reevaluation of SONGS 1 is based upon deterministic modeling of such motion from an earthquake occurring on the Offshore Zone of Deformation 8 km west of the plant. The estimation of free field earthquake ground motion from the same zone presented in the SONGS 2 and 3 Operating License review is based upon a largely empirical evaluation. Since all three of these units are at the same location and are subject to the same seismic hazard a comparative evaluation of results from both methodologies is warranted.

You are requested to prepare this evaluation including sufficient discussion and figures so that the staff may fully understand the "similarities" and differences in the results. Specific attention should be paid to include the following items.

1. Comparative plots of predicted spectra at similar levels of damping.

2. A comparison of the similarities and differences of these spectra at different frequency bands and a discussion of the sources of these differences and their significance with respect to uncertainties in the prediction of ground motion and validity of the different approaches taken.

3. A discussion and listing of the conservatisms existing in each approach and what effect these have upon the relative differences and similarities in the resultant spectra.

4. A discussion of the rationale as to why different approaches were used at SONGS 1 and SONGS 2 and 3.

5. A comparison of the basic geological and seismological assumptions utilized in each approach.

RESPONSE 361.65

361.65.1 Introduction (Q 4)

Estimates of free-field earthquake-induced ground motions at the San Onofre Nuclear Generating Station (SONGS) Units 1, 2, and 3 site have been made using two different approaches. These approaches are the "source-modeling" approach and the "empirical" approach. Analyses using the source-modeling approach for SONGS Unit 1 were initiated in 1975 and are documented in the May 1978 report "Simulations of Earthquake Ground Motion for San Onofre Nuclear Generating Station, Unit 1" and the July 1979 report "Simulation of Earthquake Ground Motions for San Onofre Nuclear Generating Station Unit 1 - Supplement 1" by Del Mar Technical Associates (TERA/DELTA). Analyses using the empirical approach for SONGS Units 2 and 3 were initiated in 1978, and are documented in the June 1979 report "Report of the Evaluation of Maximum Earthquake and Site Ground Motion Parameters Associated with the Offshore Zone of Deformation, San Onofre Nuclear Generating Station" by Woodward-Clyde Consultants (WCC) (also in the response to NRC question 361.54). Both approaches provide estimates for free-field instrumental ground motion parameters at the SONGS site due to a postu-

lated major earthquake of about M_s 7 on the Offshore Zone of Deformation located 8 km west of the SONGS site.*

In brief, the "source-modeling" approach is a computer method of rigorously incorporating rupture physics and wave mechanics into a procedure for modeling strong ground motions. Recorded past earthquakes were used to provide constraints on the mechanics of the model which was then applied to the existing seismologic and geologic conditions at the SONGS site. The "empirical" approach is a method of incorporating recorded historical data in a statistical model for estimating ground motion. A careful selection of earthquake ground-motion data was made for M_s 6 1/2 recorded at sites that reasonably represent the SONGS site conditions. These data were regressed with distance to develop response spectra at a closest distance of 8 km and extrapolated to M_s 7 using published relationships and data on the effects of magnitude on ground-motion parameters.

Use of the two approaches to estimate free-field ground motions was motivated by a need to demonstrate the conservatism of the SONGS Units 2 and 3 design response spectra

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* The estimate of free field instrumental ground motions has been made for SONGS Unit 1 is based on the existence of the OZD as postulated by the NRC and USGS, notwithstanding the Applicants' position (with respect to SONGS Unit 1) that the geologic evidence indicates that: (1) the hypothesized OZD is made up of short discontinuous segments, and (2) structures capable of producing large earthquakes are distant and capable of producing less than 1/4 g at the SONGS site. For the limited purpose of licensing SONGS Units 2 and 3, during the CONSTRUCTION PERMIT PROCEEDINGS, Applicants stipulated to the geologic model, as postulated by the NRC and USGS.

more expeditiously than the pace of the NRC and NRC consultants' review of the source modeling work which had been initiated for the purpose of seismic reevaluation of SONGS Unit 1. In Question 361.33, which was transmitted by NRC letter dated March 10, 1978, the NRC requested that the Applicants provide on the San Onofre 2 and 3 docket an assessment of the "representative ground motion to be expected at the site" from "the largest potential earthquake which can be associated with the 'Hypothesized Offshore Zone of Deformation'." Further, the NRC requested that this assessment be performed independently of the NRC/USGS geosciences licensing decision (construction-permit stage), which had been based on extensive consideration by the NRC and the USGS personnel and on extensive investigations by the Applicants and their consultants.

In evaluating the methodology to be utilized in assessing instrumental ground-motion at the site, the Applicants considered the ground motion modeling work which was being performed for and reviewed by the NRC on the San Onofre Unit 1 docket. The Applicants considered at that time, and continue to consider, the results of this modeling study to constitute an appropriate basis for evaluating the design spectrum for licensing of either or both projects. At the time the Applicants selected a methodology for assessing instrumental ground motion to support the preparation of a response to the NRC Question 361.33, it was clear that the pace of the NRC and NRC consultants' review of the modeling study was too slow to support the licensing needs of San Onofre Units 2 and 3. Therefore, the Applicants elected to base the response to Question 361.33 on the empirical approach (since performed by Woodward-Clyde Consultants, reported in June 1979) independent of the San Onofre Unit 1 modeling study. The studies were carried out separately and

independently, and were cross-reviewed to ensure high technical quality. The assumptions for each study were made independently, and incorporated mutually exclusive data sets.

The subsections that follow address the five parts of the NRC Question 361.65. For ease of reference, the title of each subsection is followed by the number of the part of Question 361.65 being addressed.

361.65-2 Assumptions, Bases, and Conservatisms (Q 2, 3, 5)

The general assumptions and the bases for the two approaches are discussed in this section, according to the following considerations:

- geology and earth structure
- faulting process
- magnitude
- stress drop
- proximity (distance/attenuation)
- focusing
- judgment and experience

Some of the more important points are summarized in Table 361.65-1. The paragraphs that follow highlight the information summarized in that table.

GEOLOGY AND EARTH STRUCTURE

Source-Modeling Approach

The properties used in the analysis were determined by seismic surveys, as documented in the TERA/DELTA report of July 1979.

Empirical Approach

The data set used consisted of recordings obtained from sites having local geology generally similar to that of SONGS (i.e., from sites having deep, very stiff sedimentary soils).

FAULTING PROCESSES

Source-Modeling Approach

The earthquake rupture was modeled as a shear crack that spreads from the hypocenter over a specified zone of rupture. Random processes are included in the source modeling to approximate perturbations or irregularities in actual earthquake rupture. The results of repetitious simulations were used in developing the spectra presented in the July 1979 TERA/DELTA report.

Empirical Approach

The data set included records from thrust and strike slip type earthquakes. Most of the records were from the 1971 San Fernando earthquake that occurred on a thrust fault.

MAGNITUDE

Source-Modeling Approach

The seismic moment was selected to yield a magnitude M_S 7, i.e., the hypothesized earthquake has a 130 centimeters of offset over a length of 40 kilometers along the OZD.

Empirical Approach

Question 361.54 directed that the calculated M_S 6 1/2 ground motions be extrapolated to an M_S 7 earthquake. The extrapolation was made in a reasonably conservative manner

to an M_S 7 earthquake as described in the response to Question 361.54.

STRESS DROP

Source-Modeling Approach

The stress drop was extracted from fault offset, fault configuration, and earth structure, and was estimated to be 100 bars. This is conservative when compared to the low stress drop (less than 30 bars) for the 1933 Long Beach earthquake which occurred on the Newport-Inglewood Zone of Deformation comprising the north end of the hypothesized OZD.

Empirical Approach

The stress drop during the 1971 San Fernando earthquake, which strongly influences the data set used for the empirical analysis, is estimated to have been about 200 bars. This value significantly exceeds the stress drop of less than 30 bars estimated for the 1933 Long Beach event. Therefore, stress drop was conservatively incorporated in the analysis.

PROXIMITY

Source-Modeling Approach

The attenuation of ground motions with distance was determined by simulating wave propagation from the rupture surface to the site. Located 8 kilometers from the closest point on the fault, using site specific earth properties.

Empirical Approach

The data used in the analysis were recorded at distances greater than the distances of SONGS from the OZD. The

extrapolation of the results to the design distance is considered conservative. Furthermore, it was shown in the response to Question 361.62 that the definition of distance used in the analysis was conservative.

FOCUSING

Source-Modeling Approach

From the different rupture configurations tested, the extreme configuration that were investigated (focusing) was used in the analysis of instrumental ground motion for the SONGS site.

Empirical Approach

The response to Question 361.56 addressed the focusing effect. It was shown in that response that the strong-motion data used in the empirical analysis were recorded under conditions of focusing that would tend to increase measured ground motions. Therefore, focusing effects were conservatively incorporated in the analysis.

JUDGMENT AND EXPERIENCE

Source-Modeling Approach

The pervasive assumption upon which the earthquake model is based is that much of the scatter in near-field recordings is due to processes that can be adequately modeled deterministically with stochastic perturbations. Particular assumptions or mechanisms used in the model are summarized in Table 361.65-1.

To apply the source-modeling approach, it is necessary to set several parameters, some of which are not well known from crack mechanics. Other than the gross characteristics

of an earthquake rupture (hypocentral locations, rupture extent and static stress drop), the dynamic stress drop is the only parameter that has been calibrated directly from strong-motion data. From studies of past earthquakes it appears that dynamic stress drop (initial slip velocity) is independent of magnitude and fault type, probably because this parameter is related to the fracture strength of earth constituents in the gouge zone of faults. Parameters such as rise time, rupture velocity, and random irregularities are assigned values based on generic knowledge of earthquakes and have been validated by modeling particular earthquake recordings.

Based on test calculations previously done and currently being performed to simulate past recorded earthquakes, the source modeling approach provides a reasonable and rational means for estimating ground motions at the SONGS site, taking into account the specific geologic and tectonic conditions.

Results generated by the earthquake model are expected to be reliable estimates of hypothesized ground motions at the sites because: the model has been calibrated and validated against near-field recordings of earthquakes in the same distance range that is relevant for SONGS; the model provides a rational basis for extrapolating from past earthquakes to hypothesized conditions at SONGS, including site-specific magnitude, distance, and earth structure; the model provides a basis for appraising the likelihood of unusual combinations of fault rupture and waveguide effects that could cause large-amplitude shaking at SONGS; and the model includes several margins of conservatism to guard against underestimating ground shaking at SONGS, as presented in Table 361.65-1.

Empirical Approach

In the WCC June 1979 report, it was shown that the site-specific analysis results were conservative with respect to the results from similar analyses of a larger data set comprised of soil-site recordings. It can also be seen in the WCC June 1979 report (Figures 8 and 9) that the results of the site-specific regression analyses are conservative with respect to the data at the close distances used in that analysis.

In the response to Question 361.55 the results of the June 1979 analysis were compared with the data obtained from the October 15, 1979 Imperial Valley earthquake. It was shown therein that the ground motions predicted from the referenced analysis were conservative with respect to the recordings obtained during the 1979 Imperial Valley earthquake.

361.65-3 Results and Discussion (Q 1, 2, and 3)

The mean response spectra developed from the source modeling and empirical approaches are presented in Figures 361.65-1, -2, -3, and -4 for damping values of 2%, 5%, 7%, and 10%, respectively. As noted in these figures, mean instrumental peak acceleration (Zero Period Acceleration) values from the source-modeling approach is 0.33g and from the empirical approach is 0.47 g.

The response spectra designated "source modeling" in Figures 361.65-1, -2, -3, and -4 are based on the results documented in the July 1979 TERA/DELTA report. The response spectra designated "empirical" in Figures 361.65-1, -2, -3, and -4 are based on the results documented in the WCC June 1979 report and in the response to NRC question 361.54. The June 1979 report documents development of the instrumental response spectrum for M_S 6 1/2 for 2% damping. Development

of the instrumental response spectrum for M_S 7 for 2% damping was done by extrapolating the associated M_S 6 1/2 spectrum using the procedure documented in the response to NRC question 361.54. The procedure described in that response was also applied to M_S 6 1/2 response spectra for dampings of 5%, 7%, and 10% to develop the M_S 7 response spectra shown in Figures 361.65-2, -3, and -4.

As expected from the evaluation of the basic features of the two approaches, the empirically derived response spectra exceed the corresponding source-modeling response spectra over the range of periods considered (0 to 2 seconds). From the nature of their deriviations, the results of both approaches are conservative, with the levels of conservatism varying with period. None of these spectra would, however, represent a design spectrum, which, based on several physical considerations, would lie below the instrumental spectrum.