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AUTH. NAME AUTHOR AFFILIATION
SHIFFER, J. D. Pacific Gas & Electric Co.
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ENCLOSURE

DIABLO CANYON POWER PLANT LONG TERM SEISMIC PROGRAM

QUARTERLY PROGRESS REPORT NO. 8

PACIFIC GAS AND ELECTRIC COMPANY

OCTOBER 1987

1675S/0051K

TABLE OF CONTENTS

1. INTRODUCTION

This is the eighth quarterly progress report for the Diablo Canyon Power Plant (DCPP) Long Term Seismic Program (LTSP). This report describes activities during the period May 1, 1987 through, July 31, 1987.

During this reporting period, Phase III activities continued in all major program elements: Geology/Seismology/Geophysics (G/S/G), Ground Motions/Seismic Hazards, Soil/Structure Interaction (SSI), Fragilities, and Probabilistic Risk Assessment (PRA). The following important meetings and workshops were held during this period:

May 5-8, 1987	NRC/PGandE workshop and field trip on G/S/G San Luis Obispo, CA
May 20-23, 1987	Geological Society of America meeting in Hilo, Hawaii. Several papers pertinent to the LTSP G/S/G program were presented and discussed.
June 3, 1987	NRC/PGandE geophysical audit Santa Barbara, CA
June 9-11, 1987	SSI audit meeting San Francisco, CA
July 2-3, 1987	PGandE LTSP Consulting Board meeting San Francisco, CA
July 15-16, 1987	NRC/PGandE workshop on Ground Motions San Francisco, CA

The following meetings and workshops are being planned during the next several months:

October 12, 1987	PGandE LTSP Consulting Board meeting
November 2-3, 1987	Fragility audit meeting, at NTS Engineering Office in Long Beach, CA
November 4-6, 1987	NRC/PGandE SSI Workshop. San Francisco, CA
Schedule to be determined	PRA audit meeting. Location to be determined.

2. GEOLOGY/SEISMOLOGY/GEOPHYSICS

2.1 Geology and Geophysics

2.1.1 Field Geologic Studies - San Luis-Pismo Synform

Field geologic studies of potential seismic sources within the San Luis-Pismo structural block and along or adjacent to its margins were completed on June 30. Efforts since that time have consisted of analysis and interpretation of field data, and preparation of draft reports. The major geologic studies undertaken during this three-month reporting period were to: (1) assess the onshore extent of the San Luis Bay fault and its effect on the flight of marine terraces; (2) assess and document the capability, geometry, and slip behavior of the Edna and Indian Knob faults; and (3) assess the total length, possible segmentation points, variations in slip rate, and downdip geometry of the Los Osos fault.

2.1.1.1 San Luis Bay Fault

The San Luis Bay fault displaces the stage 5e (120 Ka) marine terrace at the mouth of San Luis Obispo Creek. The displacement is evident in road exposures near Port San Luis, which have been logged in detail. The fault displaces the marine terrace wave cut platform (WCP) between 1 and 4 feet vertically; an additional 8 to 12 feet of fault-related warping of the WCP is also possible. The fault strikes about east-west, dips 20 degrees north near the surface, and becomes steeper (50 degrees) with depth.

An extensive program of field mapping, drilling, and age dating has been conducted to assess whether or not this fault extends to the coastline between Point San Luis and DCPP. Two zones of probable disrupted marine terraces have been identified, one at Rattlesnake Canyon and the other near Deer Canyon. No surface exposure of a fault has been observed at either location. Elsewhere along the coast between Point San Luis and Point Buchon, the marine terrace sequence has not been disrupted. The lowest terrace is a nearly continuous bench at elevation 35 to 40 feet between DCPP and Deer Canyon, at which point it steps down to the southeast.

Age dating results have confirmed the physical correlation of terraces between Point Buchon and Point San Luis. Five U-series dates have been obtained thus far; one additional sample has been submitted, and results are pending. In addition, marine fossils have been collected from five sites for climatic interpretation, and three amino-acid dates have been obtained. Vertebrate fossils, including the first recorded camel and ground sloth in San Luis Obispo County, also have been collected and identified from the lowest marine terrace.

Preliminary interpretation of the terrace sequence suggests that the 100- to 105-foot terrace (5e, 120 Ka) steps down across two offsets to the 40- to 45-foot terrace at Point San Luis. A significant portion of this disruption apparently is due to warping of the terrace. The amount of brittle

displacement is not known but is clearly less than 30 feet, and probably less than 20 feet, at each location during the past 120 Ka.

2.1.1.2 Edna Fault

Mapping and trenching investigations of the Edna fault within the Irish Hills were completed during the reporting period. Several trenches were excavated across the mapped trace of the Edna fault in an alluvial fill terrace of late Quaternary age in See Canyon, on the Avila Ranch. Prominent shears that deformed the young near-surface deposits were encountered in the first trench. Subsequent trenches revealed that these shears were buried landslide features and were not attributable to deep-seated faults of tectonic origin. The preponderance of evidence from bedrock mapping, trenching, offshore geophysical mapping, and Quaternary geomorphic studies strongly suggests that what has been mapped as the Edna fault by Clarence Hall is primarily an unconformity between the Tertiary section and Cretaceous basement rocks that has experienced localized flexural slip. No evidence was found to demonstrate that the Edna fault is a capable seismogenic source.

2.1.1.3 Los Osos Fault

Previous LTSP field investigations and analyses of marine geophysical reflection records concluded that the Los Osos fault is a capable southwest-dipping thrust. During the current reporting period, considerable effort was expended to refine our understanding of the slip characteristics of this fault, to trace it southeastward from the Los Osos Valley, and to document possible segmented behavior along its length. Three trenches dug on the Cuesta Property near Laguna Lake demonstrated that the Los Osos fault consists of two different structural components, shallow southwest-dipping thrusts that break topmost soils and steep northeast-dipping reverse faults that elevated Franciscan basement on the northeast (valley side) over Quaternary alluvial materials tentatively identified as the Paso Robles formation. The reverse faults are considered "back thrusts" that are secondary to and terminated by the main thrust.

A shallow thrust that placed Monterey formation over Paso Robles gravels on the Glick Ranch, a relationship identical to the faulting exposed in the road cuts near the reregulating reservoir at Arroyo Grande Creek, has been tentatively identified as the southeastern extension of the Los Osos fault. Trenches excavated across northeast-facing escarpments at two sites between the Los Osos and Arroyo Grande valleys show no evidence of faulting, indicating that the Los Osos fault is not a continuous structural feature between San Luis Obispo Creek and the town of Edna.

2.1.2 Field Geologic Studies - Pismo Beach to Nipomo Mesa

Field geologic studies were continued in the Pismo Beach and Nipomo Mesa areas. These studies were conducted to evaluate deformation along the southwestern margin of the Pismo-San Luis structural block. Particular structures investigated included the Wilmar Avenue fault, Oceano monocline,

and the hypothesized Santa Maria River fault. Studies included: (1) compilation and analysis of existing water well data; (2) detailed mapping of marine terraces in the Arroyo Grande area; (3) air-photo interpretation along the Wilmar Avenue fault and the Santa Maria River fault trends; and (4) field reconnaissance along the Santa Maria River.

Preliminary results suggest that bedrock beneath the Nipomo Mesa steps down to the southwest across the Oceano monocline and across a previously unidentified northwest trend between the monocline and the Wilmar Avenue fault. The steps in bedrock affect undifferentiated Tertiary clay, sand, and silt commonly containing shell material. These deposits are interpreted to be equivalent to the Pliocene Foxen Canyon, Pismo, or Careaga Formations. The bedrock steps may be the result of faulting and/or warping, stream incision, or marine terrace erosion. Further analysis of oil well and geophysical data is in progress to assess the origin of these bedrock steps.

2.1.3 Offshore Geophysical Investigations

2.1.3.1 Interpretation of High-Resolution Seismic Data

The basic high-resolution interpretive products were rendered for the remaining portion of map D8 and all of maps D1, D2, D3, and D9. This completed the basic suite of D-series work maps covering the region of California coast between Point Conception and Cape San Martin. Interpretations included:

- Shallow structure trends (faults, folds, etc.)
- Isopach of post-Wisconsin (<18,000 years) sediments
- Limits of seafloor outcrops of older (>18,000 years) rock
- Seafloor features including submarine canyons, sags, slumps, ridges, and scarps
- Bathymetry (maps D2-D6 only; bathymetry for maps D1, D7-D9 was taken from published NOAA charts)

Revisions of map sheets D5 and D6 (shallow structures map and post-Wisconsin isopach map) were made to reflect further work with the high-resolution data set and integration with the deeper CDP data sets.

After the basic suite of maps were produced, they were prepared for drafting. Comprehensive symbols were developed and applied to all nine D-series maps. Final drafting of the completed D-series maps began during this reporting period.

2.1.3.2 <u>2- to 5-Second Seismic Program</u>

Interpretation of the LTSP 2- to 5-second suite of common depth point (CDP) seismic data continued with extension of mapping northward to the latitude of Cape San Martin (sheet D8) and southward to Point Arguello (sheet D1). Primary emphasis was placed on completing detailed horizon contour maps on top Miocene and top Sisquoc unconformities. Sheets D9 and D10 were added to the detailed map series in order to provide for geophysical analysis of the northern San Simeon fault and the "Queenie" structure, respectively. This reporting period saw the completion of all D-series maps on basement and top Monterey horizon (with the exception of the top Monterey horizon for map D9).

Considerable effort was expended during this period in coordinating the interpretation of the aforementioned horizon maps with high-resolution structural trend and horizon contour maps. Comparison of the 2- to 5-second CDP maps with maps generated from high-resolution seismic data has significantly refined the interpretation derived from both sources of data. All completed interpretations were digitized and machine contoured as faulted surfaces. The digital representations of the structure maps thus created were then subtracted from one another in an appropriate fashion to create faulted isotime (time thickness) maps for all desired stratigraphic intervals.

Both the isotime and structure horizon maps were then digitally reduced in scale from 1:24,000 to 1:100,000 to produce a suite of R-series (regional) maps for all desired structural horizons and all desired stratigraphic intervals in the case of isotime maps.

2.1.3.3 <u>Processing and Reprocessing of Marine Seismic Data</u>

All reprocessing and processing work was completed during the reporting period with the exception of the Digicon deep crustal lines. These data are planned to be completed during the next reporting period.

2.1.3.4 <u>Offshore Geologic Cross Sections and Well Analysis</u>

Subsurface analysis continued with the completion of five 1:24,000 scale cross sections traversing the eastern margin of the offshore Santa Maria Basin along the reach from Point Sal south to Point Arguello.

2.2 <u>Central Coast Seismic Network</u>

During this reporting period, the previous year's pattern of low seismicity continued, with only one earthquake located within the area covered by the network. The event, of magnitude 2.0, ocurred on July 7, 1987, at 2251 (GMT) and was located about 30 km north-northeast of the DCPP site in the vicinity of the West Huasna fault zone. This is an area of ongoing low-level earthquake activity. The focal depth of the July 7 event was shallow, about 5 km, and the first-motion data indicated a predominantly right-slip focal mechanism.

During this reporting period, installation of the remaining field instrumentation of the Central Coast Seismic Network neared completion. PGandE's Line Construction crew completed the construction of the field instrument vaults. Installation of the new seismometers and data telemetry equipment is progressing and is expected to be completed during the next reporting period.

3. GROUND MOTIONS/SEISMIC HAZARDS

3.1 Empirical Ground Motion Studies

3.1.1 Development of Site-Specific Response Spectra

Preliminary site-specific response spectra were developed by performing statistical analyses on a suite of strong motion records with magnitude and distance in the ranges applicable to the DCPP site.

A set of 36 horizontal components from 18 strong motion records of seven earthquakes with magnitudes greater than 6.25 and distances within 20 km were selected for use in the study. These records were modified to magnitudes, distances, and site conditions similar to those applicable to the DCPP plant site. Statistical analyses have been made on these modified records to obtain response spectra representative of the plant site.

The scaling relationships used for modifying the strong motion records were based on the results of current LTSP regression analyses of empirical ground motion data and on current LTSP numerical modeling studies, as well as on evaluation of available relationships in the literature.

3.1.2 Refinement of Attenuation Relationships

Refined attenuation relationships for horizontal PGA and 5% damped horizontal spectral acceleration were obtained by performing regression analyses on a data set consisting of 157 strong motion records obtained in the distance range within 300 km from 55 shallow focus earthquakes in the magnitude range 4.7 to 7.4. Of these, 65 records in the distance range within 50 km were digitized and processed so that response spectral values were available.

Effects of style of faulting on ground motions were also investigated by using a subset of rock and rock-like site recordings, another subset of soil site recordings, and a combined data set of both rock and soil site recordings. The results from these regression analyses were compared with the site-specific response spectra that were developed directly from statistical analyses of near-source records that were modified to conditions similar to the plant site.

Documentation of the earthquake parameters and site conditions of the recording stations of all records used in the data base was substantially completed during this reporting period.

3.2 Numerical Modeling Program

3.2.1 Documentation of the Ground Motion Simulation Method

Preliminary documentation of the simulation method has been completed. Further studies are continuing on the selection of fault element size, the treatment of heterogeneities in the faulting process, the selection and correction of empirical source functions, and the appropriateness of calculated Green's functions.

3.2.2 Assessment of the Spectral Character of Empirical Source Functions

Records of the 1979 Imperial Valley aftershock and of the 1983 Coalinga aftershock have been used for empirical source functions. Studies were done to demonstrate the compatibility of these records for use at the DCPP site. The results indicate that the spectral content is very similar in the two sets of aftershock records. Furthermore, the spectral levels and shapes of both data sets are consistent with available strong motion records at the DCPP site from earthquakes having similar magnitudes.

3.2.3 Documentation of Ground Motion Input Data for Fragility and Soil/Structure Interaction Analyses

Preliminary documentation has been completed for the following: the regional crustal structure model; the calibration of Green's functions; the generation of a suite of 120 time-histories at the site representing a broad range of fault models; the selection of a representative sample of 14 of these time-histories for input into the fragility analysis; and a description of the wave composition, orientation, and spatial coherence of ground motions for input into the SSI analysis.

3.2.4 Estimation of Spatial Incoherence of Ground Motions

A procedure for estimating spatial incoherence of ground motions at the DCPP site has been developed and validated by using the differential array data of the 1979 Imperial Valley earthquake. In this procedure, site records of explosions and small earthquakes are used to provide an estimate of the incoherence due to wave propagation and local site effects. Simulations for a large earthquake at the site are used to provide an estimate of the incoherence due to source finiteness and wave passage. The combined incoherence model is obtained by multiplying these two contributions. This procedure has been validated by showing that the incoherence measured from records of an aftershock of the 1979 Imperial Valley earthquake, when combined with the incoherence measured from simulations of the mainshock, gives an incoherence model that closely matches the observed incoherence from actual mainshock records.

A spatial incoherence model for the DCPP site has been developed and provided to the SSI analysis.

3.2.5 Study of the Sensitivity of Ground Motions

The ground motion simulation method has been applied to study the sensitivity of ground motions to a range of source parameters. These include the closest distance to the fault, depth range of faulting, faulting mechanism, fault element size, and degree of randomness of rupture velocity and rise time.

3.3 NRC/PGandE Workshop on Ground Motions

This workshop was held in San Francisco on July 15 and 16, 1987. Participants in the workshop included the NRC Staff and its consultants, Pacific Gas and Electric Company (PGandE) staff and its consultants, consultants to the Advisory Committee on Reactor Safeguards, and representatives from the California Division of Mines and Geology.

PGandE presentations at the workshop included a summary of the status of the Diablo Canyon LTSP and reports on the progress in seismic source characterization studies, empirical ground motion studies, ground motion modeling studies, and assessment of spatial incoherence of ground motions. A summary of the ground motion data provided for use in the fragility and SSI analyses was also given. NRC consultant Dr. Kenneth W. Campbell, U. S. Geological Survey, presented preliminary results from his independent work on empirical near-source attenuation relationships.

3.4 Seismic Hazards Analysis

Updating of logic trees to incorporate recent G/S/G data is presently scheduled during the next reporting period.

4. SOIL/STRUCTURE INTERACTION

4.1 Development of Building Models

The final configurations of 3-D SSI models of the containment structure, auxiliary building, and turbine building have been developed.

4.2 Parametric Studies

Additional parametric studies were performed to examine the variations of SSI response due to different ground motion time-history inputs and due to different ground motion spatial incoherence characterization models. The results of parametric studies for different ground motion time-history inputs show that the SSI responses from different time-histories are very consistent with each other as long as these time-histories are modified to match the common ground response spectra. Based on these results, it was concluded that at most two sets of time-history input would be adequate for SSI response analyses.

4.3 SSI Analyses for Input to Fragility Analysis

SSI response analyses using two sets of three-component recorded acceleration time-histories modified to fit the median site-specific earthquake spectra were carried out for the horizontal responses of the containment and the auxiliary building. The analyses for the horizontal responses of the turbine building are still underway.

4.4 SSI Analyses for Ground Motion Spatial Incoherence

The development of the SSI analysis procedure and the associated computer programs for analyzing SSI responses with spatially incoherent ground motion inputs was completed. The procedure and the system of computer programs (SIGMAS) developed were benchmarked successfully against the results published by Luco and Wong, and Luco and Mita. The SIGMAS has been used in performing SSI parametric studies to examine the suitability of incoherence ground motion characterization models.

4.5 Containment Uplift

The modification of the nonlinear uplift response analysis computer program UPLIFT to incorporate the embedment effect was completed. Efforts are currently being made to complete the documentation of this program.

4.6 NRC Audit

The NRC Staff and its consultants conducted an engineering audit of the LTSP SSI on June 9-11, 1987, at the Bechtel offices in San Francisco. The subject of the audit was the LTSP implementation and documentation of the CLASSI and SASSI Computer programs which are being used for the LTSP-SSI calculation.

5. FRAGILITIES

Based upon the results of Phase IIIA PRA studies, the plant components that contribute most to the seismic risk of the plant are being identified. The fragilities of these components will be reevaluated and upgraded, as appropriate, in Phase IIIB.

The Phase IIIB fragility effort will also include updating of the response calculations of all the essential plant components that appear in the PRA seismic model. To develop the necessary input to the fragility analyses, a study is being performed to generate the median floor response spectra with their associated variabilities at several locations in the auxiliary building. The study involves development of random variables including structural damping, structural frequency, and soil variabilities. Independent random distributions of these variables are developed using Latin hypercube simulation with a population of 24 empirically generated and 14 numerically generated site-specific time-history motions.

6. PROBABILISTIC RISK ASSESSMENT

Phase IIIA work on the PRA is being completed by PGandE. PGandE's review of this work is in progress. A package that included electric power systems and mechanical support systems analyses was submitted to the NRC in response to the NRC's request.

PACIFIC GAS AND ELECTRIC COMPANY

PGandE + 77 BEALE STREET • SAN FRANCISCO, CALIFORNIA 94106 • (415) 781-4211 • TWX 910-372-6587

JAMES D. SHIFFER
VICE PRESIDENT
NUCLEAR POWER GENERATION

October 9, 1987

PGandE Letter.No.: DCL-87-246

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
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Re: Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82
Diablo Canyon Units 1 and 2
Long Term Seismic Program - Quarterly Progress Report No. 8
(NRC RIDS Distribution Code D031)

Gentlemen:

In compliance with License Condition 2.C.(7) of Facility Operating License DPR-80, enclosed is the Long Term Seismic Program Quarterly Progress Report No. 8 for work performed from May 1 through July 31, 1987. Copies of the progress report are also being forwarded to NRC Staff consultants and to the ACRS Staff.

Kindly acknowledge receipt of this material on the enclosed copy of this letter and return it in the enclosed addressed envelope.

Sincerely,

J D Shiffer

Enclosure

cc: E. G. Igne, ACRS (25)
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Santa Barbara, CA 93016

Mr. Don Bernreuter
Lawrence Livermore Laboratory
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Livermore, CA 94550

Dr. Robert D. Brown, Jr.
U.S. Geological Service
345 Middlefield Road
Building 8, #977
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Dr. C. J. Costantino
4 Rockingham Road
Spring Valley, NY 10977

Dr. James Davis, State Geologist
CA Division of Mines and Geology
1416 Ninth Street, Room 1351
Sacramento, CA 95814

Dr. Stephen M. Day
S-Cubed
P. O. Box 1620
La Jolla, CA 92038

Dr. George Gazetas
JEC 4049
Rensselaer Polytechnic Inst.
Troy, NY 12180-3590

Dr. David Perkins (2)
U.S. Geological Survey
Denver Federal Center
P. O. Box 25046, Mail Stop 966
Denver, CO 80225

Dr. Morris Reich
Structural Analysis Division
Building 129
Brookhaven National Laboratory
Upton, NY 11973

Dr. Jean B. Savy
Lawrence Livermore Laboratory
P. O. Box 808
Mail Stop L-196
Livermore, CA 94550

Dr. David B. Slemmons
2995 Golden Valley Road
Reno, NV 89506

Dr. A. S. Veletsos
5211 Paisley Avenue
Houston, TX 77096

Dr. Robert V. Whitman
Room 1-342
Mass. Inst. of Technology
Cambridge, MA 02139

Dr. Kenneth W. Campbell
U.S. Geological Survey
Denver Federal Center
P. O. Box 25046 Mail Stop 966
Denver, CO 80225

Dr. R. Fitzpatrick (3)
Brookhaven National Laboratory
Bldg. 130, 32 Lewis Avenue
Upton, NY 11973

Dr. Michel Bohn
6412
P. O. Box 5800
Albuqurque, NM 87185