August 20, 1985

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

Dear Mr. Baskin:

SUBJECT: SEP TOPIC II-4.F SETTLEMENT OF STRUCTURES AND BURIED EQUIPMENT-SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1

Enclosed is the staff's final safety evaluation report on SEP Topic II-4.F, which relates specifically to the review of backfill soil conditions. Other evaluations on this topic were issued to you on December 1, 1982 and November 13, 1984.

As discussed in the safety evaluation report (Enclosure 1), the staff concludes that geotechnical input parameters used for the soil and foundation analyses are appropriate for the cases being studied. The same geotechnical acceptance criteria should be used for the analyses of equipment founded on backfill soil being performed under the long-term service seismic reevaluation program.

Enclosure 2 to this letter is the technical evaluation, prepared by the Army Corps of Engineers for the NRC, which was used by the staff to complete its review.

Sincerely,

John A. Zwolinski, Chief
Operating Reactors Branch #5
Division of Licensing

Enclosures:
As Stated

cc w/encl:
See Next Page

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08/16/85	08/16/85	08/16/85	08/19/85

Needs add'l distribution.

Mr. Kenneth P. Baskin
Southern California Edison Company

San Onofre Nuclear Generating Station
Unit No. 1

cc

Charles R. Kocher, Assistant
General Counsel
James Beoletto, Esquire
Southern California Edison Company
Post Office Box 800
Rosemead, California 91770

David R. Pigott
Orrick, Herrington & Sutcliffe
600 Montgomery Street
San Francisco, California 94111

Dr. Lou Bernath
San Diego Gas & Electric Company
P. O. Box 1831
San Diego, California 92112

Resident Inspector/San Onofre NPS
c/o U.S. NRC
P. O. Box 4329
San Clemente, California 92672

Mayor
City of San Clemente
San Clemente, California 92672

Chairman
Board of Supervisors
County of San Diego
San Diego, California 92101

Director
Energy Facilities Siting Division
Energy Resources Conservation &
Development Commission
1516 - 9th Street
Sacramento, California 95814

Regional Administrator, Region V
U.S. Nuclear Regulatory Commission
1450 Maria Lane
Walnut Creek, California 94596

Joseph O. Ward, Chief
Radiological Health Branch
State Department of Health
Services
714 P Street, Office Bldg. 8
Sacramento, California 95814

Mr. Hans Kaspar, Executive Director
Marine Review Committee, Inc.
531 Encinitas Boulevard, Suite 105
Encinitas, California 92024

Enclosure 1

SYSTEMATIC EVALUATION PROGRAM
SAN ONOFRE GENERATING STATION, UNIT 1
Docket No. 50-206

TOPIC II-4.F Settlement of Structures and Buried Equipment

I. INTRODUCTION

Topic II-4.F pertains to the geotechnical engineering review of the properties and stability of subsurface materials and foundations as they influence the static and seismically induced settlement of the plant's critical structures and buried equipment.

II. REVIEW CRITERIA

This topic was reviewed using the following criteria:

A. 10 CFR Part 50, Appendix A

1. General Design Criterion (GDC)1: "Quality Standards and Records." This criterion requires that structures, systems and components important to safety be designed, fabricated erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety be maintained by or under the control of the licensee throughout the life of the plant.

2. GDC 2: "Design Bases for Protection Against Natural Phenomena." This criterion requires that safety-related protions of the system be design to withstand the effects of earthquakes, tornados, hurricanes, floods, tsunami, and seiches without losing the capability to perform their safety functions.

B. 10 CFR Part 100, Appendix A

"Seismic and Geologic Siting Criteria for Nuclear Power Plants". These criteria describe the investigations required to obtain the geologic and seismic data needed to determine site suitability and identify the geologic and seismic factors that must be taken into account in the siting and design of nuclear power plants.

III. RELATED SAFETY TOPICS AND INTERFACES

The geotechnical engineering aspects of slope stability are reviewed under Topic II-4.D. Other topics that interface with II-4.F include:

II-3.B.	Flooding Potential and Protective Requirements
II-3.C	Safety-Related Water Supply (Ultimate Heat Sink)
II-4.E	Dam Integrity
III-3.A	Effects of High Water Level on Structures
III-3.C	In-Service Inspection of Water Control Structures
III-6	Seismic Design Considerations
IX-3	Station Service and Cooling Water Systems
XVI	Technical Specifications

IV. REVIEW GUIDELINES

In general, the review was conducted in accordance with Section 2.5.4 of the NRC Standard Review Plan (NUREG-0800 July, 1981). The geotechnical engineering aspects of the design and as-constructed conditions were reviewed and compared to current criteria, and the safety significance of any differences was evaluated.

The following NRC Regulatory Guides (RG) were used in the review.

A. RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants." This guide describes geotechnical engineering site investigations programs that would normally meet the needs for evaluating the safety of sites from the standpoint of how the foundation and earthworks would comply with 10 CFR 100 and CFR 100, Appendix A under anticipated loading conditions, including earthquakes. RG 1.132 provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, for the spacing and depth of borings, and for sampling.

B. RG 1.138, "Laboratory Investigation of Soils for Engineering Analysis and Design of Nuclear Power Plants." This guide describes laboratory investigations and testing practices acceptable for determining the soil and rock properties and characteristics that are needed for the engineering analysis and design of nuclear power plant foundations and earthworks so they will comply with 10 CFR 100, and 10 CFR 100, Appendix A.

V. EVALUATION

A. Site Description

The SONGS 1 site is located on the California coast about 51 miles north of San Diego and 62 miles south of Los Angeles. The plant site is on the shoreline and cuts into a seacliff bluff with a finished plant grade elevation of +20 feet MLLW. The original site elevation ranged from +80 to +115 feet. The topographic features of the immediate coastal area include a narrow band of beach sand terminating at seacliffs about 60 to 80 feet high in the vicinity of the site. A gentle rolling coastal plain extends inland to the western foothills of the Santa Margarita Mountain Range about one and one-half miles to the east. The plant is operated by the Southern California Edison Company (SCEC).

B. In-Situ Material

The in-situ foundation material at the site is a Pliocene age sand named the San Mateo Formation. The formation is between 500 and 1000 feet thick at the site. At grade, the formation is a very dense, poorly cemented, well graded, fine to coarse sand that will easily stand on vertical cuts. Original foundation exploration performed in 1962 included 14 test holes in which undisturbed soil samples were obtained as well as standard penetration tests (SPT). Laboratory testing included specific gravity, natural moisture content, unit weight, particle size analysis, minimum and maximum density, relative density, consolidation and direct shear. Density tests indicated that the in-situ San Mateo sands are at or near the maximum density possible. This was confirmed by the consistently high SPT blow counts which generally met refusal (50 blows in 3 inches or less). Considerable additional field exploratory sampling and laboratory testing, including dynamic strength testing, was performed in 1972 and 1974 and they too confirm the strength and density of the San Mateo Formation.

C. Backfill Material

Backfill used at the SONGS-1 site was exclusively sand from the San Mateo Formation. The material classifies as a well graded sand (SW) under the Unified Soil Classification System. The specifications for the original construction required the backfill to be compacted to 95 percent Modified Proctor density and all original record control tests performed in 1964 and 1965 confirmed compliance with the requirements. All previous safety assessments were based on the assumption of a dense backfill. Not until 1982 during excavation for new construction was it discovered that backfill compacted to less that 95% existed. From a total of 84 density tests taken in the undercompacted backfill, 47 (56 percent), 29 (34 percent) and 8 (10 percent) were below 95, 90, and 85 percent, relative compaction respectively.

The SCEC determined the areal extent and condition of loose backfills using the following steps: (1) define backfill areas; (2) define degree of compaction in each area; and (3) assign an appropriate category to the backfill in each area. The areas where backfill existed was determined based on an interpretation of numerous construction photographs, discussions with construction personnel, and field observations made during subsequent construction. Using the above considerations a site plan was developed showing the areal extent of the backfill. The degree of compaction in the backfill was determined based on results of all available field tests made during original and subsequent construction. The field density tests performed in test pits and excavations made after discovery of low density backfill were supplemented by probing with a 3/8 inch diameter steel pole. The final step in the SCEC determination of the areal extent and conditions of loose backfill was to assign an appropriate category to the backfill in each area. In addition to the above described test results, the configuration of the backfill in the excavations was also considered with regard to the amount of working space and the type of compaction equipment observed in construction photographs. The categories were defined as follows: Category A, well compacted with a minimum relative compaction of 95 percent; Category B, moderate to well compacted with relative compaction of 90 to 95 percent; Category C, moderately compacted with relative compaction of 85 percent.

Based on our review of the available information, we concur with the licensee's assessment as to the areal extent of the backfill. The San Mateo sand is the type of material that will compact quite easily with minimal compactive effort and the procedures used by SCEC to assign density categories to different areas should provide a conservative estimate of density.

D. Liquefaction Evaluation

The liquefaction potential and dynamic behavior of backfill soils which will be saturated and potentially subjected to seismic loading was assessed using state-of-the-art procedures that account for density, aging, fill geometry, ratio of vertical to horizontal earth pressure, and confining pressure. We concur with the procedures and judgements used for this assessment. A brief description of the SCEC procedures and results is presented in the following paragraphs.

The method used for the liquefaction assessment compared the dynamic strength of the backfill material, as determined with laboratory cyclic triaxial tests, to the average induced shear stress from a magnitude 7 earthquake at 8 kilometers from the site. The seismically induced shear stresses were determined by analyzing the response of a one-dimensional model of the SONGS site using the program SHAKE by Schnabel and Lysmer (1972). Although the studies showed that most of the backfill material not meeting the density requirements will liquefy during the design earthquake, no mass movement of soil will occur because the surface slope is flat and all backfill is confined to limited areas by structures or undisturbed San Mateo sand. Liquefaction is therefore defined as the potential for the development of pore water pressures with limited strain potential.

The results of the liquefaction studies were quantified in terms of factor of safety against liquefaction and pore pressure ratio for the various compaction categories and locations. The safety factor against liquefaction is determined by dividing the laboratory dynamic strength by the shear stress induced by the design earthquake; and the pore pressure ratio is determined by dividing the seismically induced pore water pressure by the initial effective confining pressure. Specific results showed that liquefaction and/or high pore pressure ratios were possible in any backfill that failed to meet the density requirements. Since no mass movement of the fill material can occur, the effect of inadequately compacted backfill on the safety related structures would be limited to (1) changes in the dynamic shear modulus and damping values used to evaluate the response of the various structures in or on the under compacted backfill; (2) settlements due to earthquake loading; and (3) possible bearing capacity failures due to loss of backfill strength during liquefaction. These effects are discussed in the following paragraphs.

1. Variation of dynamic shear modulus and damping

   The shear modulus vs. strain and damping vs. strain relationships for the in-situ San Mateo sand and well compacted backfill were determined based on laboratory cyclic triaxial tests and on geophysical measurements. The results of these studies were reported in the SONGS 2 and 3 PSAR. The effect of the loose backfill on the modulus and damping values were developed based on the shape of the strain curves published by Seed and Idriss (1970). These curves are based on results of more than a dozen studies by a number of investigators using different laboratory testing procedures. We agree that the relationships developed in these studies provide an appropriate means to determine the effect of density on the shear modulus and damping values for the compacted backfill.

2. Settlement evaluation

   Seismically induced settlements of backfill above and below the water table were estimated using the procedures suggested by Silver and Seed (1972) and Lee and Albaisa (1974) respectively. Settlement was estimated individually at each location where safety related structures or buried equipment rested over or in backfill. The density, induced pore water pressure ratio, and induced shear strain for each fill zone were determined as described in the preceding paragraphs. These values were used along with the relationships presented in the above referenced papers to calculate the settlement at each location. We concur with the procedures used to estimate the settlement and agree with the results of the settlement study. The procedures and judgements used by the licensee in this study are appropriately conservative and should account for uncertainty in subsurface conditions.

3. Foundation evaluation

SCEC addressed the probable effect that deviations from past assumed backfill properties have on the safety related structures and buried equipment. They did this by performing soil-structure interaction analyses considering the changed foundation properties previously discussed. The structures affected by the loose fill were individually analyzed using appropriate support characteristics for each case. For structures without loose backfill, a re-evaluation was not required. Thirty-six separate items consisting of structural foundations, equipment foundations, and structural components were originally located on or in backfill and have been addressed by SCEC. The status of each assessment is listed in Tables 1 and 2.

All foundations with a potential for bearing capacity failures due to loss of soil shear strength during liquefaction have been shown to be safe by assuming total loss of support under the portion of the foundation where liquefaction could occur. In same cases, the structure or equipment foundation was modified to span the loose backfill and derive support from adjacent stable foundations. In other cases, adequate performance of the backfill support material was demonstrated.

A few foundation assessments will be conducted by SCEC as a part of their ongoing review and analysis program; a subsequent SCEC report that includes those items is expected. Our review of the SCEC assessments is limited to evaluating the geotechnical parameters. We find that these parameters conservatively cover the range of probable engineering behavior.

E. Conclusion

Based on a review of the documents listed in Table 3 we concur with the judgements, procedures and results of the geotechnical assessment performed by the licensee. We also agree that the geotechnical input parameters used for the soil and foundation analyses are appropriate for the cases studied. The studies, analyses and modifications that have been completed show no resultant safety problems due to the presence of loose backfill. SCEC's continuing assessment should be required to meet the same geotechnical acceptance criteria as used for the completed work reviewed and evaluated in this report.

REFERENCES

1. Lee, K. L., and Albaisa, A., (1974), "Earthquake Induced Settlements in Saturated Sands", Journal of the Geotechnical Engineering Division, ASCE, v. 100, no. GT4, April.

2. Silver, M.L., and Seed, H.B., (1972) "Settlement of Dry Sands During Earthquakes", Journal of the Soil Mechanics and Foundation Division, ASCE, v. 98, no. SM4, April.

3. Schnabel, P. and Lysmer, J. (1972), SHAKE - a computer program for earthquake and response analysis of horizontally layered sites, Earthquake Engineering Research Center, University of California, Berkeley, Report EERC-72-12.

4. Seed, H.B. and Idriss, I.M. (1970) "Soil Moduli and Damping Factors for Dynaminc Response Analysis", Report No. EERC 70-10, Earthquake Engineering Research Center, University of California; Berkeley, California

TABLE 1

STATUS OF STRUCTURAL FOUNDATION EVALUATION
(SOURCE - SCEC, FEBRUARY, 1985)

NO.	STRUCTURE	STATUS
1	Containment Structure and Sphere Enclosure Building	Founded on native soil. Reevaluation not required
2A	Turbine Building	Founded either on native soil or footings modified to span backfill.
2B	Turbine Generator Pedestal	Founded on native soil. Reevaluation not required.
3	Ventilation Equipment Building	Partially founded on backfill. Evaluation meets acceptance criteria
4	Reactor Auxiliary Building	Founded on native soil. Evaluation meets acceptance criteria
5	Circulating Water System Intake Structure	Founded on native soil. Evaluation meets acceptance criteria.
6	Control Building	Generally founded on native soil. Very few footings partially founded on shallow backfill. Evaluation meets acceptance criteria.
7	Seawall	Generally founded on native soil. Evaluation meets acceptance criteria.
8	Diesel Generator Building	Founded on native soil. Reevaluation not required.
9	Fuel Storage Building	Founded on native soil. Evaluation meets acceptance criteria.

TABLE 2

STATUS OF EQUIPMENT FOUNDATIONS AND STRUCTURAL COMPONENTS EVALUATION
(SOURCE - SCEC, FEBRUARY, 1985)

Item No.	Description	Status
1	Auxiliary feedwater pumps	Modified foundation to span backfill.
2	Auxiliary Feedwater pumps	Modified foundation to span backfill.
3	E-W Duct Bank, East of intake structure	Evaluated to span backfill, meets acceptance criteria.
4	Air Compressor	Not part of seismic reevaluation program.
5	Air Receivers	Not part of seismic reevaluation program.
6	Duct Bank to North Tsunami Gate	Not Part of seismic reevaluation program.
7	Motor Control #3	Part of long term seismic evaluation program.
8	Conduit Duct Bank	Evaluated to span backfill.
9	Turbine coolers	Evaluated for the in-situ soil condition, meets acceptance criteria.
10	Intake Culverts	Evaluated to span backfill, meets acceptance criteria.
11	Spent Fuel Pit Pump	Not part of seismic reevaluation program.
12	Refueling Water Pump	Part of long term seismic evaluation program.
13	Pipe Tunnel	Evaluated to span backfill, meets acceptance criteria.
14	480V Switchgear Room	Modified foundation to span backfill.

TABLE 2 (CONT)

Item No.	Description	Status
15	Column Footing for piping supports	Modified foundation to span backfill
16	Column Footing for supports	Modified foundation to span backfill.
17	Column Footing for Piping Supports	Founded on Native Soil. Reevaluation not Required.
18	Column Footing for Piping Supports	Founded on native soil. Reevaluation not required.
19	Column Footing for Piping Supports	Founded on native soil. Reevaluation not required.
20	Column Footing for Piping Supports	Part of long term seismic evaluation program.
21	Column Footing for Piping Supports	Part of long term seismic evaluation program.
22	N-S Duct Bank, East of intake structure	Evaluated to span backfill, meets acceptance criteria.
23	Refueling Water Storage Tank	Part of long term seismic evaluation program.
24	Auxiliary Feedwater piping trench	Designed to span backfill.
25	Auxiliary Feedwater tank	Founded on native soil.
26	Salt Water Cooling Line	Part of long term seismic evaluation program.
27	Refueling Water filter pump and Refueling Water Filter	Part of long term seismic evaluation program.

TABLE 3

DOCUMENTS REVIEWED

Date	Doucument Title
August 17, 1982	Soil Backfill Conditions Report
October 18, 1982	NRC Evaluation
October 21, 1982	Meeting with NRC
December 1, 1982	NRC Draft Topic Evaluation
April 18, 1983	SCEC Topic Evaluation and Chapter 1 to 3 of Revised Soil Backfill Conditions Report
September 1, 1983	Chapters 4, 5, Addendum 1, and Appendices A to F of Revised Soil Backfill Conditions Report
September 20, 1983	Crack Mapping report and Addendum 3 of Revised Soil Backfill Conditions Report
November 28, 1983	Addendum 3 of Revised Soil Backfill Conditions Report
May 17, 1984	Additional Information

SYSTEMATIC EVALUATION PROGRAM TOPIC II- 4.F: SETTLEMENT OF STRUCTURES AND BURIED EQUIPMENT SAN ONOFRE NUCLEAR GENERATING STATION, UNIT 1

GEOTECHNICAL EVALUATION REPORT

Synopsis. A geotechnical engineering case review of the soil backfill conditions at San Onofre Nuclear Generating Station, Unit 1, was performed by the Tulsa District Corps of Engineers. In April, 1982, Southern California Edison Company (SCEC) notified the Nuclear Regulatory Commission that soil backfill conditions encountered during excavation activities associated with new construction were not consistent with prior soil backfill property assumptions. A detailed assessment of the effect of any deviation from past assumed backfill properties on the seismic response of safety related structures and equipment was performed under the management of SCEC. Based on a review of this work, the Corps has concluded that the studies performed by the licensee are adequate to appropriately define the in-situ soil backfill properties and to conservatively estimate the seismically induced settlements that may occur during and after the design earthquake. All structures in or on backfill were evaluated by performing soil structure interaction analyses using appropriate properties for the soil backfill. These structures either met acceptance criteria or were modified so that their support spanned the unsuitable backfill. The results of all studies that have been completed show no safety problems due to the effects of deviations from past assumed backfill properties.

Introduction. This report presents the results of the Corps of Engineers' Geotechnical review of various documents describing the foundation conditions relating to the backfill used at the San Onofre Nuclear Generating Station, Unit 1 (SONGS 1) and the ability of the backfill to support safety related structures and buried equipment during and after the design earthquake. Enclosure 1 is a complete list of documents provided the Corps of Engineers for review. The documents are part of the geotechnical assessment required under Topic II-4.F of the Systematic Evaluation Program (SEP) of the Nuclear Regulatory Commission (NRC). The assessment was performed under the management of the licensee, Southern California Edison Company (SCEC). The following paragraphs provide a summary of the SCEC's geotechnical assessment along with the Corps of Engineers' (COE) comments and evaluation.

Site Description.

General. The SONGS 1 site is located on the California coast about 51 miles north of San Diego and 62 miles south of Los Angeles. The plant site is on the shoreline and cuts into a seacliff bluff with a finished plant grade elevation of +20 feet. The original site elevation ranged from +80 to +115 feet. The topographic features of the immediate coastal area include a narrow band of beach sand terminating at seacliffs about 60 to 80 feet high in the vicinity of the site. A gentle rolling coastal plain extends inland to the western foothills of the Santa Margarita Mountain Range about one and one-half miles to the east.

In-Situ Material. The in-situ foundation material at the site is a Pliocene age sand named the San Mateo Formation. The formation is between 500 and 1000 feet thick at the site. At grade, the formation is a very dense, poorly cemented, well graded, fine to coarse sand that will easily stand on vertical cuts. Original foundation exploration performed in 1962 included 14 test holes in which undisturbed soil samples were obtained as well as standard penetration tests (SPT). Laboratory testing included specific gravity, natural moisture content, unit weight, particle size analysis, minimum and maximum density, relative density, consolidation and direct shear. Density tests indicated that the in-situ San Mateo sands are at or near the maximum density possible. This was confirmed by the consistently high SPT blow counts which generally met refusal (50 blows in 3 inches or less). Considerable additional field exploratory sampling and laboratory testing, including dynamic strength testing, was performed in 1972 and 1974 and they too confirm the strength and density of the San Mateo Formation. These field explorations and the laboratory testing to define the engineering properties of the in-situ foundation sands has been previously reported to the NRC for their licensing needs and was not a part of this Corps of Engineers review.

Backfill Material. Backfill used at the SONGS-1 site was exclusively sand from the San Mateo Formation. The material classifies as a well graded sand (SW) under the Unified Soil Classification System. The specifications for the original construction required the backfill to be compacted to 95 percent modified proctor density and all original record control tests performed in 1964 and 1965 confirmed compliance with the requirements. All previous safety assessments were based on the assumption of a dense backfill. Not until 1982 during excavation for new construction was it discovered that backfill compacted to less than 95% existed. From a total of 84 density tests taken in the undercompacted backfill, 47(56 percent), 29 (34 percent) and 8 (10 percent) were below 95, 90, and 85 percent, relative compaction respectively.

Areal Extent of Loose Backfills. The SCEC determined the areal extent and condition of loose backfills using the following steps: (1) define backfill areas; (2) define degree of compaction in each area; and (3) assign an appropriate category to the backfill in each area.

The areas where backfill existed was determined based on an interpretation of numerous construction photographs, discussions with construction personnel, and field observations made during subsequent construction. Using the above considerations a site plan was developed showing the areal extent of the backfill. The degree of compaction in the backfill was determined based on results of all available field tests made during original and subsequent construction. The field density tests performed in test pits and excavations made after discovery of low density backfill were supplemented by probing with a 3/8 inch diameter steel pole.

The final step in the SCEC determination of the areal extent and conditions of loose backfill was to assign an appropriate category to the backfill in each area. In addition to the above described test results, the configuration of the backfill in the excavations was also considered with regard to the amount of working space and the type of compaction equipment observed in construction photographs. The categories were defined as follows: Category A, well compacted with a minimum relative compaction of 95 percent, Category B, moderate to well compacted with relative compaction of 90 to 95 percent; Category C, moderately compacted with relative compaction of 85 percent. Based on a review of the available information, the COE concurs with the licensee's assessment as to the areal extent of the backfill. The San Mateo sand is the type of material that will compact quite easily with minimal compactive effort and the procedures used by SCEC to assign density categories to different areas should provide a conservative estimate of density.

<u>Liquefaction Evaluation</u>. The liquefaction potential and dynamic behavior of backfill soils which will be saturated and potentially subjected to seismic loading was assessed using state-of-the-art procedures that account for density, aging, fill geometry, ratio of vertical to horizontal earth pressure, and confining pressure. The COE concurs with the procedures and judgements used for this assessment. A brief description of the procedures and results is presented in the following paragraphs.

The method used for the liquefaction assessment compared the dynamic strength of the backfill material as determined with laboratory cyclic triaxial tests to the average induced shear stress from a magnitude 7 earthquake at 8 kilometers from the site. The seismically induced shear stresses were determined by analyzing the response of a one-dimensional model of the SONGS site using the program SHAKE by Schnabel and Lysmer (1972). Although the studies showed that most of the backfill material not meeting the density requirements will liquefy during the design earthquake, no mass movement of soil will occur because the surface slope is flat and all backfill is confined to limited areas by structures of undisturbed San Mateo sands. Liquefaction is therefore defined as the potential for the development of pore water pressures with limited strain potential.

The results of the liquefaction studies were quantified in terms of factor of safety against liquefaction and pore pressure ratio for the various compaction categories and locations at the site. The safety factor against liquefaction is determined by dividing the laboratory dynamic strength by the shear stress induced by the design earthquake; and the pore pressure ratio is determined by dividing the seismically induced pore water pressure by the initial effective confining pressure. Specific results showed that liquefaction and/or high pore pressure ratios were possible in any backfill that failed to meet the density requirements. Since no mass movement of the fill material can occur, the effect of inadequately compacted backfill on the safety related structures would be limited to: (1) changes in the dynamic shear modulus and damping values used to evaluate the response of of the various structures in or on the under compacted backfill; (2) settlements due to earthquake loading; and (3) possible bearing capacity failures due to loss of backfill strength during liquefaction.

Variation of Dynamic Shear Modulus and Damping. The shear modulus-vs.-strain and damping-vs.-strain relationships for the in-situ San Mateo sand and well compacted backfill were determined based on laboratory cyclic triaxial tests and on geophysical measurements. The results of these studies were reported in the SONGS 2 and 3 PSAR and are not part of this review. The effect of the loose backfill on the modulus and damping values were developed based on the shape of the strain curves published by Seed and Idriss (1970). These curves are based on results of more than a dozen studies by a number of investigators using different laboratory testing procedures. The Corps of Engineers concurs that the relationships developed in these studies provide an appropriate means to determine the effect of density on the shear modulus and damping values for the compacted backfill.

Settlement Evaluation. Seismically induced settlements of backfill above and below the water table were estimated using the procedures suggested by Silver and Seed (1972) and Lee and Albaisa (1974) respectively. Settlement was estimated individually at each location where safety related structures or buried equipment rested over or in backfill. The density, induced pore water pressure ratio, and induced shear strain for each fill zone were determined as described in the preceding paragraphs. These values were used along with the relationships presented in the above referenced papers to calculate the settlement at each location. The Corps of Engineers concurs with the procedures used to estimate the settlements and agrees with the results of the settlement study. The procedures and judgements used by the licensee in this study are appropriately conservative and should account for uncertainty in subsurface conditions.

Foundation Evaluation. Assessment of the probable affect that deviations from past assumed backfill properties have on the safety related structures and buried equipment was made by SCEC by performing soil structure interaction analyses considering all of the factors previously discussed. The affected structures were evaluated by an assessment of changes in the dynamic characteristics due to less dense backfill. For structures without associated backfill, this re-evaluation was not required. Thirty-six separate items consisting of structural foundations, equipment foundations, and structural components were evaluated and the status of each evaluation is listed in Tables 1 and 2 (enclosure 2). In each case that has been resolved, the structure and/or equipment either met acceptance criteria or was modified to span the backfill. All foundations with a potential for bearing capacity failures due to loss of strength during liquefaction were shown to be safe with a total loss of support under the portion of the foundation where liquefaction could take place. Those items not resolved at this time are still being evaluated and will be addressed in a later report. The COE review of the structural assessment was limited to evaluating the geotechnical input. This input conservatively covers the range of probable values.

Conclusion. Based on a review of the documents listed in enclosure 1, the COE concurs with the judgements, procedures and results of the geotechnical assessment performed by the licensee. We also agree that the geotechnical input parameters used for the soil structure interaction analyses are appropriate for the cases studied. The studies, analyses and modifications that have been completed show no resultant safety problems due to the presence of loose backfill. The yet unresolved items should be required to meet the same criteria used for the completed work.

REFERENCES

1. Lee, K. L., and Albaisa, A., (1974), "Earthquake Induced Settlements in Saturated Sands", Journal of the Geotechnical Engineering Division, ASCE, v. 100, no. GT4, April.

2. Silver, M.L., and Seed, H.B., (1972) "Settlement of Dry Sands During Earthquakes", Journal of the Soil Mechanics and Foundation Division, ASCE, v. 98, no. SM4, April.

3. Schnabel, P. and Lysmer, J. (1972), SHAKE - a computer program for earthquake and response analysis of horizontally layered sites, Earthquake Engineering Research Center, University of California, Berkeley, Report EERC-72-12.

4. Seed, H.B. and Idriss, I.M. (1970) "Soil Moduli and Damping Factors for Dynaminc Response Analysis", Report No. EERC 70-10, Earthquake Engineering Research Center, University of California; Berkeley, California

List of Documents Furnished to Corps of Engineers for their Review (Task 5-Review of San Onofre I)

Document	Date	Document Title
1	August 17, 1982	Soil Backfill Conditions Report
2	October 18, 1982	NRC Evaluation
3	October 21, 1982	Meeting with NRC
4	December 1, 1982	NRC Draft Topic Evaluation
5	April 18, 1983	SCEC Topic Evaluation and Chapters 1 to 3 of Revised Soil Backfill Conditions Report
6	September 1, 1983	Chapters 4, 5, Addendum 1, and Appendices A to F of Revised Soil Backfill Conditions Report
7	September 20, 1983	Crack Mapping report and Addendum 3 of Revised Soil Backfill Conditions Report
8	November 28, 1983	Addendum 3 of Revised Soil Backfill Conditions Report
9	May 17, 1984	Additional Information

ENCL 1

TABLE 1

STATUS OF STRUCTURAL FOUNDATION EVALUATION
(SOURCE - SCEC, FEBRUARY, 1985)

NO.	STRUCTURE	STATUS
1	Containment Structure and Sphere Enclosure Building	Founded on native soil. Reevaluation not required
2A	Turbine Building	Founded either on native soil or footings modified to span backfill.
2B	Turbine Generator Pedestal	Founded on native soil. Reevaluation not required.
3	Ventilation Equipment Building	Partially founded on back-fill. Evaluation meets acceptance criteria
4	Reactor Auxiliary Building	Founded on native soil. Evaluation meets acceptance criteria
5	Circulating Water System Intake Structure	Founded on native soil. Evaluation meets acceptance criteria.
6	Control Building	Generally founded on native soil. Very few footings partially founded on shallow backfill. Evaluation meets acceptance criteria.
7	Seawall	Generally founded on native soil. Evaluation meets acceptance criteria.
8	Diesel Generator Building	Founded on native soil. Reevaluation not required.
9	Fuel Storage Building	Founded on native soil. Evaluation meets acceptance criteria.

TABLE 2

STATUS OF EQUIPMENT FOUNDATIONS AND STRUCTURAL COMPONENTS EVALUATION (SOURCE - SCEC, FEBRUARY, 1985)

Item No.	Description	Status
1	Auxiliary feedwater pumps	Modified foundation to span backfill.
2	Auxiliary Feedwater pumps	Modified foundation to span backfill.
3	E-W Duct Bank, East of intake structure	Evaluated to span backfill, meets acceptance criteria.
4	Air Compressor	Not part of seismic reevaluation program.
5	Air Receivers	Not part of seismic reevaluation program.
6	Duct Bank to North Tsunami Gate	Not Part of seismic reevaluation program.
7	Motor Control #3	Part of long term seismic evaluation program.
8	Conduit Duct Bank	Evaluated to span backfill.
9	Turbine coolers	Evaluated for the in-situ soil condition, meets acceptance criteria.
10	Intake Culverts	Evaluated to span backfill, meets acceptance criteria.
11	Spent Fuel Pit Pump	Not part of seismic reevaluation program.
12	Refueling Water Pump	Part of long term seismic evaluation program.
13	Pipe Tunnel	Evaluated to span backfill, meets acceptance criteria.
14	480V Switchgear Room	Modified foundation to span backfill.

TABLE 2 (CONT)

Item No.	Description	Status
15	Column Footing for piping supports	Modified foundation to span backfill
16	Column Footing for supports	Modified foundation to span backfill.
17	Column Footing for Piping Supports	Founded on Native Soil. Reevaluation not Required.
18	Column Footing for Piping Supports	Founded on native soil. Reevaluation not required.
19	Column Footing for Piping Supports	Founded on native soil. Reevaluation not required.
20	Column Footing for Piping Supports	Part of long term seismic evaluation program.
21	Column Footing for Piping Supports	Part of long term seismic evaluation program.
22	N-S Duct Bank, East of intake structure	Evaluated to span backfill, meets acceptance criteria.
23	Refueling Water Storage Tank	Part of long term seismic evaluation program.
24	Auxiliary Feedwater piping trench	Designed to span backfill.
25	Auxiliary Feedwater tank	Founded on native soil.
26	Salt Water Cooling Line	Part of long term seismic evaluation program.
27	Refueling Water filter pump and Refueling Water Filter	Part of long term seismic evaluation program.