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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

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BEFORE ADMINISTRATIVE JUDGES
James L. Kelley, Chairman
Elizabeth B. Johnson
Dr. Cadet Hand, Jr.

In the Matter of	)	
	)	
SOUTHERN CALIFORNIA EDISON COMPANY, ET AL.	)	Docket Nos. 50-361-OL 50-362-OL
	)	
(San Onofre Nuclear Generating Station, Units 2 and 3)	)	

PARTIAL INITIAL DECISION

January 11, 1982

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Appearances

Messrs. David R. Pigott, Edward B. Rogin, Samuel B. Casey and John A. Mendez, San Francisco, California, Charles R. Kocher and James A. Beoletto, Rosemead, California, for the Applicants.

Mr. Richard J. Wharton, San Diego, Califronia, for the Intervenors, Carstens, *et al.*, on geology/seismology issues.

Ms. Phyllis M. Gallagher, Anaheim, California, and Charles E. McClung, Jr., Laguna Hills, California, for the Intervenors, GUARD and Carstens, *et al.*, on the low-power operating license motion.

Messrs. Lawrence J. Chandler, Benjamin H. Vogler, Richard K. Hoefling and Donald F. Hassell, Bethesda, Maryland, for the Nuclear Regulatory Commission Staff.

PARTIAL INITIAL DECISION

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SCOPE OF DECISION

Southern California Edison Co., San Diego Gas and Electric Co., and the Cities of Anaheim and Riverside, California (the "Applicants") are the joint owners and applicants for operating licenses to cover Units 2 and 3 of the San Onofre Nuclear Generating Station. Review of the application, originally filed in 1977, was (like many similar applications) substantially delayed by the Commission's responses to the Three Mile Island accident.[1/] As a result, Unit 2 is virtually completed as this opinion is rendered.

This proceeding was contested with respect to seismic and emergency planning issues. In order to minimize unnecessary delay, the Applicants moved for a fuel-loading and low-power operating license after the seismic hearings were closed and during the emergency planning hearings. The motion was predicated upon a favorable ruling on the seismic issues and a determination that the current state of emergency preparedness

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1/ As the Commission explained in its "Statement of Policy on Conduct of Licensing Proceedings" --

> Historically, NRC operating licensing reviews have been completed and the license issued by the time the nuclear plant is ready to operate. Now, for the first time the hearings on a number of operating license applications may not be concluded before construction is completed. This situation is a consequence of the Three Mile Island (TMI) accident, which required a reexamination of the entire regulatory structure. 46 Fed. Reg. 28533, 28534.

at the Station and off site are adequate, given the low risks of a radiological emergency associated with fuel loading and low-power testing.

We now decide the seismic issues in the Applicants' favor by the strong, if not overwhelming, weight of the evidence; we also determine that the current state of emergency preparedness is more than adequate for a low-power license. Accordingly, the Director of Nuclear Reactor Regulation is authorized to issue a fuel loading and low-power operating license to the Applicants for Unit 2. Our decision on the adequacy of emergency plans for full-power operations at Units 2 and 3, the only remaining issues, will come at a later date.

I. FACTUAL AND PROCEDURAL BACKGROUND

A. Site Location and Major Geologic Features.

The San Onofre facilities are located on an 80C acre site within the United States Marine Corps Base, Camp Pendleton, California. The site fronts on the Pacific Ocean and is about five miles down the coast southeast from San Clemente, California.

Levels of seismic activity vary significantly in different parts of Southern California. The areas of highest seismicity are on and near the San Andreas and San Jacinto fault systems, the present boundary between the Pacific and North American plates. Seismic activity generally decreases westward away from the plate boundary. The nearest approach of these plate boundary fault systems to San Onofre is about forty-five miles. The coastal region around San Onofre has experienced relatively moderate seismic activity during the past two centuries for which historic records of earthquakes exist.2/

There are a number of offshore faults in the coastal waters off Southern California, some of which are active. Of greatest concern to San Onofre is an offshore structure beginning with the Newport-Inglewood Zone of Deformation near Long Beach, passing the facility about eight kilometers offshore as the South Coast Offshore Zone of Deformation, and extending south to the San Diego area as the Rose Canyon Fault Zone. This entire structure, extending from near the Santa Monica Mountains to San Diego, is known as the Offshore Zone of Deformation or "OZD."3/ As will be seen, one of the disputed issues in this proceeding is whether the OZD is a single, throughgoing fault, or whether it is comprised of separate segments of faults or "zones of deformation."

About one-half mile from the facility the Cristianitos fault is clearly expressed in the sea cliffs. The Cristianitos is the closest significant geologic feature to San Onofre. It

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2/ Instrumental records of earthquakes go back only about 50 years. See Findings of Fact 25, 26. Testimony of Stewart Smith at 5-6 and Figures SWS, 1-D. Testimony of Jay Smith at 14. Sean Biehler at Tr. 3987-99.

3/ Testimony of Jay Smith at 17-18.

proceeds inland from the sea cliffs for about 25-30 miles and appears to die out about one mile offshore.[4/] The Cristianitos has long been considered to be inactive.[5/]

The name "Cristianitos" was recently given to a nearby offshore zone of deformation now known as the Cristianitos Zone of Deformation or "CZD." The CZD is located southeast of the plant site, between the site and the OZD.[6/] The characteristics of the CZD were extensively litigated by the parties.

. Major Regulatory Requirements.

Nuclear power plants must be designed to protect the public from the dangers of radioactive releases that might otherwise be caused by an earthquake. The regulations prescribe detailed investigations to be performed, and criteria to be applied, to establish the design criteria for a particular site.[7/] We provide next a simplified description of the regulatory framework as a perspective for the discussion that follows.

4/ Testimony of Jay Smith at 37-38.

5/ See text accompanying note 37, infra.

6/ The most prominent features of the CZD are depicted in Figure DGM-E, accompanying the written testimony of Dr. Moore.

7/ These requirements are set forth in considerable detail in "Seismic and Geologic Siting Criteria for Nuclear Power Plants," 10 CFR Part 100, Appendix A.

The linchpin for the regulatory scheme is the "safe shutdown earthquake," or "SSE." The purpose of the SSE determination is "to estimate the magnitude of the strongest earthquake that might affect the site of a nuclear power plant during its operating lifetime."[8/] The SSE is defined as "that earthquake which produces the maximum vibratory ground motion for which [critical plant safety systems] are designed to remain functional." App. A, III(C).

Large earthquakes only occur on pre-existing active faults.[9/] Therefore a particular active fault capable producing an earthquake, which would in turn generate the strongest ground motion at the site -- sometimes called the "controlling geologic feature" -- must be selected.[10/] Taking into account historic earthquake data, the distinctive geology of the area, prevailing stresses in the earth's crust, and other factors, seismologists make expert judgments about maximum magnitude earthquake -- i.e., the "safe shutdown earthquake" -- that could occur on that feature.[11/] All parties and the Board

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8/ Pacific Gas and Electric Co. (Diablo Canyon Nuclear Power Plant) ALAB-644, ___ NRC ____, slip op. p. 11 (1981).

9/ Testimony of Clarence Allen at Tr. 4870-71.

10/ Appendix A, IV(a)(7).

11/ See. e.g., Testimony of Stewart Smith, pp. 4-14 and footnote 54, below.

agreed that the controlling feature for San Onofre is the Offshore Zone of Deformation or "OZD."12/

There remains for determination the "maximum vibratory ground motion" that an SSE at the location on the fault closest to the site would cause at the site.13/ This prediction involves not only the magnitude of the SSE, but a number of other factors including distance from the site, seismic wave propagation characteristics of subsoils, and the tendency of seismic waves to attenuate non-uniformly at various distances.14/ The maximum vibratory ground motion is equivalent to the peak sustained horizontal ground acceleration registered on seismographs and measured in units of gravity, "g." It is this peak ground acceleration value -- for example, 0.5g -- that is then used as the anchor point in developing a design response spectrum for the facility. Adherence to the response spectrum in the engineering and construction processes is intended to ensure that the reactor's critical safety features would withstand the SSE determined for it.15/

12/ Although there are, of course, active California faults capable of producing larger earthquakes -- for example, the San Andreas -- their comparative distance from the site means that resultant ground motion would attenuate below that to be expected from the nearby OZD.

13/ Appendix A, V(a).

14/ See, e.g., Testimony of Lawrence Wight, pp. 5-14.

15/ See, e.g., Testimony of Robert McNeill, pp. 9-25.

C. The Construction Permit Proceeding.

Units 2 and 3 of San Onofre were authorized for construction in 1973.16/ Then as now, the seismic hazards associated with the site were strongly contested. The single stipulated seismic issue was "whether, assuming the geological model set forth in the Regulatory Staff's Safety Evaluation, 0.67g is a reasonably conservative design basis earthquake ..." for San Onofre. 6 AEC at 938. Following hearings, the Licensing Board found that 0.67g did represent a reasonably conservative "design basis earthquake."

A few clarifying points are necessary concerning what the construction permit Licensing Board did and did not do, and how its determinations relate to the present case. First, that Board spoke of a "design basis earthquake" determination, not a "safe shutdown earthquake." The two phrases are synonomous, the former phrase being frequently used before the late 1973 promulgation of Appendix A.17/

Second, the Board rather confusingly characterized its 0.67g determination as an "earthquake." As explained above, the "g" determination denotes the intensity of ground motion to be expected at the reactor site, not the magnitude of an earthquake at its epicenter on a particular fault. In arriving at its 0.67g determination the construction permit board concluded

16/ Southern California Edison Co. (San Onofre Nuclear Generating Station, Units 2 and 3), 6 AEC 929 (1973).

17/ See Appendix A, Footnote 1. The Licensing Board decision preceded promulgation of Appendix A.

that, among other methods, postulation of an Intensity X earthquake (using the relatively imprecise Modified Mercalli scale) on the OZD was appropriate. 6 AEC at 949. However, that board did not make any explicit finding of a maximum magnitude for a safe shutdown earthquake on the OZD.[18/] That is being done for the first time in this proceeding.

Finally, it is important to recognize that the geologic and seismic characteristics of the controlling geologic feature, the OZD, were not litigated and determined at the construction permit stage. The geological "model" proposed by the Staff and the U.S. Geological Survey at that time described the OZD as "an extensive linear zone of deformation, at least 240 km. long ... and capable of an earthquake whose magnitude could be commensurate with the length of the zone." 6 AEC at 942. This ambiguous language can be read to describe the OZD as a single, "throughgoing" fault. For their part, however, the Applicants viewed the OZD as a series of separate faults and zones capable of producing only small earthquakes. This disagreement was resolved at that time by the Applicants' stipulation to the Staff's "model," but only for the purpose of determining the appropriate design spectrum. The Board approved the Staff model as an appropriately conservative approach, while at the same time noting that there may then have been "a small preponderance

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18/ Because the M_S7 SSE now determined for San Onofre confirms the acceptability of the previously determined peak ground acceleration value of 0.67g, the omission of an SSE determination at the construction permit stage turns out to have no effect at the operating license stage.

of the evidence" in favor of the Applicants' position. 6 AEC at 943. Thus, the actual geologic and seismic characteristics of the OZD were litigated for the first time in this proceeding.

D. This Operating License Proceeding.

1. Preliminary Stages. In March 1977, the utilities filed their application for operating licenses for Units 2 and 3 of San Onofre. In April 1977, a notice of an opportunity for interested persons to request a hearing was published in the Federal Register, 42 Fed Reg. 18460. Thereafter, several organizations and individuals petitioned to intervene and for a hearing, urging consideration of numerous contentions.

The only intervenor group to be admitted as a party and to participate in the seismic hearing was led by Mr. August Carstens of La Jolla, California. The Carstens group includes several other individuals and an environmental organization, Friends of the Earth.[19] The group was referred to in the hearings as the "Carstens Intervenors" or "Intervenors" and will be referred to similarly in this opinion.

Following an initial prehearing conference, the Board admitted contentions on a variety of subjects, including one broadly-worded seismic contention, as follows:

19/ The other individuals in this group are Mrs. August Carstens, Lloyd and Selma Von Haden, Donald May and Mrs. Donif Dazey. Another intervenor organization, GUARD, participated only in the emergency planning phase of the proceeding. The State of California and the California Public Utilities Commission were admitted pursuant to 10 CFR 2.715(c), but took no active part in the proceeding.

> The seismic design basis for SONGS 2 & 3 is inadequate to protect the public health and safety and does not comply with 10 CFR, Part 100, Appendix A, in that the earthquake which could cause the maximum vibratory ground motion has not been assigned as the safe shutdown earthquake.20/

This contention was admitted for discovery purposes only, in the expectation that it would be limited or refined following discovery and prior to hearing.21/

Except for intermittent discovery, very little happened in this proceeding for the next three years. The NRC Staff's review of Units 2 and 3 was substantially delayed by the necessary diversion of resources to respond to the 1979 Three Mile Island accident. The Staff's Safety Evaluation Report, NUREG-0712, was ultimately issued in February, 1981, and the Advisory Committee on Reactor Safeguards submitted a favorable report on the geology and seismology of San Onofre.22/

20/ Order of January 27, 1978, p.2.

21/ Order of January 27, 1978, pp. 2-3. The Board admitted three other contentions from the Carstens Intervenors, concerning emergency planning, uranium fuel costs and the effects of cavities caused by dewatering activities. The emergency planning contention was later revised and litigated. The other two contentions were dismissed on motions for summary disposition, except that the dewatering contention was partially and conditionally retained in the event that the earlier vibratory ground motion determination were later shown to be incorrect. Order of January 26, 1981. Since we have found that the 0.67g ground motion value assigned at the construction permit stage is appropriately conservative for San Onofre, the dewatering contention is now completely resolved.

22/ The ACRS letter report dated February 10, 1981, is included in the record as Appendix C to Supplement No. 1 to the Safety Evaluation Report, Staff Exhibit 1.

Further discovery was precluded in late February 1981 by stipulation of the parties; a final prehearing conference was held in late April.

2. Refinement of Seismic Contentions. A major purpose of the final prehearing conference was to specify and refine the Carstens Intervenors' single, broadly-worded seismic contention, quoted above. This proved to be a complex process. In response to the Board's invitation to submit more specific contentions,23/ the Intervenors proposed fifty-six contentions, all of which were assertedly encompassed within their original broad contention.24/ The Applicants counter-proposed four contentions, with which the NRC Staff substantially agreed. The Board heard extended oral argument on these contentions.25/

The Board's Order of May 8, 1981, among other things, admitted four contentions substantially as agreed to by all parties and subject to the possibility of expansion upon appropriate further showings by the Intervenors. These showings related to any pertinent additional geological discoveries made after the construction permits and to a range of previously submitted and unduly vague contentions concerning alleged inadequacy of investigations or reviews performed by the

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23/ Order of March 31, 1981.

24/ Intervenors Proposed Agenda and Revised Contentions, dated April 18, 1981.

25/ Tr. 312-392.

Applicants or the Staff. In addition, the May 8 Order ruled out a number of the Intervenors' proposed contentions on various grounds.

The Intervenors and the Staff thereafter filed objections to various other parts of the Order of May 8, but no objections to the admitted contentions were filed by any party. As provided by 10 CFR 2.752(c), we thereafter issued a revised prehearing conference order, making certain minor changes in the contentions as previously admitted.[26/] We rejected as separate contentions the Intervenors' proposed revisions of their "investigation" contentions. However, we made it clear that the substance of these contentions could be litigated, as relevant, under the admitted contentions.

The contentions, as revised and admitted for the hearing, were as follows:

1. Whether as the result of ground motion analysis techniques developed subsequent to issuance of the construction permit or data gathered from earthquakes which occurred subsequent to issuance of the construction permit, the seismic design basis for SONGS 2 & 3 is inadequate to protect the public health and safety.

2. Whether characterization of certain offshore geologic features as a zone of deformation, referred to as the Christianitos Zone of Deformation (CZD), or whether any additional information about the CZD which became available subsequent to issuance of the construction permit render the seismic design basis for SONGS 2 & 3 inadequate to protect the public health and safety.

3. Whether the seismic design basis for SONGS 2 & 3 is inadequate to protect the public health and safety as a result of discoveries subsequent to issuance of

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26/ Order of May 28, 1981.

the construction permit of the following geologic features:

(1) ABCD features at the site.

(2) Features located at Trail 6, Target Canyon, Dead Dog Canyon, Horno Canyon, and "onshore faults E and F."

(3) Such other features as the parties may agree are relevant to the seismology of the SONGS site or with respect to which Intervenor Friends of the Earth makes a threshold showing of relevance.

4. Whether based on the geologic and seismic characteristics of the OZD, including its length, assignment of $M_S 7$ as the maximum magnitude earthquake for the OZD renders the seismic design basis for SONGS 2 & 3 inadequate to protect the public health and safety.

The regulations contemplate that a comprehensive geologic and seismic review of the proposed reactor site will be conducted at the construction permit phase, with an "update" approach sufficing at the operating license stage.27/ It is only sensible to determine earthquake hazards inherent in the site before a massive reactor structure is built on it. And once the reactor is built it would usually not be productive to perform for a second time the full review performed at the construction permit stage. Apart from the possibility of newly discovered information, the geologic features of interest to the site, and previously reviewed, will not have changed for tens of

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27/ (Text of footnote is on following page 13a)

27/ (Footnote from previous page)

The regulations are not as clear as they could be in this regard. It is significant, however, that the investigative obligations of Appendix A are only imposed explicitly on applicants for construction permits. Appendix A, II. An "update" obligation is imposed on applicants for operating licenses by 10 CFR 50.34(b)(1).

The Intervenors argue that the Applicants have violated investigatory obligations imposed by various provisions of Appendix A. See Intervenors' Conclusion of Law D. As we read AppendixA, the cited provisions do not apply to Applicants for operating licenses. Rather, such Applicants have an obligation to perform such further investigations as may be necessitated by discoveries of new information following issuance of the construction permit to ensure the safety of the facility. The Applicants in this case fully discharged that obligation.

thousands to perhaps millions of years, let alone the few years elapsing between the construction permit and operating license stages.

In this case, Contentions 1-3 conform to the "update" pattern; they are limited to developments occurring since the construction permit. However, Contention 4 -- by far the broadest and most complex contention -- is not so limited in time. It addresses the geologic and seismic characteristics of the OZD and the maximum magnitude earthquake that might occur on it. As explained by the Applicants, who initially offered it as a counter-proposal, Contention 4 "encompasses all of the geology of the structure without really any limitation as to time."28/

It may be debatable whether a contention of this breadth is, strictly speaking, required to be litigated in this operating licensing proceeding.29/ In a case where the construction permit seismic review is conducted under the present regulations, the issues in this contention would be addressed as that stage; to address them again at the operating license stage would be redundant and wasteful. But the construction permit review in this case preceded promulgation of

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28/ Tr. 313.

29/ The Applicants explained the scope of this contention with reference to the requirements of a Staff standard review plan. Tr. 312-313. While that may have set the parameters of the seismic review as between the Applicants and the Staff, such plans have no legal effect in contested proceedings.

the present regulations in late 1973; those regulations provide no guidance on the proper scope of operating license reviews in cases like this. In any event, we believe for several reasons that Contention 4's broad scope is only prudent in the circumstances of this case, whether or not abstract analysis of the regulations indicates it is required.

First, the geologic and seismic characteristics of the OZD, factors crucial to the seismic hazard at San Onofre, were not litigated at the construction permit stage. Second, no maximum earthquake intensity or magnitude was assigned to the OZD. To be sure, the Staff and its consultants made an intensity determination of X on the Modified Mercalli scale for the OZD, but this was never adopted by the construction permit Board. Moreover, this Board does not have very much confidence in the Modified Mercalli scale --- based as it is on observations of damage rather than instrument readings -- as a basis for predicting ground motions. Instrumented recordings of magnitude are more reliable for that purpose. Although such determinations are inherently imprecise, it is important to determine a maximum magnitude earthquake for the OZD as accurately as possible. Finally, it is significant that all parties stipulated to the substance of Contention 4.

3. <u>The Hearings</u>. The dates for hearing were being set as the Commission was issuing its "Statement of Policy on Conduct of Licensing Proceedings." Mindful that Unit 2 of San Onofre would probably be completed before we could reach an initial

decision, the Board attempted to move the process along "at an expeditious pace, consistent with the demands of fairness." Policy Statement, p.3. We first set the beginning of the evidentiary hearing for June 15, 1981. The Intervenors objected, seeking a postponement until the end of July. Following consideration of their arguments and over the objections of the Applicants and Staff, we granted a week's postponement until June 22.[30/] We saw nothing during the course of the hearing to indicate that the Intervenors were prejudiced by the hearing schedule.[31/]

The hearings began on June 22, 1981, in San Diego, California and, after two short recesses, concluded on August 4, 1981. There were 25 days of hearing; the testimony and cross-examination of 28 witnesses filled almost 7,000 pages of transcript.[32/] Almost all of the witnesses were of

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30/ Order of May 28, 1981, pp. 8-11.

31/ For example, although the Intervenors cited a need for more time to prepare pre-filed testimony, such testimony was actually filed for only three witnesses, and only one of these (Dr. Brune) had lengthy testimony. The remaining five intervenor witnesses testified under subpoena.

32/ The Intervenors had moved prior to hearing for permission to use supervised legal interns to assist in the presentation of their case. The Board granted that request, over the Applicants' and Staff's objection. Order of June 3, 1981. Counsel for the Intervenors in the seismic proceeding, Mr. Wharton, later expressed his intention not to employ legal interns in that proceeding, but to employ them later in the emergency planning hearing. However, Mr. Wharton did not participate in the emergency planning hearing. As a result, legal interns did not participate in the case at all.

exceptionally high quality, typically exhibiting strong academic credentials and extensive experience. The testimony was buttressed by over 70 exhibits, many of them voluminous. After the record was closed, each party submitted extensive proposed findings of fact and conclusions of law. On the basis of this very substantial record and it thorough analysis by the parties, the Board believes that the issues were thoroughly ventilated.

4. Exclusion of Evidence -- The Cristianitos Fault.

Generally speaking, evidence was liberally admitted throughout the hearing. Perhaps the most significant exception was the Board's granting of a motion to strike the testimony and exhibits of an Intervenor witness who was called to prove the seismicity of the Cristianitos fault. The Applicants, supported by the Staff, moved to strike this evidence following its presentation as an offer of proof. They argued that this evidence was based primarily on matters predating the 1973 construction permit proceeding, and that its consideration should therefore be foreclosed.[33/] The motion was granted on that ground, and on the independent ground that the witness' presentation lacked any probative value.[34/] Although our basic reasons for these rulings were given on the record, some additional explanation is warranted in this decision.

33/ Tr. 4593-4600.

34/ Tr. 5187-5198.

(a) Lack of Probative Value. The lack of probative value ruling was based upon the witness' sketchy qualifications as an expert, the superficiality and questionable accuracy of his pre-filed evidence, and his demeanor upon cross-examination. Each of these bases is, we think, fully reflected in the record, and need not be restated at length here. We will cite as illustrative particular matters that underlay our exclusion ruling on this ground.

This witness was called as an expert in seismology. He holds a BS degree in geology and geophysics. However, he has done no graduate work, nor is he licensed to practice, in those areas. Relevant work experience in seismology might have compensated for these deficiencies, but such experience was not strongly demonstrated. It appeared that most of the witness' recent work experience concerned data collection and retrieval through computer programs. Tr. 4806-08.

The evidence presented by this witness to demonstrate the seismicity of the Cristianitos fault area was very simplistic. What he did, essentially, was transfer earthquake location data covering the period 1932 to 1980 from the epicenter catalogue published by the California Institute of Technology to a map of the vicinity of the Cristianitos Fault. He then drew error circles of different sizes around the estimated epicenters, the size depending upon the presumed accuracy of the location.[35] On the basis of this exercise, the witness concluded that the Cristianitos fault area "has experienced considerable seismic activity in the recent past," and that "at least 20 earthquakes could have occurred on the Cristianitos fault."

The foregoing "analysis" (excepting, possibly, the conclusion) did not require any expertise at all. With minimal instructions, it could have been carried out by practically anybody. Beyond that, the data employed here is questionable from two standpoints. For one thing, the pre-1975 data (the bulk of that used here) has little guarantee of accuracy because of less precise methods then used to locate epicenters; the pre-1971 data is especially open to question. Written testimony, pp. 2-4, Tr. 4798-99. In addition, cross-examination indicated that significant errors may have been made in the purely mechanical transcription of the data. Tr. 4824-30.

To say only that the area of the Cristianitos is seismically active adds nothing to what has been generally known for decades. But even in that regard, the witness in effect retracted on cross-examination the only thing he had said in his written testimony about area seismicity -- i.e., what he had first characterized as "considerable seismic activity" in the Cristianitos area became on cross-examination merely "non-negligable" seismic activity. Tr. 4836.

34/ The results of this effort are depicted in Figures 1 and 2 appended to the witness' written testimony.

More fundamentally, we question whether any useful conclusions can be drawn about the seismicity of the Cristianitos fault itself from this circle drawing exercise. The witness acknowledged that the Caltech catalogue information was not adequate for detailed investigations of fault activity. Tr. 4817. The record reflects that much more sophisticated analyses are required to reach any definite conclusions about a particular fault.36/

The Board was also influenced by the witness' demeanor on cross-examination. This is an important but rather ephemeral factor, difficult to tie to particular lines of the record. It was our strong feeling, however, upon listening to cross-examination and asking our own questions, that the witness "lacked the kind of responsiveness and assurance that we expect in a qualified expert." Tr. 5196. We concluded from all of this that the witness had nothing useful to tell us about seismic conditions affecting San Onofre.

(b) Foreclosure of Issues at the Operating License Stage. As previously described, the Cristianitos Fault is the closest significant geologic feature to San Onofre. If the Cristianitos were shown to be a capable fault, it would certainly be significant, and perhaps crucial, to the safety of the San Onofre facility. That was the purpose of the evidence we have just described. However, in the circumstances of this

36/ See, e.g., the testimony of Sean Biehler concerning the relationship of two small 1975 earthquakes to the Cristianitos fault. Tr. ff. 3648.

case the Board determined that the prior opportunity to litigate the capability of the Cristianitos at the construction permit stage foreclosed the relitigation of that question in this operating license proceeding, absent a sufficient showing of changed circumstances, a showing that was not made.

As far back as 1964 when the construction permit was granted for Unit 1, the Atomic Energy Commission's licensing board referred to the Cristianitos as "an inactive fault."37/ However, neither the overall seismicity of the site nor the capability of the Cristianitos was a contested issue in that proceeding.

The Cristianitos and its characteristics received extensive scrutiny in the 1973 construction permit proceeding for Units 2 and 3. The Staff's Safety Evaluation states that --

> Although the site is located within 1 mile of the Cristianitos fault zone, exposures of parts of this fault at the coast and at the Plano Trabuco excavations made by the applicant about 16 miles north of the coastal exposure, show that the overlying terrace deposits have not been offset by the fault at these locations. All of the available evidence indicates that the Cristianitos fault is inactive 38/

Although the seismicity of the site was vigorously contested, no contention was raised and no explicit findings were made about the Cristianitos. The single seismic contention concerned the ground vibrations to be anticipated from the OZD. The most

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37/ Southern California Edison Co., et al., 2 AEC 366, 376 (1964).

38/ SER, p. 16. The Safety Evaluation also included analyses of the Cristianitos by the U.S. Geological Service. Appendix C, pp. 7-8, 19-22.

reasonable inference to be drawn from this exclusive focus on the OZD is that the intervenors at the construction permit stage made a conscious decision not to litigate the capability of the Cristianitos. Given the record we have only sketched, it is certain that they actually knew quite a bit about the Cristianitos and its seismic significance, or lack thereof.

The same people and groups comprising the Carstens Intervenors were not intervenors in the 1973 proceedings. However, there is some overlap among the participants. GUARD, another intervenor group, was one of the "Consolidated Intervenors" which litigated seismicity in 1973. This time around, however, GUARD confined its participation to emergency planning issues. The Intervenors' principal witness in 1973, and again in 1981, was Dr. James N. Brune, a highly qualified seismologist from the University of California at San Diego.39/ The intervenors in both proceedings were represented by counsel.

In the light of the foregoing factual summary, we turn to the applicable law on foreclosure of issues at the operating license stage which were or could have been litigated at the construction permit stage. We use the term "foreclosure"

39/ The Board wishes to acknowledge the substantial contributions Dr. Brune made to this proceeding on a pro bono publico basis, both as a witness and as an expert cross-examiner. Although the conclusions we reach are largely at variance with the views he expressed, we believe that our conclusions are more carefully considered, and therefore sounder, as a result of his participation.

advertently because, as we shall explain, we do not think that the judicially-developed doctrines of "res judicata" and "collateral estoppel" should be transplanted intact from the civil litigation of private rights to the Commission's publicly-oriented licensing scheme. We view those doctrines as possibly useful guidelines to a sound result, but not as Procrustean beds.[40/]

The Supreme Court has stated the doctrines of res judicata and collateral estoppel, as follows:

> Under the doctrine of res judicata, a judgment on the merits in a prior suit bars a second suit involving the same parties or their privies based on the same cause of action. Under the doctrine of collateral estoppel, on the other hand, the second action is upon a different cause of action and the judgment in the prior suit precludes relitigation of issues actually litigated and necessary to the outcome of the first action. Parklane Hosiery, Inc. v. Shore, 439 U.S. 322, 326 n. 5 (1979).

In its 1974 Farley decision,[41/] the Appeal Board made it clear that those doctrines could be given effect in licensing proceedings. Farley involved an attempt by one who had been an intervenor at the construction permit stage to intervene again at the operating license stage to relitigate exactly the same

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40/ It is well settled that doctrines developed by the courts do not have to be applied in full rigor to the administrative process. Rather such doctrines can be modified to serve the frequently different objectives of the agencies. See, e.g., Consumers Power Co. (Midland Plant), 7 AEC 19, 31 (1974); United Church of Christ v. FCC, 425 F.2d 543, 546-550 (1969).

41/ Alabama Power Co. (Farley Nuclear Plant), 7 AEC 210.

contentions. Thus it was clear that "all of the essential elements of at least collateral estoppel" were present.42/ In those circumstances, the Farley Board had no occasion to consider whether, as in this case, an issue might be foreclosed, even though not all of the traditional elements of res judicata or colleteral estoppel were present.43/

There are two elements arguably missing in the present case from the hornbook elements of res judicata and collateral estoppel -- identity of parties and full prior adjudication of the issue. We believe that under a functional analysis of the Commission's licensing system, neither of these elements should be considered a prerequisite to foreclosure.

Identity of Parties. The major reason underlying an identity of parties requirement in the context of judicial enforcement of private rights is to ensure a person's "day in court," a concern grounded in constitutional considerations. Individually owned causes of action are normally treated as property; and property cannot be taken away without due process of law. For example, if both Smith and Jones are injured by Brown's negligence, and Smith sues Brown first and loses, Jones is not barred from suing Brown thereafter.

42/ Id. at 215.

43/ Similarly, subsequent decisions in this agency applying Farley have not been factually analogous to this case. See, e.g., Houston Lighting and Power Co. (South Texas Project), 10 NRC 563 (1979), aff'd, 11 NRC 14 (1980); Toledo Edison Co. (Davis-Besse Station), 5 NRC 557 (1977). Our research has not disclosed any cases, judicial or administrative, completely analogous to this case.

But there is no valid analogy between a case involving only private property rights and intervention in nuclear power licensing.44/ Intervenors are not admitted to prove, and we do not sit to enforce, private rights. The only ultimate issues in the case are whether the license application shall be granted, denied, or conditioned. Intervenor groups address those issues from their own perspectives of the public interest. Once this public interest function is recognized, it follows that the identity of the intervenor group in the earlier proceeding is irrelevant.45/ As we stated earlier on the record :

> If, for example, the Sierra Club litigates something in 1973, there is no reason in our view why the Union of Concerned Scientists should be able to litigate the same thing eight years later. Tr. 5192.

Prior Adjudication. Under the doctrine of res judicata, foreclosure applies not only to matters that were actually litigated, but also to matters that could have been litigated, but were not -- so long as both were encompassed within the same "cause of action." Clearly, the capability of the Cristianitos fault could have been litigated at the construction permit stage in 1973. Given the Farley Board's indication that the construction permit and operating license proceedings can be

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44/ The Constitutional element is missing altogether. Hearings at the instance of intervenors have been provided for by Congress as a matter of prudence, not constitutional compulsion.

45/ See Cleveland Illuminating Co. (Perry Nuclear Plant), Memorandum and Order of July 28, 1981, slip op., pp. 39-42.

considered the same "cause of action,"[46/] and putting lack of party identity to one side, foreclosure can be rationalized on a res judicata basis in this case.

The reason for the broad "could have been litigated" scope of res judicata applies with full force here. Over a century ago, the Supreme Court recognized "the necessity of having the subject of particular litigation, as a whole, at once before the court, and not by piecemeal ...." Cromwell v. Sac County, 94 U.S. 351, 358 (1877). Similarly, it is in everyone's best interests to have the seismicity of a nuclear power plant site fully and finally explored at the construction permit stage, subject only to the possibility of newly-discovered information being explored at the operating license stage. To be sure, a construction permit intervenor probably will not seek to raise every conceivable seismic contention. As a matter of litigation tactics and husbandry of resources, an opponent of the plant might choose quite selectively among possible vulnerabilities in the site. But the result of such a selective approach should not be that everything unchallenged then should be left wide open for litigation at the operating license stage.

Unlike res judicata, decisions cast in the collateral estoppel rubric typically require that the matters in question have been actually litigated and decided in the earlier proceedings.[47/] In the present case, the construction

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46/ 7 AEC at 215, note 7.

47/ Alabama Power Co., supra note 41, pp. 213, 217.

permit board did not make any explicit finding about the Cristianitos fault.48/ It can be argued that the determination of the OZD as the controlling geologic feature is, by necessary implication, a determination that the Cristiantos is not a capable fault, particularly considering the extensive information before the construction permit board about the Cristianitos.49/ But we prefer to rest our forclosure decision on a broader ground.

We do not believe that prior litigation and decision of an issue should be a prerequisite to its foreclosure at the operating license stage. Here again, we find no valid analogy between the judically-developed private rights doctrine of collateral estoppel and the Commission's licensing scheme. Presumably, a major purpose underlying the prior litigation requirement was to ensure that the evidence bearing on the matter was actually marshalled and received objective evaluation. That can only be done by private litigatants through actual litigation. But in the nuclear power licensing context, significant safety considerations are reviewed by the Staff and the Advisory Committee on Reactor Safeguards, whether

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48/ The only reference to the Cristianitos in the opinion is in finding 52 at 6 AEC 939. This finding merely describes certain materials in the record.

49/ The courts have extended collateral estoppel effect beyond ultimate facts in issue to "mediate" evidentiary facts underlying them. See The Evergreens v. Nunan, 141 F.2d 927 (C.A. 2, 1944) (Learned Hand, J.).

or not they are raised by an intervenor.[50/] With these assurances of impartial review, we believe that it is enough to cause later foreclosure if, as here, the matter was known to and could have been placed in issue before the construction permit board in a contested proceeding.

50/ The importance of these reviews has received judicial acknowledgment. See Union of Concerned Scientists v. AEC, 499 F.2d 1069, 1077 (C.A.D.C., 1974). Some cases have applied collateral estoppel to an action brought by an individual whose only legal interests were adequately represented in a previous suit brought by an authorized governmental entity. See, e.g., Southwest Airlines Co. v. Texas International Airlines, Inc., 546 F.2d 84 (5th Cir.), cert. denied, 434 U.S. 832 (1977) (As a government empowered to enforce its ordinances, city had represented in prior suit those same interests which private party now sought to litigate); Restatement (second) of Judgments § 85(d) (Tent. Draft No. 2, 1975); accord. United States v. ITT Rayonier, Inc., 627 F.2d 996 (9th Cir), (concurrent state and federal enforcement powers under Federal Water Pollution Control Act established sufficiently close relationship between federal and state agencies such that federal agency collaterally estopped from relitigating issue in federal enforcement action which had already been decided in state enforcement action).

II. SUMMARY OF DECISIONS ON MAJOR SEISMIC ISSUES

A. Introduction.

This section summarizes the detailed findings of fact in the following section. It includes a statement of each major issue, a description of the positions of the parties and a brief summary of their evidence, and the main reasons for the result we reach. This section provides a relatively brief narrative description of what we have decided, and why -- central elements that are sometimes lost in lengthy and technical findings of fact.

This section is intended not only to explain, but also to supplement the findings of fact. Accordingly, it has independent legal significance. Should any unintended inconsistency arise, however, between this section and our findings, the findings govern.

B. The Safe Shutdown Earthquake.

The required determination of a "safe shutdown earthquake" for San Onofre led the Board and parties to focus on the nearby Offshore Zone of Deformation or "OZD," the controlling geologic feature in this case. This issue was framed in terms of whether the assignment of M_S7 as the maximum magnitude earthquake for the OZD was consistent with its geologic and seismologic characteristics and therefore acceptable from a safety standpoint. The Applicants and Staff supported the M_S7 magnitude for the SSE; the Intervenors contended that a substantially higher magnitude should be assigned. The issue was tried along four principal lines of evidence: historic seismicity, the characteristics, particularly the length, of the OZD, and two earthquake magnitude methodologies that had been developed separately by the Applicants and Staff for this case.

The historic seismicity of the OZD in terms of large earthquakes (M_S6 or greater) is sparse. The northern segment of the OZD near Long Beach experienced an instrumented M_S6.3 earthquake in 1933. Apparently there have been only two other large earthquakes on the OZD in historic times, one near San Diego in 1800 and a second near San Juan Capistrano in 1812. Both of these earthquakes have been estimated at about M_S6.5.

Characteristics and Length of the OZD.

Various geologic characteristics of the OZD, particularly its length, are relevant to its potential for high magnitude earthquakes. As a general proposition, long, "throughgoing" faults are capable of generating large earthquakes, while short, segmented faults tend to produce smaller earthquakes. In the present case, the Intervenors sought to prove that the OZD is a single, throughgoing fault about 400 km long. The Applicants and the Staff maintained that the OZD is only about 240 km long, and that it is segmented into three discrete sections.

The Intervenors pointed to some ambiguous language in the Staff's safety evaluation at the construction permit stage which can be read to imply that the OZD was then viewed as a single fault. However, the Staff testimony in this case rejected that interpretation. It was clear, in any event, that the construction permit Board did not make findings about the characteristics and length of the OZD. The great weight of the evidence in this proceeding refuted the single, throughgoing fault theory of the OZD.

The OZD as a whole is comprised of three distinct segments: (1) the Newport-Inglewood Zone of Deformation (NIZD) to the north, (2) the South Coast Offshore Zone of Deformation (SCOZD) in the center, (3) and the Rose Canyon Fault Zone (RCFZ), in the south. The OZD is a branching system of faults and folds, the style of which varies from segment to segment. For example, right lateral ("strike slip") displacement is characteristic of the faulting on the NIZD. By contrast, the displacement on the RCFZ is predominantly vertical (the normal faulting pattern). There was substantial, uncontroverted evidence that the NIZD is terminated at its southern end by a prominent geological feature, the San Joanquin Structural High. Similarly, there is a gap between the central segment, the SCOZD, and the southern segment of the OZD, the RCFZ.

The three segments of the OZD described above are collectively about 240 km long. The Intervenors contended that, in addition, the OZD should be viewed as connecting to the south to the Agua Blanca Fault and to the Vallecitos-San Miguel Fault system. These proposed extensions of the OZD would make it about 400 km long and theoretically capable of producing a very large earthquake.

The evidence over the purported connection between the OZD and the Agua Blanca Fault was in dispute. There was some evidence suggesting at least the possibility of such a connection. However, the weight of the evidence was strongly against that possibility. For one thing, there was no evidence to show that the two fault zones had ever been involved in a single seismic event. In addition, significant differences exist between the two zones in their geomorphic features and tectonic activity. There are no demonstrable connections between them.

The Intervenors presented an expert witness who had proposed a connection between the OZD and the Vallecitos-San Miguel Fault system. He admitted that there was no way to physically connect that system and the OZD. His testimony supporting such a connection was based almost entirely upon hypothesis.

The Board rejects the proposed connection between the OZD and the Vallecitos-San Miguel Fault system. Although such a connection seems remotely possible, the weight of the evidence indicates that it is extremely unlikely. The Applicants and

Staff presented a strong case against such a postulated connection.

The foregoing evidence focused the Board's attention on the 240 km long OZD as the controlling geologic feature. The next step was to determine the maximum magnitude earthquake that could occur on that feature -- i.e., of the safe shutdown earthquake or "SSE." The Applicants and the Staff relied primarily on two methods.

Maximum Magnitude by Slip Rate Method.

One method for determining the largest earthquake a fault is capable of generating is derived from a study of relationships between slip rates and magnitudes of earthquakes that have actually occurred on particular faults. Slip rate is a quantitative measure of fault activity and is derived from the geologic record. Basically, one needs to know how much displacement has occurred on a particular fault and over how long a time period. As a rule of thumb, faults with high slip rates (in excess of two mm per year) can produce large earthquakes (M_S7 or greater). Conversely, faults with low slip rates (less than one mm per year) tend to generate smaller earthquakes.

Although the slip rate study presented by the Applicants contained a number of refinements, both in terms of data base selection and manipulation of data, the basic conceptual approach was fairly simple. They compiled information on slip rates of faults relevant to the San Onofre analysis; for example, only strike/slip faults were examined. They then compiled historic earthquake magnitude data on the selected faults and plotted both the slip rates and magnitude data. By drawing a line bounding the maximum observed earthquakes, they established a "historic earthquake limit." They then performed a second analysis designed to take into account ranges of error in slip rate, and other factors. The bounding line of this analysis produced a "maximum earthquake limit" for the range of faults studied.

One of the principal concerns about the validity of the slip rate method was whether there was an adequate historical data base. This is a valid concern. The historic record of California earthquakes extends back only about 200 years, and the instrumental world record only about 50 years. This is a relatively short record from which to extrapolate conclusions about earthquakes that often have much larger recurrence periods. On the other hand, the study was not limited to California faults and earthquakes; it included data from faults all over the world possessing characteristics common to California strike/slip faults.

In addition, the study identified a large number of low-slip rate California strike/slip faults which were not used because it was not possible to make an estimate of slip rate. However, none of these faults has actually experienced a large earthquake during the historical period. This substantiates the proposition that faults with low slip rates generally do not produce large earthquakes.

For purposes of this study, it was assumed that the OZD had a slip rate of 0.5 mm per year. This produced a maximum earthquake estimate of M_S6.5. Estimates of the slip rate on the NIZD (the northern segment of the OSD) have ranged up to a high value of 0.68 mm per year. Using this slip rate, the maximum earthquake prediction for the OZD would be M_S7. The Board views this M_S7 estimate as conservative.

Maximum Magnitude by Fault Length Method.

An alternative method for estimating maximum magnitude earthquakes on faults was developed by Dr. Slemmons, the Staff's consultant and witness. Under this approach, earthquake magnitudes are predicted on the basis of fault length. Dr. Slemmons compiled world-wide data summarizing observations of total fault length and rupture length as a means for relating these facts to the maximum magnitude of an earthquake that might occur on a given fault. He arrived at 22% as the mean rupture length to be expected. The 22% value was in turn derived from earthquakes ranging in magnitude from M_S8.25 to M_S5.9. For faults with a total length of more than 1,000 km, the average percentage of rupture is about 25 to 30%. In the length ranging from 600 to 1,000 km, the average percentage of the largest observed rupture-to-fault-length is about 22%. Finally, for shorter faults in the range of interest to the OZD, the percentage value is about 15%.

Dr. Slemmons' world-wide data base showed that for faults with a length of more than 1000 km it is possible to have earthquakes of M_S8 or greater. In the range of 400 to 600 km, the maximum values observed decrease to 7 to 7.5. Lastly, for faults comparable to the OZD, the values are around 7 or below. If we assume a 240 km fault length for the OZD and use Slemmons' equation to compute magnitude for 15%, 22% and 30% rupture, we arrive at magnitudes of 6.74, 7.0 and 7.2, respectively.

The Intervenors sought to undercut Dr. Slemmons' analyses and results by adding an additional standard error of deviation to the standard of deviation and other conservatisms already incorporated in his analyses. The Board believes that Dr. Slemmons' analyses are conservative as they were presented. To cite but one example, Dr. Slemmons uses only the largest percentage rupture reported for each fault to obtain the average rupture length for all faults. Addition of another standard of deviation to his calculations would be unwarranted. We believe that the fault length method reinforces the determination reached under the slip rate method -- that M_S7 is an appropriately conservative maximum magnitude earthquake for the OZD.

In summary, the Board finds, based upon the geologic and seismic characteristics of the OZD, including its length, that M_S7 is the maximum magnitude earthquake that could occur on the OZD. It is, within the meaning of the regulations, the safe shutdown earthquake for the San Onofre site.

C. Strong Ground Motion.

Although the engineering design basis for the San Onofre plants (referred to here as the "design spectrum") had been established in 1972 based on peak ground acceleration (PGA) data and analytical methods then available, the maximum magnitude earthquake that could occur on the OZD (the SSE) was not then determined. Having now established an SSE of $M_S 7$ on the OZD, the evidence went to demonstrating what ground motions might result at the site from such an earthquake, and to comparing those with the design spectrum motions to which the plants were designed.

This case involved predicting strong ground motions in the "near-field" of a large earthquake. There is no precise definition of "near-field," but there is general agreement that for a large California earthquake, 10 km from the fault qualifies. San Onofre is about 8 km from the closest approach of the OZD.

Perhaps the most serious difficulty in predicting near-field strong ground motion arises from the relatively small data base. Strong ground motion predictions are based upon instrumented recordings which have only been available for about 50 years. During that time, there have been relatively few large earthquakes in geologic settings similar to San

Onofre. Fewer still of those earthquakes have been well recorded.

The Applicants nevertheless presented extensive testimony and voluminous exhibits in the strong motion area, making the most of the available data. The Intervenors did not present any similar studies. They took the position that the present data base is too limited to allow confidence in any predictions about strong ground motion. Dr. Clarence Allen, a distinguished seismologist and a subpoenaed witness for the Intervenors, took a middle view. He acknowledged limitations in the present data base, but considered it sufficient to make some useful predictions. The Board agrees with that veiw.

Empirical Analyses.

The Applicants presented two empirical analyses of strong motion data to determine PGAs that might result at the site from an M_S7 earthquake on the OZD 8 km from the site. Both analyses made use of data bases (not the same) carefully selected to include recordings in the near-field of large earthquakes on strike slip faults, and in reaso ably similar geologic settings. Each data base was subjected to regression analysis to determine the site specific accelerations. The results were compared with the corresponding values to which San Onofre Units 2 and 3 had been designed in order to test the adequacy of the design. In all cases the design parameters were greater than those predicted by the regression analyses, indicating an additional margin of safety in design.

The Board concludes that these empirical studies have substantial probative value. They were independently conducted, produced consistent results, and withstood the test of cross-examination. Although more data in the near-field might give us greater confidence in the results, we nevertheless believe that the available data provides an adequate basis for the conclusions reached.

Theoretical Modeling Studies.

The empirical studies were complimented by theoretical modeling of strong ground motion at the San Onofre site. Theoretical modeling of the physical processes of earthquakes by the use of computers is a relative recent development. This method attempts to correlate observed earthquake phenomena with their possible physical causes through mathematical descriptions and computer simulations. Models provide a sophisticated method for extrapolating site specific ground motions from recorded past earthquakes at other sites. Because models have built into them principles of rupture physics and weight mechanics, fewer data are needed to make extrapolations than from conventional methods.

The modeling studies performed for San Onofre were extremely complex. They produced PGA results well below the 0.67g value embodied in the design spectrum. The studies were the subject of extensive cross-examination and they were also reviewed critically by a Board witness. The questions raised in these discussions typically went to abstruse aspects of the theoretical model. Suffice it to say for our purposes that none of these questions appeared to suggest fundamental flaws in the model; rather, they seemed to relate to refinements that might be made. In any event, the Applicants had responsive answers to all the questions that were raised.

The NRC Staff states that "as of this time, no consensus with sufficient detail exists within the seismological community that would allow the exclusive use of theoretical models in order to estimate ground motion in the near-field." The Board agrees with this observation. Until there is greater experience with modeling techniques, we think it would not be prudent for a licensing board to make definitive determinations about some of the very technical questions that have been raised by critics -- unless such determinations are necessary to decide the case, a situation that does not obtain here. However, we believe that the modeling studies performed for San Onofre can be taken into account as further evidence of the adequacy of the design spectrum. We were impressed with the level of effort devoted to these studies. It is particularly significant that their results were validated against near-field recordings of several California earthquakes in the distance range relevant to San Onofre.

The Intervenors called as a witness Dr. David Boore of the U.S. Geological Survey. Dr. Boore is a coauthor of a recent scholarly paper on predicting strong ground motion. Application of an equation from the Boore paper produced a predicted PGA in excess of the 0.67 PGA now incorporated in the design spectrum. Both the Staff and the Applicants argued that the data base in the Boore paper was biased against accurate predictions in the near-field. The authors appeared to concede that point noting that "for distances less than 40 km from earthquakes with M greater than 6.6 the prediction equations are not constrained by data, and the results should be treated with caution." The Applicants also stressed that the Boore equations did not take into account the effects of magnitude saturation in the near field, a subject discussed in the findings.

The Board believes that the Boore formula probably does not produce accurate predictions in the near field of large earthquakes. It is particularly significant that when data recorded beyond 50 kilometers is excluded from the analysis, the predicted PGA values are well below the 0.67g previously established for San Onofre.

Development of the Design Spectrum.

The Applicants' presented evidence on the development of the engineering design spectrum for the facilities, based upon the results of PGA studies. A number of conservatisms were incorporated into the design spectrum, providing additional margins of safety. Perhaps the greatest conservatism is represented by the fact that the design spectrum for San Onofre was taken directly from the instrumental spectrum derived from predicted PGA data. This is contrary to standard engineering practice, in which the design spectrum is usually scaled down from the instrumental spectrum by taking into account the site geology and characteristics of the structures to be erected.

In this case, no allowances were made for mass, depth of embedment or other factors that cause the motions governing structural response to be less than those recorded by free field instruments. In this connection, a Staff witness, Dr. Leon Reiter, testified that he considered the facility, one of at least 30 he has reviewed, to be probably the most conservatively designed.

Other Strong Motion Issues.

Several related matters were considered in connection with the strong ground motion question. The Board finds that some recent recordings of unexpectedly high vertical accelerations are not relevant to the safety of San Onofre. On the question of magnitude saturation, the Board determines that the existence and significance of that phenomenon were not very convincingly demonstrated. However, the record supports a finding that saturation probably does occur at about M_S6.5-to-7, and that it probably would result in moderation of peak ground accelerations in the near field.

We also considered the possible effect of focusing of seismic waves (sometimes called directivity) in the San Onofre context. The Applicants proved that the focusing phenomenon, while a matter of some significance, is not of great safety concern. Moreover, the spatial relationship between the San Onofre site and the OZD indicates that high degrees of focusing are not likely to occur there.

D. Newly-discovered Geologic Features.

Several geologic features in the area were discovered after the construction permits were issued in 1973. Testimony was presented concerning whether these features compromised the seismic design of the San Onofre facilities. As matters developed, this contention was essentially uncontested; although the Intervenors questioned the Applicant and Staff witnesses, they did not put on a direct case, and they presented only a few proposed findings.

In 1974 anomalous geologic features were discovered in the rock at or near the site excavation for Units 2 and 3. These features were designated the "A, B, C and D" features by the Applicants and reported to the NRC Staff. The Staff requested the Applicants to perform a study of these features in order to assess the possibility of ground rupture under the reactors. The Applicants thereafter undertook extensive and detailed investigations, and filed a thorough report with the NRC Staff.

The ABCD features are minor features; there has not been any significant movement (displacement) on them for a long time, probably about 100,000 years. These features, which may or may not be of tectonic origin, are referred to variously in the record as "joints," "shears" and "faults." But in view of their small aggregate displacements and the long periods of time since any displacement, it makes no practical difference what label is affixed to them. They have no safety significance for San Onofre.

Several other minor and newly-discovered geologic features were also explored at the hearing. However, the evidence was largely uncontradicted and the Board finds that these features are also of no safety significance.

E. <u>The Cristianitos Zone of Deformation</u>.

Subsequent to the issuance of the construction permit for San Onofre Units 2 and 3, two geologists, Drs. Greene and Kennedy coined the name "Cristianitos Zone of Deformation" (CZD) for an area of the sea floor lying to the south of the San Onofre site and between the site and the OZD. Greene and Kennedy, employees of the USGS and the California Division of Mines and Geology, respectively, were subsequently asked by the NRC Staff to review the relationships between the CZD and the OZD. Their review is included in the Staff's Safety Evaluation Report and both appeared as witnesses in the hearings.

Their review characterized the CZD as a zone of fractured and faulted structures consisting of correlateable faults and folds that extended, offshore of San Onofre, to within one kilometer of the OZD. They concluded that the CZD merges with or is truncated by the OZD.

The Intervenors sought to show that movement on the OZD might initiate movement on the CZD, and that the onshore Cristianitos fault was a part of the CZD. Under this theory, an earthquake on the OZD might ultimately cause movement on the

Cristianitos fault, which closely approaches the San Onofre site.

Greene and Kennedy indicated on maps accompanying their review that there were "data voids" in certain critical areas such that they could not determine precisely how or whether the CZD and OZD are associated. The data voids were extensively explored during the hearings and for compound reasons it became obvious that attempting to collect more data in the data void areas probably would not remove those labels from the maps. Data voids did not necessarily indicate a lack of data; rather the lithology and sediments on the ocean floor and electronics of the method combined in such a way as to make data interpretation difficult or impossible.

The Applicants carried out a massive research program which included both onshore and offshore data gathering. Analysis of that data reveals in a convincing and professional manner that the CZD is an area of relatively minor faults and folds, as compared to the OZD. The faults associated with the CZD end at or below the surface with no evidence of seafloor displacement. No faults of the CZD extend onshore and the Cristianitos fault does not have a connection or other structural relationship with the OZD. The evidence supports the conclusion that the last displacement on faults of the CZD occurred in Miocene times, about 5 to 6 million years ago. Thus, even assuming that the CZD and OZD merge, as Greene and Kennedy concluded, the inactivity of the CZD faults means that this merger has no safety significance for San Onofre.

III. FINDINGS OF FACT

A. Introductory Findings.

1. Site Description. The Applicant's proposed findings of fact begin with groups of introductory and background findings (AF 19-149)[51/]. Most of these findings are expressly adopted by the Staff (SF 30-32) and none of them are contested. Some of these proposed findings -- notably those concerning the characteristics of the OZD -- are more appropriately addressed in the context of specific issues. But we believe that the Applicants' proposed findings 47-60, 103-111, 124-125, 133-135 and 139-146 are helpful as introductory material, and we find that they are supported by the record. We are adopting these findings verbatium, as proposed, in the following 37 paragraphs.

Many of the findings incorporate portions of findings proposed by the parties, either verbatium or in close paraphrase. In some cases, we have adopted an entire proposed

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51/ Proposed findings of fact will be cited beginning with an "A" for applicants, "I" for Intervenors and "S" for the NRC Staff, followed by "F" for findings and a number for the appropriate paragraph. For example "AF 19" denotes paragraph 19 of the Applicants' proposed findings.

Exhibits ("Ex.") will be cited similarly -- e.g., "A. Ex. 25" denotes Applicants' Exhibit Number 25. The Staff's Safety Evaluation Report (S. Ex. 1) is usually cited as "SER."

finding or group of findings exactly as proposed; that is indicated by explicit attribution and/or quotation marks.

2. "The SONGS[52/] site is within the Camp Pendleton Marine Corps base on the coast of southern California, in northern San Diego County, approximately 62 miles southwest of Los Angeles and approximately 51 miles northwest of San Diego." (J. Smith, written testimony, p. 8; Figure JLS-A).

3. "The site lies on a rather narrow, gently sloping coastal plain that extends seaward from the mountain upland on the east and is terminated by a line of sea cliffs having a narrow beach at their base. The sea cliffs rise to heights of 60-100 feet above sea level, and are incised by eroding guillies and large ephemeral streams that drain the mountains northeast and southeast of the site. The major drainage channels are San Mateo Creek approximately 2-3/4 miles northwest of the site, San Onofre Creek approximately 1 mile northwest of the site, and Las Flores Creek approximately 7-1/2 miles southeast of the site." (J. Smith, written testimony, pp. 8-9; Figures JLS-B, JLS-C).

4. "A rectangular area has been excavated approximately 60-80 feet below the original surface of the coastal plain to accommodate the site facilities. The excavated area is bounded by cut slopes that provide excellent exposures of soil and rock

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52/ "SONGS" is an acronym sometimes used to denote the San Onofre Nuclear Generating Station.

units at the site." (J. Smith, written testimony, p. 9; Figure JLS-D).

5. "The beach at SONGS is covered by thin sand layer -- up to ten feet thick -- and is horizontal for about 50 to 100 feet from the sea cliff before sloping an additional 100 to 150 feet into the tidal zone at a slope of about 5%." (J. Smith, written testimony, p. 9).

6. "The sea floor off San Onofre slopes less than about 1% for the first 13,000 feet, and then 1.25% out to the edge of the continential shelf at a distance of 4.6 miles, where the water depth is about 300 feet. Beyond this the continental slope is also gentle, sloping between 9-10% to a depth of 2400 feet at 8.8 miles from shore." (J. Smith, written testimony, p. 9).

2. Regional Geology.

7. "The geomorphic provinces of southern California display distinctive geomorphic and tectonic characteristics, and thereby provide a useful framework for discussion of regional geology. SONGS lies near the western edge of the Peninsular Ranges Province, which includes the Los Angeles Basin at its north and a series of mountain ranges and valleys trending northwest and extending southward into Mexico. The rocks of this province are chiefly granitic and intrusive rocks that are 80-120 million years old; older rocks of sedimentary and volcanic origin metamorphosed by the intrusive rocks; and marine and nonmarine strata of Late Cretaceous, Tertiary and

Quaternary age. The rocks of this province most important to SONGS are the Miocene and younger sedimentary units including the San Onofre Breccia, the Monterey, Capistrano and San Mateo Formations, and Pleistocene terrace and alluvial deposits." (J. Smith, written testimony, pp. 10-11; Figures JLS-E, JLS-F).

8. "West of the Peninsular Ranges Province lies the Continental Borderland Province of southern California. It includes the offshore basins and ridges between the continental shelf and the continental slope approximately 200 miles offshore, the western edge of the Los Angeles Basin and the Palos Verdes Peninsula, and the islands of Santa Catalina and San Clemente. The basement rocks of this province are largely metamorphic, and are referred to as Catalina schist or Franciscan-type basement. The contact between this basement lithology and the granitic or continental basement of the Peninsular Ranges is generally believed to coincide at depth with the Newport-Inglewood zone of folds and faults in the Los Angeles basin. Sedimentary rocks overlying the basement are thick and widespread, and range in age from late Miocene to late Pleistocene age. Stratification of these formations and their contacts with other formations are readily discernible in offshore seismic reflection profiles because the formations have contrasting geophysical properties which permit recognition of structural features, important time lines, and zones of deformation." (J. Smith, written testimony, pp. 11-12; Figure JLS-E).

9. "North of the Continental Borderlands and Peninsular Ranges Provinces, the east-west trend of the Transverse Ranges Province lies across the northwest grain of California geology. The rocks of the Transverse Ranges include granitic and metamorphic rocks of pre-Tertiary age and deformed Tertiary sedimentary rocks. The transverse orientation of the province is attributed to crustal shortening, folding and uplifting of major blocks within the western part of the province that took place largely prior to about 13 million years ago. Subsequently, thrust faulting has been active along the southern margin, and translation along the San Andreas fault zone has caused a rightlateral offset of the eastern end of the province." (J. Smith written testimony, pp. 12-13; Figure JLS-E).

10. "The Salton Trough Province lies east of the Peninsular Ranges, and, at its closest approach, is about 70 miles from San Onofre. It constitutes a series of increasingly broad valleys draining southward toward the Gulf of California. Basement rocks in this province are granitic and metamorphic rocks of pre-Cenozoic age, and they are overlain by thick sedimentary and volcanic rocks of late Tertiary age. Tectonic activity is intense in this province because of translation along the crustal plate-boundary and lateral extension across active spreading centers in the southern part of the province." (J. Smith, written testimony, p. 13; Figure JLS-E).

11. "The tectonic framework of the site region consists of faults and other expressions of deformation. The site region is

dominated by the San Andreas fault zone, a crustal dislocation extending over 600 miles from north of San Francisco, south through California and into the Gulf of Mexico, having a cumulative strike-slip displacement of more than 300 miles. Northwest of the Transverse Ranges the fault zone has a relatively simple pattern of long and narrow breaks, whereas to the southeast it bends broadly and splits into the San Andreas and the San Jacinto zones. The entire series of faults constituting the San Andreas-San Jacinto fault zone is about 30 miles wide at the latitude of San Onofre and marks the rupture boundary along which two major crustal plates have been moving for millions of years. The nearest approach of this zone to San Onofre is about 45 miles." (J. Smith, written testmony, p. 14; Figure JLS-G; Tr. 808, 813).

12. "Northwest-trending structural zones in southern California came into being about 30 million years ago. Although the San Jacinto fault developed much later, both it and the San Andreas have been continuously active and characterized by high slip rates during Pleistocene time and by modern seismicity. Surface expression of recent faulting is more prominent and continuous for the San Andreas-San Jacinto zone than for any other fault in southern California." (J. Smith, written testimony, pp. 14-15; Figure JLS-G; Tr. 815-816).

13. "The Whittier-Elsinore fault is roughly parallel with the San Andreas-San Jacinto zone and lies about 23 miles east of SONGS. It extends from the southern boundary of the Tansverse

Ranges to the Mexican border, a distance of approximately 145 miles. Its principal movements have been a combination of lateral and dip-slip motion. Cumulative horizontal displacement is small, approximately 8-13 km. During the last five million years, major lateral motion on the zone has been buttressed on the north by the Transverse Ranges." (J. Smith, written testimony, p. 15; Figure JLS-G; Tr. 820).

14. "The Santa Monica-Malibu Coast fault is a north-dipping reverse fault forming the northern boundary between the Transverse Ranges and the geomorphic provinces to the south. Although early movement on the fault may have been left-lateral slip, much of the movement during the last five million years has been reverse dip-slip (thrust), reflecting north-south compression associated with the San Andreas stress-strain system." (J. Smith, written testimony, p. 15; Figure JLS-G).

15. "The Newport-Inglewood zone of folds and faults crosses the Los Angeles basin from the northwest, where it is terminated at the surface by the Santa Monica-Malibu fault zone, southward to Newport Beach where it projects offshore to the southeast." (J. Smith, written testimony, p. 16; Figure JLS-G).

16. "The Capistrano Embayment is a north-south trending structural trough about 22 miles long that is bounded by the Cristianitos fault on the east and the San Joaquin Hills on the west. The trough has a narrow wedge-shape that opens southward

and is about 9 miles wide at the coast." (J. Smith, written testimony, p. 38).

17. "Mapping and interpretation of subsurface data indicate that the Capistrano Embayment is a downwarp produced by westward extension and gravity sliding in the upper crust between the Cristianitos fault and the Los Angeles Basin between about 10-4 million years before present. Further opening of the Embayment and renewed movement on the Cristianitos fault are precluded now because crustal stresses have changed direction and the Los Angeles basin is now filled with sediments that prevent sliding." (J. Smith, written testimony, p. 38; P. Ehlig, written testimony, pp. 17-18, 28-29; Tr. 971-974)."

3. <u>Geologic Evolution of the Region</u>.

18. "The geologic evolution of the SONGS region has been complex and has produced significant structural features and stratigraphic units. Beginning about 200 million years (m.y.) ago eastward subduction in the vicinity of the Peninsular Ranges brought together oceanic crust and continental crust. Sediments accreted against the continental crust during Triassic and Jurassic time, and volcanic rocks were emplaced over them in Late Jurassic and Early Cretaceous time. From 120 m.y. to 85 m.y. ago (Cretaceous time) the sedimentary/volcanic sequence was intruded by granitic batholiths accompanied by uplift and erosion. Subsequent subsidence along the western margin of the Peninsular Ranges permitted the sea to transgress eastward, forming a shoreline and depositing sediments against the

batholithic rocks along a tectonic hinge line called the Santillan-Barrera line." (P. Ehlig, written testimony, p. 4-6; Figures PLE-A, PLE-B).

19. "From Late Cretaceous through Early Miocene time (90-20 m.y. ago), the coastline changed and transgressed landward across the Santillan-Barerra line. During Early Miocene time (about 20 m.y. ago) the shoreline was west of SONGS and trended north-northwesterly." (P. Ehlig, written testimony, p. 6-7; Figure PLE-C).

20. "Conditions changed radically about 16 m.y. ago (Middle Miocene time), resulting in: the appearance of Catalina Schist at the surface offshore; shedding of schist debris northeasterly to form the San Onofre Breccia; widespread volcanism within and north of the San Joaquin Hills; and crustal extension causing opening of the Los Angeles Basin and development of northwest-trending ridges and basins in the Continental Borderland." (P. Ehlig, written testimony, p. 7-8; Figures PLE-D, PLE-E).

21. "The Continental Basement of the Peninsular Ranges became juxtaposed with the Franciscan schist basement offshore along a major zone of faulting. The juxtaposition of different basement rocks is important because the two formed in very different environments and indicate emplacement against each other by faulting." (P. Ehlig, written testimony, pp. 8-9; Figure PLE-F).

22. "The contact between the different basement rocks near SONGS probably lies offshore along the OZD, but the presence of a thick sedimentary cover inhibits verification." (P. Ehlig, written testimony, p. 9; Figure PLE-F).

23. "During Middle Miocene time a southward-plunging uplift developed in the San Joaquin Hills simultaneously with emplacement of volcanic rocks and the possible intrusion of gabbro in the underlying basement." (P. Ehlig, written testimony, p. 11).

24. "In the period from 16 to 14.5 million years ago the Los Angeles Basin began to open and subsidence progressed throughout the area to produce a deep water basin conducive to accumulation of laminated diatomaceous shale of the Monterey formation. The Monterey formation interfingers with massive sandstone deposited as small submarine fans along the coast southeast of SONGS, reflecting the presence of a relatively steep submarine slope along the western margin of the Peninsular Ranges." (P. Ehlig, written testimony, pp. 11-12).

4. <u>Regional Seismicity</u>.

25. "The south coast region has not been an area of high seismic activity during either the instrumental or pre-instrumental historic period dating back to 1769." (S. Smith, written testimony, p. 5).

26. "Although earthquakes less than magnitude 4 are widely distributed over southern California, they show a clustering along major faults on which larger earthquakes have occurred.

Localized stress concentrations associated with microearthquakes occurring throughout California have little bearing on the pervasive regional stress required to generate significant damaging earthquakes. No significant zone of seismic activity has existed during the nearly half century during which accurate recording of earthquake location has been possible. This data supports the idea the principal plate boundary at the latitude of SONGS occurs on the San Andreas and San Jacinto fault systems, and that activity generally decreases westward away from these faults." (S. Smith, written testimony, pp. 5-6; Figures SWS-A, SWS-B, SWS-C, SWS-D; Tr. 1553).

27. "The nature of the stress fields operative at the present time, and at the time of development of the OZD, have been investigated to arrive at an assignment of maximum magnitude. To compare this with the contemporary record of seismicity, earthquake focal mechanisms have been determined to provide the most direct way of estimating slip directions of faults during earthquakes. From the slip direction or focal mechanism during earthquakes, the direction of principal stresses can be inferred." (S. Smith, written testimony, pp. 8-9).

28. "Despite difficulties of limited seismographic coverage up until the last decade in southern California, and the continuing lack of seismographic coverage on all sides of a coastal site, some information on focal mechanisms in the southern California coastal region is available. The principal

conclusion drawn from the focal mechanisms, whose pattern is irregular with little preference for any one slip direction, except some preference for a general northerly direction for the compressive axis, is that regional stress levels are not high along the south coast region. If the SONGS areas were part of the active section of a plate margin, much more consistency in focal mechanism and a higher level of seismicity would be expected." (S. Smith, written testimony, pp. 9-10).

29. "Where stress levels are not dominated by a regional stress field, then residual stresses that are much more influenced by local geologic conditions, which are more irregular, will be the ones revealed by current seismic activity." (S. Smith, written testimony, p. 10).

5. Wrench Tectonics.

30. "During the hearing, several attempts were made to characterize the OZD and other faults in terms of "wrench tectonics." Current theories of wrench tectonics attempt to relate certain types and patterns of shallow folding and faulting to horizontal shearing strain within the underlying crystalline crust, based on experimental deformation produced in clay models. In wrench fault modeling, surface deformation develops directly above the shear zone at depth. Consequently, such deformation cannot be extrapolated for great distances away from the fault to attribute all of the regional deformation to wrench faulting, particularly as suggested by simple laboratory

experiments." (P. Ehlig, written testimony, p. 23; Tr. 1023, 1026, 1027).

31. "The basic concepts of wrench tectonics have been known for several decades in association with studies of strike-slip faults, but they have become popular recently because they may permit the identificaiton of zones along which petroleum-bearing structures may occur in a systematic pattern. Because petroleum interest is in the overlying sediments, basement rock at depth is modelled to produce the deformation seen in the near surface, which may not be appropriate for normal rock and which does not indicate what is happening at depth. (P. Ehlig, Tr. 1023). Aside from establishing a sense of shear, however, wrench tectonic concepts do not deal with the nature, origin and causes of deepseated basement deformation." (P. Ehlig, written testimony, pp. 23-24; Tr. 1023).

32. "The theory of wrench fault tectonics makes many simplified assumptions that lead to very simple patterns so that one can explain any pattern of deformation given the right scheme. However, to be correct it is necessary to put the deformation into the context of a given region." (P. Ehlig, Tr. 975).

33. "The concept of wrench fault tectonics as used by Wilcox and others (1973) and Moody and Hill (1956), involves ways to produce every type of deformation seen. This is objectionable because, unless one looks at the details on a local basis, one cannot conclude whether or not something is the

result of complex motion in a lateral shear system." (P. Ehlig, Tr. 1030-1031).

34. "Wrenching is the process of deforming near-surface rocks by horizontal shearing strain along a steeply-inclined zone or fault within the underlying basement. A wrench fault is a high-angle strike-slip fault of great linear extent which involves basement deformation. A wrench zone is a swath of terrane deformed by wrenching prior to and concurrently with strike-slip along the throughgoing wrench fault." (P. Ehlig, written testimony, p. 24).

35. "Among the major weaknesses of wrench tectonic concepts is the fact that local stress fields change orientation through time due to interaction between the crustal plates, with the result that faults and folds formed during one stage of the tectonic evolution of a region may be inactive during a later stage when other types of deformation may be taking place along a new orientation. Furthermore, most of the earth's crust is inhomogeneous and new ruptures tend to follow surfaces of weakness. Thus, the geometry of faulting is influenced by the fabric of the crust and not just the orientation of the stress field. Although wrench tectonic concepts and models may be used to identify wrench zones underlain by deepseated strike-slip faults, the concepts are of little value when interpreting regional tectonic history." (P. Ehlig, written testimony, pp. 25-26).

36. "The OZD does not fit into a wrench tectonic system because of its geologic evolution. For example, assuming the OZD marks the boundary between the Peninsular Range basement and the Catalina Schist, the OZD originated about 15 to 16 million years ago during the Middle Miocene. At that time the OZD was probably part of a system of right-lateral wrench faults which formed the Pacific-North American plate boundary within the California Continental Borderland. Now, however, activity on the OZD is in response to the effects of crustal compression along the Big Bend in the San Andreas fault, or to drag along the plate boundary. Therefore, Quaternary deformation along the OZD is a secondary effect of interaction between the Pacific and North American crustal plates, and the theory of wrench faulting is not applicable to the OZD at the present time." (P. Ehlig, written testimony, pp. 27-28; Tr. 1016).

37. "The northwest-trending faults west of the San Andreas fault to the San Clemente fault are strike-slip faults, but they are not all characterized by exclusive strike-slip motion, they have not all been active simultaneously, and they have not necessarily been part of the plate boundary. Thus, it would be inappropriate to consider them as wrenching the blocks between them." (P. Ehlig, Tr. 1027-1029).

B. <u>The Safe Shutdown Earthquake</u>

1. <u>Introduction</u>. Contention 4 states that:

> Whether based on the geologic and seismic characteristics of the OZD, incuding its length, assignment of M_S7 as the maximum magnitude earthquake for the OZD renders the seismic design basis for SONGS 2 and 3 inadequate to protect the public health and safety.

The Board appreciates the historical prespective presented in the SER (Section 2.5) on Geology, Seismology and Geotechical Engineering and adopts Findings 13, 15, 16, and 17, in part, of the Staff's Proposed Findings of Fact for review of that historical and factual perspective. These findings relate to conclusions reached prior to construction permit issuance and are adopted and repeated in the following Findings numbered 2 through 5. The Board also appreciated the clear exposition of the different magnitude measurements of earthquake source size as set forth in the SER and in the Staff's Proposed Findings of Fact 23 in part, 24, 25, 26, 27, and 28. These Findings are adopted and repeated as Findings 6 through 11 in the following text. These are not matters in controversy and are adopted here for their explanatory value.

2. "The geology and seismology of the site were reviewed in detail prior to issuance of construction permits for San Onofre 2 and 3 by the Staff of the U.S. Atomic Energy Commission (AEC), the predecessor to the U.S. Nuclear Regulatory Commission (NRC), and its geological and seismological advisors, the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA), respectively. The findings

of that review were published on October 20, 1972 as part of the Safety Evaluation Report relating to construction of San Onofre 2 and 3. (SER § 2.5.1.1.) These matters were fully considered by the Atomic Safety and Licensing Board (CP Licensing Board) in a contested proceeding as reflected in its Initial Decision, LBP-73-36, 6 AEC 929, 938-950 (1973)."

3. "A comprehensive geological investigation of the site region performed by the Applicants included detailed examinations of excavation along the Cristianitos fault and of the sea cliff exposures, geologic mapping, and field examinations, and offshore seismic reflection profiles. The information and the data were presented to the AEC in the San Onofre 2 and 3 Preliminary Safety Evaluation Report with amendments, which was reviewed by the Staff and its advisors (SER § 2.5.1.1) and was considered by the CP Licensing Board."

4. "The Staff interpreted the geologic information and data to indicate the existence of a zone of deformation about five miles offshore from the San Onofre site which extends from the Newport-Inglewood fault zone to the north, to the Rose Canyon fault zone to the south. It concluded in the Safety Evaluation Report:

> The present evidence indicates an extensive, linear zone of deformation, at least 240 kilometers (km) long extending from the Santa Monica Mountains to at least Baja, California. We and our consultants consider this zone of deformation to be potentially active and capable of an earthquake whose magnitude could be commensurate with the length of the zone. Onshore, data does not show evidence that there are any faults immediately underlying the planned reactor facilities. Although the site is located

> within 1 mile of the Cristianitos fault zone, exposures of parts of this fault at the coast and at the Plano Trabuco excavations made by the applicant about 16 miles north of the coastal exposure, show that the overlying terrace deposits have not been offset by the fault at these locations. All of the avaiable evidence indicates that the Cristianitos fault is inactive when evaluated using procedures described in the proposed 10 C.F.R. Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," November 25, 1971. (Id.)"

5. "The essence of this conclusion with respect to the offshore geology was expressly adopted by the CP Licensing Board in its Initial Decision (LBP-73-36, supra, at 943, finding 61), as the "model...appropriate...for use in evaluating the effect of those facilities on the health and safety of the public."

6. "In the CP review the Staff and its seismological advisor (NOAA) used a Modified Mercalli Intensity of X to characterize the maximum earthquake that could affect the San Onofre 2 and 3 site. This earthquake was assumed to occur along the Offshore Zone of Deformation (OZD) about five miles from the site. During the OL review the Staff concluded that magnitude is a better indicator of earthquake source strength than intensity. Intensity is a measure of observed damage and felt effects. It depends upon the size of the earthquake, its depth, the distance from the earthquake source, the nature of the geologic materials between the source and the point of observation itself. Although an attempt is made in the intensity scale to account for differences in structural design, it is only done in a very general way. Particular problems are associated with determination of intensities greater than VIII.

Very often these intensities are based upon ground failure (landslides, soil liquefaction, etc.) which are very much dependent upon local conditions rather than ground shaking. Many investigators (for example, Nason, 1978; and Tocher and Hobgood, 1978) have suggested great caution in assigning these high intensities. (SER § 2.5.2.3)."

7. "Magnitude is a measure of earthquake source size using instrumental recordings of ground motion at different distances. Different magnitude scales measure different components of motion in different frequency ranges and care must be exercised in choosing the appropriate scale for the intended purpose. Local Magnitude (M_L), the original magnitude scale, was developed from recordings of small earthquakes (M_L less than 5.0) at distances between 20 and 600 km in southern California. It is determined utilizing the largest ground motion recorded on the Wood-Anderson seismograph. As a result, it is particularly sensitive to short period (about 0.8 seconds) horizontal motion. It is not applicable at distances greater than 500 or 600 km and must be used with great care outside of California. (Id.)"

8. "Surface wave magnitude (M_S) was developed subsequently to complement M_L for earthquakes of greater size and at different locations. It is determined from longer period (20 second) motion. Richter magnitude (M) as it is commonly, but very often not precisely, used is equal to M_L for

magnitudes less than about 6 and M_S for larger earthquakes (Nuttli, 1979). (Id.)"

9. "The reason M_L cannot be used for larger earthquakes is the apparent saturation of the scale at around 7 1/4. The great San Francisco earthquake of 1906, for example, had an estimated M_S of 8 1/4 while the M_L is only estimated to have been between 6 3/4 and 7 (Jennings and Kanamori, 1979). M_L saturates because the amplitude of the shorter period waves which determine M_L do not simply increase as the fault length increases. As Kanamori (1978) states, "The amplitude of seismic waves represents the energy released from a volume of crustal rock whose representative dimension is comparable to the wave length." Seismic waves used in the determination of M_L may only reach wave lengths of 6 km. Thus, they cannot be expected to adequately reflect the energy release of earthquakes associated with ruptures tens of kilometers long. Similarly, they do not adequately reflect the seismic moment of such earthquakes. (Id.)"

10. "Seismic moment, defined as being equivalent to the product of rigidity, fault area, and fault displacement, is the measure most easily related to geologic fault parameters. (Id.)"

11. "In the range of interest for San Onofre (magnitude 6 to 7.5), M_S, determined from waves whose lengths are about 60 km, is more related to seismic moment than M_L. According to Kanamori (1979), at magnitudes greater than 6, the average M_L

begins to deviate and becomes less than the average M_S for the same earthquake until the M_L reaches the previously mentioned saturation point of about 7 1/4.[53] According to Kanamori's estimate, an M_S of about 7 would have an average M_L of 6.6 or 6.7. By assuming a simple linear relationship between M_S and M_L, Nuttli (1979) arrives at a similar result. (Id.) Thus, in estimating earthquake size from fault studies in southern California, the most directly relateable magnitude scale based upon rupture lengths less than hundreds of kilometers would be M_S."

12. References to earthquake magnitude are to M_S in the rest of this decision unless otherwise noted.

13. During the course of the hearings in San Diego numerous, well-qualified witnesses appeared regarding the geology and seismology of the San Onofre region of southern California. This included extensive testimony on the Offshore Zone of Deformation (OZD) and estimates of the maximum magnitude earthquake which might be generated by it.

14. The primary witnesses for the Applicants were Mr. J. L. Smith, Dr. P. L. Ehlig, Mr. E. G. Heath and Dr. S. W. Smith. The Intervenors called Dr. James Brune, Mr. Mark Legg,

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53/ M_S also saturates at about 8.3 and does not reflect the energy release in a truly great earthquake where fault rupture reaches hundreds of kilometers. For this purpose, a new magnitude scale M_W was developed (Kanamori, 1978). For example, the great Chilean Earthquake of 1960 had an M_W of 9.5 while its M_S was only 8.3 (Id.)

Dr. Gordon Gastil, Mr. Clarence Allen and Dr. John Anderson. The Staff's witnesses were Mr. A. T. Cardone, Dr. L. Reiter, Mr. J. F. Devine, Mr. R. F.Morris and Dr. D. B. Slemmons. (J. Smith, written testimony; Ehlig, written testimony; Heath, written testimony; S. Smith, written testimony; Brune, written testimony, ff. Tr. 4122, Legg, written testimony, ff. Tr. 5213; Staff Exhibit 1, SER, Sections 2.5.1.2, 2.5.1.11, 2.5.2.1, 2.5.2.3.1, 2.5.2.3.2, 2.5.2.3.4, 2.5.2.4; Cardone, supplemental testimony, ff. Tr. 5560; Reiter, supplemental testimony, ff. Tr. 5566; Slemmons, Tr. 5458; SER, Appendix E and Appendix G).

15. As the hearing progressed, it became increasingly obvious that the state of the art in predicting maximum earthquakes is such that no single approach to the question is accepted as yielding the definitive answer. Moreover, there are a number of ways of estimating the maximum earthquake that could affect a given site. Estimates of maximum earthquakes focus upon nearby faults and the principal factors to be considered include the seismic history of the area, the gelogic record of deformation, the regional stress as inferred from focal mechanisms and the faulting characteristics of the particular structure of concern. (S. Smith, written testiony, p. 4-5.

2. <u>Historic Seismicity</u>.

16. The area of southern California that includes the San Onofre site has not been an area of high seismic activity in historic times. The historic California record goes back to

mission records (1769) and since 1932 we have modern instrumental records. (SER § 2.5.2.2; S. Smith, written testimony, p. 5; FSAR Section 2.5.1.1; Tables 2.5-1 and 2.5-3; Tables 2.5-2 and 2.5-4).

17. Of all the historical earthquakes identified by the Applicant, three are of particular interest. These occurred on November 22, 1800, December 8, 1812 and March 11, 1933. The California Division of Mines and Geology has estimated magnitudes for the 1800 and 1812 events based upon felt reports. The 1800 event was near San Diego, while the 1812 event was near San Juan Capistrano and destroyed the mission there. There were few European settlements in California at the time of these events and the locations ascribed to these earthquakes can only be considered approximations. Both of these early earthquakes were considered to have had magnitudes of 6.5. It is not clear whether this is M_S or M_L, but since the calibration function used to determine magnitude (Toppozada, 1975) used mostly M_S for larger events, it seems reasonable to assume that M_S is the appropriate measure. (SER 2.5.2.3.1).

18. The 1933 earthquake had its epicenter on the Newport-Inglewood fault zone (NIZD) and is the largest instrumentally recorded event in the south coastal area of California. The NIZD is the northern section of the OZD. This earthquake had both an M_S and an M_L of 6.3. (SER § 2.5.2.3.1).

19. A fourth earthquake of note was reported on February 24, 1892. Information on this event is limited to felt reports; it was felt strongly in southern California, southwestern Arizona and Baja California. Based upon interpretations of the felt reports, it was suggested this event, possibly associated with the Agua Blanca fault in Baja California, could have had a magnitude of close to M_S 8. Reinterpretation of the felt reports has led to a more recent and more detailed account which suggests the 1892 event had a magnitude of 6.9 (probably M_S) and was located in the Peninsular Range of northern Baja California. That fault system is believed to be related to the spreading of the Gulf of California rather than the San Miguel Fault Zone or other postulated extensions of the OZD into Baja California. (SER § 2.5.2.3.1).

20. The largest instrumentally recorded earthquake in Baja California of postulated significance to San Onofre was the El Alamo event of February 9, 1956. That earthquake was associated with the San Miguel fault, had a surface rupture length of at least 19 km and magnitudes of M_S 6.8 and M_L of 6.6. Evidence for a connection of the San Miguel fault with the OZD is discussed in subsequent findings. (SER § 2.5.2.3.1).

21. The largest historical earthquakes of use in assessing the maximum earthquake on the OZD are M_S 6.3, 6.5 and 6.5 in southern California and, possibly, M_S 6.8 in Baja California. (Id.).

3. Length and Characteristics of the OZD.

22. Two major controversial matters in our hearings focussed upon the OZD and related directly to the magnitude of earthquakes that zone might generate. These were, first, whether the OZD should be treated as a single, throughgoing fault, and, second, whether the OZD extends into Baja California and should be treated as a longer zone than the model that had been assumed at the CP stage. These two matters will be examined, in order, in the following findings.

23. Central to much of the controversy was the precise intent of the quotation appearing in Section 2.5.1.2 (p. 2-34) of the SER taken from the SER at the CP stage which says, "We and our consultants consider this zone of deformation to be potentially active and capable of an earthquake whose magnitude could be commensurate with the length of the zone."

24. Insight into the intent of the above quotation was provided by Staff Witness Devine, an employee of the USGS. Mr. Devine had been involved in the discussions at the CP stage and was a witness in these proceedings. He made it clear that the USGS did not intend to say that the OZD was a single fault capable of rupturing along its entire length in a single event. But they had thought that, given the need for conservatism in nuclear design, the OZD should be viewed as a single zone. Devine, Tr. 5332-33; also see Allen, Tr. 4880).

25. Intervenor Witness Dr. Brune testified that there is no physical reason why an earthquake rupture could not proceed

along the whole length of the OZD. Dr. Brune noted that the Imperial fault ruptured along essentially its full length in 1940 and he cited the 1975 study of Clarence Allen showing that the Izu earthquake ruptured nearly 100% of its length in 1930. (Dr. Burne, written testimony, pp. 12, 13, 21, 22).

26. The Board believes that the data from the 1930 Izu earthquake in Japan is not persuasive that the OZD in California may rupture along its full length. Differences in fault behavior appear to exist between different styles of faulting and different tectonic environments. (Heath, Tr. 4044; Reiter, Tr. 5819-20).

27. We believe there are at least two physical reasons why we may disregard the data from Japan. First, there is the general tectonic setting. Japan is characterized as a subduction zone, whereas California is characterized by strike-slip transcurrent faulting. Second, Japan is characterized by checkerboard (or block) faulting and California is characterized by branch faulting. These findings were confirmed by witnesses Brune and Allen (Brune, Tr. 4568; Allen, Tr. 4884-85).

28. The 1940 Imperial fault rupture does not produce convincing evidence that a fault, such as the OZD, may rupture along its full length. Witness Slemmons stated that he knew of no case where he was certain that a fault had ruptured for its full length. (Tr. 6244). He noted specifically of the Imperial fault that the 1940 rupture extended nearly the full length of a

segment of a much larger fault system associated with the plate boundary. (Slemmons, Tr. 6220-21).

29. In response to a Board question, Staff Witness Slemmons stated he thought the OZD could be interpreted as though it was a single continuous fault (Tr. 6317). He also indicated he knew of no physical reason that a fault could not rupture along its entire length (Tr. 6220; 6343). But, this witness also noted that full rupture of the OZD is unlikely based upon the historic record and that the empirical data base does not support such a likelihood (Tr. 6220).

30. Applicants' Witness, Dr. Stewart Smith, offered a physical reason why ruptures in fault systems (zones) do not progress along 100% of the system. He explained that stress conditions in the rupturing surface are no longer high enough to permit breaking and sliding of the materials. This happens at the ends of faults and leads to ruptures and segments (Tr. 6377-78). He had earlier noted that ruptures are associated with the top 15-20 kilometers of brittle rocks and that earthquakes are derived from changes in this brittle region (Tr. 6376).

31. Numerous witnesses testified that they did not regard the OZD as a single continuous fault. Rather it is a zone of branching faults and folds. (Allen, Tr. 4732, 4880; S. Smith, written testimony, p. 12; Heath, written testimony, pp. 10-12).

32. The weight of the evidence convinces the Board that the OZD is a segmented, branching system of faults and folds and

that the assumption of a rupture along its full length is speculative and unreasonably conservative. All of the available data indicates that earthquakes do not actually cause ruptures the full length of the faults on which they occur. Therefore, full length ruptures must not happen for some physical reason, simply because earthquake behavior is governed entirely by physical reasons. That we may not know everything there is to know about this phenomenon -- just as we do not know everything about the fission process -- does not negate its existence. Some further evidence of the segmented nature of the OZD is presented in the following findings.

4. The Offshore Zone of Deformation and Its Segments.

33. From north to south the OZD consists of three tectonic elements as follows: (1) the Newport-Inglewood Zone of Deformation (NIZD); (2) the South Coast Offshore Zone of Deformation (SCOZD); and (3) the Rose Canyon Fault Zone. (Heath, written testimony, p. 10, Figures EGH, A-E).

(a) The Newport-Inglewood Zone of Deformation.

34. Right lateral displacement is characteristic of the style of faulting of the NIZD. (Heath, written testimony, p. 11).

35. The NIZD is about 30 million years old and shows some evidence that it was the plate boundary in the historic past. (J. Smith, Tr. 810-11, 813).

36. The NIZD extends about 45 miles southeastward from the Santa Monica-Malibu fault zone. It changes from well-developed folds and faults in en eschelon pattern across the Los Angeles

basin to a series of fault splays essentially unaccompanied by folds in the Newport Beach area adjacent to the San Joaquin Hills. (J. Smith, written testimony, p. 19).

37. The structural counterpart to the San Joaquin Hills can be traced offshore in seismic profiles as a structually elevated feature transverse to the NIZD. This feature, the San Joaquin Structural High, interrupts the southeast continuation of the NIZD. Structural, gravity and stratigraphic evidence indicate termination of the NIZD against the San Joaquin Structural High. (J. Smith, written testimony, pp. 19-20).

38. Both the Staff and the Applicants concluded that the NIZD is interrupted or terminated at its south end by the San Joaquin Structural High (Applicants' Finding of Fact No. 74-75, Staffs' Finding of Fact No. 38). This conclusion was not spoken to in the Intervenors' Findings of Fact.

39. The Board agrees with the foregoing and found no evidence to controvert this position. The NIZD itself is a zone of segmented faults with intervening folds such that a rupture of its full length seems unlikely, and the weight of the evidence strongly supports the concept that the NIZD is best regarded as a segment of the longer zone referred to as the OZD. We also incorporate here by reference Applicants' Findings of Fact Nos. 64-66, which were uncontested, and which provide additional evidence of the southerly interruption of the NIZD.

(b) <u>The South Coast Offshore Zone of Deformation</u>.

40. The SCOZD extends for about 42 miles from the east flank of the San Joaquin Structural High to slightly southwest of Oceanside. (J. Smith, written testimony, p. 20).

41. The pattern of faulting on the SCOZD is similar to that of the NIZD, but is of a lower level of deformation. (Heath, written testimony, p. 11; 13-14).

42. It is expressed as a zone of branching and discontinuous faults and folds trending north to northwest and is found only offshore. Prominent elements of the SCOZD are the San Onofre Shelf Anticline, the San Onofre Shelf Syncline and the South Coast Offshore Fault. Other elements include prominent unconformities between stratigraphic units interpreted to be San Onofre Breccia, Monterey and Capistrano Formations. There are, additionally, wave cut platforms and their overlying Pleistocene deposits and minor faults and folds. (J. Smith, written testimony, p. 20).

43. The features noted above are seen in seismic reflection profiles. The length, continuity and apparent displacement on faults diminish upwards and the zone's expression in upper Miocene rocks is a series of short, discontinuous breaks along the crest and flanks of a prominent anticline (<u>Id</u>.; also see written testimony, Heath, p. 13-14).

44. The SCOZD dies out southwest of Oceanside without emerging onshore. (J. Smith, written testimony, p. 20).

45. The Board interprets the SCOZD as the middle segment of the OZD. We note the absence of any data showing continuity with the NIZD, and the differences in displacement between the SCOZD and NIZD, in support of our conclusion. We note, too, the absence of any data showing a single, throughgoing fault on the SCOZD.

(c) The Rose Canyon Fault Zone.

46. The RCFZ extends for about 45 miles southeast of the SCOZD and, on shore, is coincident with a sublinear northwest trending topographic depression from La Jolla Cove south through Rose Canyon. It continues along the east side of Mission Bay to San Diego Bay, where it appears to turn westward and to die out seaward. (J. Smith, written testimony, p. 21).

47. To the north of La Jolla Cove the RCFZ extends to the Oceanside area and either dies out or emerges onshore without connecting to the SCOZD. (*Id.*)

48. Displacement across the RCFZ is predominantly vertical (i.e., normal fault), with the west side up along the northern and southern parts, and west side down in the central part. (*Id.*)

49. The Board has concluded that the RCFZ is an identifiable segment of the OZD and notes the rather different style of displacement displayed by the segment. No evidence of a physical connection via a major throughgoing fault to the SCOZD was presented.

50. By way of summary of the Board's findings concerning the OZD, we note the following matters. The Intervenors persistently attempted to show that the OZD was controlled by a major, throughgoing fault capable of rupture along its full length. But apart from Dr. Slemmons testimony (Tr. 6317) that he believed the OZD could be interpreted as a single continuous fault, there was virtually no evidence to support this theory. In our hearings the OZD was repeatedly characterized by other witnesses as a segmented zone. The SER and the witnesses for the Applicants, the USGS and the Staff all characterized the OZD as a discontinuous zone divided into three segments, the NIZD, SCOZD and RCFZ. Witness Allen testified that the zone does not contain a single, continuous well defined fault zone (Tr. 4732). The evidentiary record supports the description of the OZD as some 240 km long, composed of a series of discontinuous, short, en eschelon fault segments, drag-fold anticlines and synclines, which progressively changes its style of faulting from north to south. Of major significance for us was the uncontested evidence of the San Joaquin Structural High which interrupts or terminates the NIZD at its southern end, a fact which emphasizes the unlikelihood of a throughgoing rupture of the OZD.

51. The Board's findings on the OZD rest heavily upon the exhibits and testimony presented by the Staff and the Applicants. The Intervenors' primary witnesses had not made

independent studies of the San Onofre area and that fact was testified to by Dr. Brune (Tr. 4207-4208) and Mr. Legg (Tr. 5156). Nor do the Proposed Findings of Fact of the Intervenors challenge the findings we have presented other than in their attempt to mischaracterize the OZD as a structure controlled by a single, continuous fault capable of rupture along its full length.

(d) Geologic Evidence of Seismicity.

52. We have already discussed some of the history of earthquakes in the southern California area and will turn now to a brief discussion of an interpretation of prehistoric earthquakes along the OZD. Applicants' witness Prof. S. Smith testified that his investigations of the San Onofre area had revealed a "consistent picture of relative stability over four different time scales involving four different types of data; the instrumental record of half a century, the historic record of several centuries, the geomorphic record of several hundred thousand years, and the geologic record of several million years." He further stated, "By itself, no one of these could be used as conclusive evidence that large earthquakes have not (and will not) occur in this area, but taken together they provide a very strong case for just this conclusion." (S. Smith, written testimony, p. 8).

53. Prof. Smith also testified that the geologic record indicates that earthqakes larger than M_S 6.5-7.0 could not

have occurred on the OZD with any regularity for the past one million years. (Id., p. 7; Tr. 1535).

54. Further, Prof. Smith stated it was his opinion that there probably have never been earthquakes as great as M_S 6.5-7.0 on the SCOZD. (Tr. 1537).

55. Lastly, and as reinforcement of our eventual conclusion, we will note that Prof. Smith uses the M_S 7.0 estimate to cover his uncertainty and that he did not think there had been any M_S 6.5 earthquakes on the "offshore zone," nor did he think there would be any in the future. (Tr. 1557).

(e) Proposed Southern Extension of the OZD to the Agua Blanca Fault.

56. Intervenors' witness Legg proposed a connection between the Agua Blanca - Coronado Banks fault and the Rose Canyon Fault under Mexican waters offshore of Baja California. (Legg, written testimony, pp. 2-5; also see Intervenors' Exhibit No. 3, CDMG Map sheet 42).

57. The SER also notes that Legg and Kennedy (1979) stated that a connection of the OZD with the Agua Blanca fault zone was "possible." (SER § 2.5.1.11). (SER Figure 13A and SER, p. E-28 for fault locations).

58. The Intervenors Proposed Finding of Fact No. 34 states, "The NRC Staff is of the opinion that the OZD may be a branch of the Coronado Banks fault zone and may ultimately connect with the Agua Blanca fault zone. (Supplemental Testimony of Anthony T. Cardone, p. 4, paragraph #4)." While this is accurate, it is taken out of context. The Board notes

72. The Intervenors, in their findings concerning the extension of the OZD, review the materials in the SER (Intervenors' Findings Nos. 14 and 15), the testimony of Michael Kennedy (Tr. 2262-63) showing that the Rose Canyon fault extends to the Mexican border (Intervenors' Findings Nos. 11, 12 and 13), and the testimony of Dr. Gastil (Intervenors' Findings Nos. 16 through 28) in support of possible connections between the OZD and the Vallecitos-San Miguel fault zone.

73. Dr. Gastil admitted there was no way to physically connect the OZD to the Vallecitos-San Miguel fault zone. Dr. Gastil's testimony concerning connections of the OZD to these faults and of those to one another was based upon hypotheses (Tr. 5131, 5134, 5136) and faith (Tr. 5910-5911).

74. The Board rejects the concept that the OZD continues into Baja California and connects with the Vallecitos-San Miguel fault zone. Although such connections are remotely possible, they are extremely unlikely. We adopt Applicants' Proposed Findings of Fact Nos. 80 through 88 and Nos. 171 through 174 as the better interpretation and a more factual statement of the relationships of the concerned structures, and repeat those as the following findings numbered 75 through 87.

75. "Applicants have on several occasions investigated faults in Baja California that lie southerly of the Rose Canyon fault zone to determine whether they are related to the OZD. The investigations involved at least ten days and included literature review, or examination of aerial photographs, and

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75. "Applicants have on several occasions investigated faults in Baja California that lie southerly of the Rose Canyon fault zone to determine whether they are related to the OZD. The investigations involved at least ten days and included literature review, or examination of aerial photographs, and

field reconnaissance. The faults in question are the Vallecitos fault, the Tijuana lineament, and the San Miguel fault. (P. Ehlig, written testimony, p. 29-33; Tr. 1086-1088)."

76. "There is no apparent association between the Rose Canyon fault and the Vallecitos fault because the northern end of the Vallecitos either dies out or is overlapped by Eocene-age conglomerate, and no lineament or other features suggestive of a through-going fault along the projected trend of the Vallecitos fault can be observed in aerial photographs. Furthermore, in a few places northeast-trending geologic features extend without visible offset across the projected trend of the Vallecitos fault. (Ehlig, written testimony, pp. 29-30; Tr. 975-977; S. Smith, Tr. 6376)."

77. "The San Miguel and Vallecitos faults are roughly parallel with each other, and are right stepping en enchelon, but they do not align with the Rose Canyon fault, and the Vallecitos and Rose Canyon do not fit an en echelon model. (Ehlig, Tr. 975-917, 1080)."

78. "The Imperial fault and the Cerro Prieto fault are not aligned with each other but are separated by an active spreading center. Consequently there is a mechanism there for transferring the motion from one nonaligned fault to the other. However, no such mechanism exists between the Vallecitos and San Miguel faults in Baja California. (Ehlig, Tr. 1076-1077)."

79. "Evidence for a possible concealed fault along the Tijuana Valley is equivocal, and the causes of the so-called

Tijuana lineament may result from other than faulting. Within exposed basement rock terrane there is no northwest-trending feature nor geomorphic evidence coinciding with a hypothetical fault along the Tijuana lineament, suggesting that the lineament is not a fault-controlled feature and does not connect with the Rose Canyon fault. (Ehlig, written testimony, 30-31; Tr. 1074, 1085-1086)."

80. "In southern California and Baja California it is possible to have a deep linear fault in the basement rock that does not express itself at the surface only if the displacement is very small and only if the rocks are reasonably flexible, such as sediments or sedimentary rocks. (Ehlig, Tr. 1077). In very rigid rocks exposed at the surface, it is not possible to have a throughgoing zone without having some combination of surface interconnection between the various faults. (Ehlig, Tr. 1078). Therefore, it is not theoretically possible for the RCFZ, the Vallecitos fault zone, and the San Miguel fault zone to be connected by a deep linear break in the basement rock. (Ehlig, Tr. 1079; S. Smith, Tr. 6378)."

81. "Investigation of the area between the southern extent of the Vallecitos fault and the San Miguel fault indicates there is no apparent relationship between the two faults. They have subparallel trends, but remain about 7 km apart at their closest approach. Both faults have small displacements, and the Vallecitos fault appears to be old and inactive. (Ehlig, written testimony, p. 31; Figure PLE-P)."

82. "The northern part of the San Miguel fault is overlain by old alluvium many thousands of years old, and displays no evidence of Holocene activity. The San Miguel fault terminates near the northwest corner of Valle San Rafael, and exhibits only about 200 meters of total displacement. The overlapping presence of dikes across the fault precludes the existence of a northwest-trending strike-slip fault of significant displacement along the San Miguel fault. (Ehlig, written testimony, p. 32; Tr. 1069)."

83. "The trace of the Vallecitos fault is well marked by canyons and other topographical features, but geologic contacts appear to extend across the trace without detectable offset. Intrusive dikes and old alluvium lie across the Vallecitos fault and indicate no evidence of young displacement. Gordon Gastil reports no evidence of any Quaternary displacement or even Cenozoic displacement across the Vallecitos fault. Thus, the Vallecitos fault lacks significant displacement in the vicinity of its approach with the San Miguel fault. There is no basis for estimating the slip rate of the Vallecitos fault because there is not solid evidence on the amount of total displacement and the period of time over which it was active. (Ehlig, written testimony, p. 33; Figure PLE-P; Tr. 1070-1071, 1089)."

84. "Geologic evidence suggests that a connection between the Rose Canyon fault and the Vallecitos faults has never happened in the past and there is no reason for us to expect it in the future. (S. Smith, Tr. 6376-6377). For seismological

purposes, there is no reason to consider that a single rupture could ever progress along the Rose Canyon/Vallecitos/Calabasas/San Miguel system. (S. Smith, Tr. 6378)."

85. "The mechanical connection between discontinuous fault segments is dependent upon the distance between the ends of the fault segments and the deformation or slip occurring on the fault strands. When the displacement is very large, dramatic kinds of deformation occur in the region between the two fault strands. An example of this is the right-stepping Cerro Prieto-Imperial faults. Between these two strands there is a spreading center and a volcano. If the displacements on the fault strands are small, then the deformation between the fault strands is reduced and often can be accommodated by elastic or plastic distortion. A mechanical connection between the faults is therefore not necessary. Faults represent the accommodation of strain in the crust. If large accommodations are necessary, then connections are necessary as well. If the displacements are small, then short faults can accommodate the displacements and no connection is necessary. (S. Smith, Tr. 6373)."

86. "It is very important to look at the amount of displacement on each of the faults and the style, nature and amount of deformation between the ends of such faults. If there is no significant deformation between them, then there is no need to postulate that they are connected. (S. Smith, Tr. 6374)."

87. "It is not, therefore, a geologically or seismologically plausible scenario that an earthquake on either the Rose Canyon fault or the Vallecitos fault could propagate from one feature to the other. These faults are not connected at the surface, the total displacements along the faults is small, and there is no significant distortion between the offset fault traces. (S. Smith, Tr. 6376)."

88. The Board concludes that the OZD does not connect to the Vallecitos-San Miguel fault zone and rejects Intervenors' Proposed Finding of Fact No. 36. That finding represents unwarranted speculation and is of no real utility in attempting to establish a reasonable basis for estimating the maximum magnitude earthquake to be planned for at the San Onofre site.

89. We have already discussed the history of earthquakes in the area of interest to the site (our findings 16 to 21 above) as well as an interpretation of the prehistoric/geologic record of earthquakes (our findings 51 to 55) and will now consider the seismic potential of the OZD. We note that all parties have essentially concurred that the OZD is the controlling feature for the SONGS site, though the Intervenors attempt to show that the "Cristianitos Zone of Deformation" (CZD) may represent a capable fault system, and their Proposed Findings Nos. 147-148 speak to that. We will discuss the CZD later.

5. <u>Slip Rate and Magnitude Relationships</u>.

90. One proposed method for determining the maximum magnitude earthquake a fault may generate is derived from a study of the slip rate/magnitude relationships of faults. Slip rate is the distance moved for a given unit of time. Such a method was devised by the Applicants' consultant Woodward-Clyde and was developed by Edward Heath, the Applicants' witness in our hearings. The history of the development of this methodology and the Staffs' review of it is presented in the SER §§ 2.5.1.9 and 2.5.1.10 up to the time of the issuance of the SER (February 1981).

91. The Staff, in its Proposed Findings of Fact Nos. 42-59, reviewed the essence of the material in the SER and matters brought forth in the hearings concerning slip rate/magnitude relationships of earthquakes. Their conclusion, concerning the assignment of M_S7.0 as the maximum magnitude earthquake to be planned for on the OZD, is set forth in the Staff's Proposed Finding No. 108(2)(a).

92. Concerning the slip rate/magnitude method, the Applicants, in their Proposed Findings of Fact Nos. 153-157 and 193-221 present detailed findings and references to the record in support of their position that M_S7.0 is the "most conservative maximum magnitude earthquake for the OZD" and that "a reasonable maximum magnitude earthquake for the OZD is M_S6-1/2." (Applicants' Proposed Finding No. 219.)

93. The Intervenors presented their Proposed Findings of Fact on the slip rate/magnitude methodology in their Findings Nos. 67-95. These findings are critical of the interpretation supported by the Staff and the Applicants, though no independent study of slip rate/magnitude relationships was presented by the Intervenors.

94. Slip rate is a quantitative measure of fault activity and is derived from the geologic record. Heath characterized his method as a "degree-of-activity approach" which considers the "relative behavior of faults, particularly in terms of strain release or long term slip rates; the size, periodicity, and energy release of seismic events; the mechanical and compositional properties of the faults; and the tectonic setting." Broadly, his approach used "both a qualitative and quantitative comparison of features, such as maximum historic earthquake, fault rupture length, total displacement, degree of deformation, and long-term slip rates...." (Heath, written testimony, pp. 6-8).

95. One criticism of Heath's method offered by the Intervenors was that the method was new and untested and had not received adequate scientific peer review (Intervenors' Findings Nos. 67, 68, 70-72 and 88).

96. The Intervenors are correct that the method was developed in 1978 but it has since then been reviewed by the NRC Staff, consultants for the Applicant, the U.S. Geological Survey, the California Division of Mines and Geology and by Dr.

Slemmons for the NRC. (Heath, written testimony p. 24; Tr. 1276-77, 1414, 1433-34, 4044).

97. The proposed method is new, but it is founded on background and work by many investigators which cover many years. (Applicants' Finding of Fact 152). What is strongly convincing of the utility of the approach is the fact that since geologic slip rates reflect average fault displacements over very long intervals of time, the behavior of faults in the past can be evaluated and can provide a basis for projecting the future behavior of the fault. (Heath, written testimony, p. 18). Heath stated the slip rate/magnitude method grew out of the study of comparing faults by their degree of activity and provides a quantitative comparison (Heath, Tr. 1280-1281, 1437).

98. The Board is not inclined to discount the results derived from the slip rate/magnitude study merely because it is a new method. Too, we believe the review of this method before and during the hearings represents a substantial "peer review". We do not suggest that this method standing alone is an adequate basis for assigning the SSE for San Onofre, but we agree with the Applicants, the Staff and Dr. Slemmons that this approach can be properly viewed as one of several approaches to the determination of the maximum magnitude earthquake.

99. In developing the slip rate/magnitude method, the witness Heath developed two new concepts. These were called

the Historical Earthquake Limit (HEL) and the Maximum Earthquake Limit (MEL). The development of these concepts is well stated in Heath's Written Testimony, pp. 23-27. (Also see Applicants' Exhibit No. 9, EGH-7; Heath, written testimony, Figures EGH-K and EGH-M).

100. The slip rate data upon which the HEL and MEL are based was compiled from the scientific literature. The data base included the NIZD, other strike slip faults in southern California and other strike slip faults from similar settings around the world. (Heath, written testimony, p. 23-24, and Applicants' Exhibit No. 9).

101. The Intervenors also made the point that the slip rate magnitude method is limited by the short observational time we have had for historic earthquakes. They argued that the data base of points available is too small to be reliable (Intervenors' Proposed Findings of Fact Nos. 69, 75, 77-83 and 89-91).

102. The Intervenors cite Dr. Slemmons' (at SER, E-7) concern with the short historic record available. (Intervenors' Proposed Finding No. 77). That concern exists, but the Intervenors choose to ignore the final paragraph at SER E-7 to E-8 wherein Dr. Slemmons concluded in his review of fault slip rate that the assignment of the magnitude $M_S7.0$ for the segments of the OZD provided a conservative estimate.

103. We noted earlier that the historical record of earthquakes in California extends back about 200 years and the

instrumental record about 50 years. Thus, our historic record is indeed a brief one. This fact, however, does not of necessity negate the utility of the slip rate/magnitude methodology. The Intervenors make much of the fact that the M_S6.3, 1933 Long Beach earthquake on the NIZD controls the bounding line for the HEL (Intervenors' Finding of Fact No. 79). What the Intervenors do not cite is the fact that the Applicants identified approximately 230 strike slip faults at least 10 km long in the Coast Ranges, Peninsular Ranges, Mohave Desert and Transverse Ranges of California. Of these, about 180 to 190 were not useable because direct slip rate estimates could not be made. However, none of the 230 faults have had large earthquakes, though some may have been associated with events of less than M_S5. It would seem reasonable that, given a 200 year history, a few, or at least one, of this large sample of faults with presumed low slip rates (i.e., less than 1 mm per year) should have generated a major earthquake, if such was possible. In the absence of evidence of large earthquakes (M_S6.5 or larger) on low slip rate strike slip faults, the Board concludes that the 1933 Long Beach earthquake may very well represent the near maximum earthquake possible on the NIZD. Thus, though we have but a brief historic record, the evidence suggests strongly that it is an adequate historic record for the slip rate method. (Heath, Tr. 1441-1443, 1449-1450, 4037-4038, 4050-4051).

104. There seems little likelihood that faults with slip rates above about 5mm per year have not already been identified and thus there is no expectation that additional faults can be easily added to the HEL or MEL figures (Figures EGH-K and EGH-M of Heath's written testimony) above that slip rate. (Heath, Tr. 1449-1450).

105. The Board concludes that while the MEL and HEL are based upon a less than optimal data base, it is sufficient to assist the Board in determining the SSE for San Onofre.

106. To obtain the plot referred to as the MEL, Heath added a factor of plus or minus 0.2 magnitude to the M_S values assigned for each earthquake, and he used the range of reported slip rates where the literature contained varying estimates. Thus, each point plotted is surrounded by an "error box" and the MEL line is drawn connecting the lower right corners of the more extreme boxes to enclose all data points. (Heath's Figure EGH-M in written testimony of Heath). The Board finds this is a reasonable and conservative basis for establishing the MEL.

107. Among the varying estimates of slip rate for the NIZD was a high value of 0.68mm per year. If that rate is used, the MEL predicts that an M_S7.0 could be generated by the NIZD. Since this is the highest slip rate estimated for the NIZD, the Board concludes that the estimation of an M_S7.0 for the NIZD is a conservative estimate. (See Heath's Figure EGH-M and SER 2.5.1.10).

108. Still another criticism of the slip rate/magnitude method put forth by the Intervenors was that significant data from Japanese faults and the San Miguel fault were not included by Mr. Heath in the data base. (Intervenors' Findings of Fact Nos. 84-87).

109. Dr. Brune was critical of the elimination of the Japanese slip rate/magnitude data by Mr. Heath (Id.). However, the Intervenors fail to note that both Mr. Heath (Tr. 4044) and Dr. Reiter (Tr. 5819-5820) justified the elimination of the Japanese data because of the different tectonic environment in Japan.

110. Two of our earlier findings (Nos. 26 and 27) relate to the differences in tectonic setting and faulting in Japan and provide, for us, substantive reasons why data from Japanese faults, earthquakes and slip rates are best not included in analyses for the southern California setting of the San Onofre site.

111. The Applicants' elimination of data on slip rate from the San Miguel fault was for a different reason, namely, the data on total slip and the period of time over which it occurred is inadequate to develop a meaningful slip rate (Heath, Tr. 1486-1487, 1490-1491).

112. The Intervenors in their Proposed Finding No. 84 make much of Dr. Gastil's testimony on his direct knowledge of the San Miguel fault. They chose to ignore the fact that Dr. Gastil freely admitted that he did not know the slip rate of the Agua

Blanca fault (Tr. 5121), and in order to provide an estimated slip rate, they have arbitrarily assigned time periods for the approximately 250 meters displacement described on the San Miguel fault by Dr. Gastil. No factual basis exists to defend that estimate, nor indeed to provide any other than hypothetical slip rates for the San Miguel fault.

113. The Board concludes that the enumerated reasons justify not including data from either Japanese or the San Miguel faults in the data base for Heath's analysis of the MEL. We reject the Intervenors' Proposed Findings as based more upon hypotheses than upon facts.

114. The Intervenors noted in their Proposed Finding No. 73 that Mr. Heath had no credentials or qualifications in the area of statisics and probabilities (Tr. 1256-1257). They also noted in their Finding No. 76 that Dr. Brune considered Mr. Heath's method to be probabilistic, not deterministic (Brune, written testimony, p. 14).

115. The Board agrees with the preceding paragraph, but we also believe that these matters do not undercut Mr. Heath or his method. Heath's HEL is a plot of historic and factual data, and his MEL, by use of "errorboxes", adds significant conservatism to the HEL line. Credentials and qualifications in statistics and probability theory are not needed either to construct or interpret the HEL and MEL. The Board also notes that deterministic findings are not available in this area.

116. The Intervenors in their Proposed Findings of Fact No. 10 state, "The slip-rate of the Rose Canyon fault is an average rate of 15 cm per thousand years or 1-2 mm per year. (Testimony of Michael P. Kennedy, Tr. p. 2258, l. 2-7)." Unfortunately the Intervenors have mixed Dr. Kennedy's estimates of the dip separation rate with the horizontal slip rate in their finding. The 15 cm per thousand years of dip separation (Tr. 2258) would yield a rate of 0.15 mm slip per year. Horizontal slip, based upon Dr. Kennedy's estimate of 1 to 2 meters per thousand years, yields a slip rate of 1 to 2 mm per year (Tr. 2354-55). That rate is based upon ancient movement in the Pliocene, i.e., several million years ago (Tr. 2355). Moreover, Dr. Kennedy testified that movement along the fault diminished in the younger overlying rocks and that his 1 to 2 mm per year slip was an average slip for the Pliocene and younger rocks along a segment of the fault (Tr. 2355-56). No estimate of slip rate is available for the younger rocks concerned. The Intervenors do not further use the incorrect slip rate data cited above. The Board agrees with the Applicant's rejection of Dr. Kennedy's estimate, adopts, and incorporates by reference Applicants' Proposed Findings Nos. 204-207 which set forth a more factual and appropriate interpretation of the geology of this area.

6. Fault Rupture Length and Magnitude.

117. We may now focus our attention on another method of estimating the maximum magnitude earthquake likely to be

generated on the OZD. We refer here to the work of the Staffs' consultant and witness, Dr. Slemmons, having to do with fault rupture length (SER, E-9 to E-16).

118. The Staff's Proposed Findings of Fact Nos. 68-82 reviewed the record concerning fault rupture length and concluded with respect to the OZD that "Postulation of an earthquake in excess of M_S = 7 would be inconsistent with the geologic and seismologic evidence of the OZD". (Staffs' Proposed Finding of Fact No. 78).

119. The Applicants also treated the rupture length method of determining earthquake magnitude in their Proposed Findings of Fact Nos. 182-192. The Applicants used a broader selection of facts in these findings than those developed by the Staff, but their conclusion does not differ from that of the Staff.

120. The Intervenors in their proposed findings on the rupture length method present a long, concerted attack on the position reflected in SER, Appendix E, based largely upon their view of the testimony of Dr. Slemmons, Dr. Brune and Mr. Legg. (Intervenors' Proposed Findings of Fact Nos. 41-66).

121. By use of Dr. Slemmons paper "State-of-the-Art for Assessing Earthquake Hazards in the United States," published in May, 1977 (Table 13) the Intervenors arrive at a magnitude of 8.6 earthquake for the 240 km long OZD (Intervenors' Finding of Fact No. 42) and a magnitude of 8.89 for the 420 km long OZD plus its assumed extension into Baja California. (Intervenors' Finding of Fact No. 43). Portions of Slemmons' 1977 paper were

numbered by the Intervenors as their Exhibit No. 27 (Tr. 6229), although this Exhibit was never admitted into evidence. There is no support in this record for the suggestion that an earthquake of magnitude greater than M_S8 could occur on the OZD. The Intervenors' references to earthquakes of 8.6 and 8.9 on the OZD are in the realm of fantasy. See testimony of Intervenors' witness Anderson at Tr. 4944.

122. The very high magnitudes noted in the foregoing finding are based on the fact that one of Slemmons' curves (Curve E of Figure 13 of his 1977 paper) is based on mean values with a standard deviation (standard error of estimate) of 0.694. Thus, the curve being used is a mean curve with 50% of the data points higher and 50% lower than that value. To include estimates of magnitude representing 84% of the data one must add and substract 0.694 (magnitude) to the mean value (Slemmons, Tr. 6229-6231).

123. The Intervenors elicited a wide variety of estimates of maximum magnitude earthquakes in excess of $M_S7.0$, from Dr. Slemmons during their cross-examination based upon adding one standard deviation to the mean value of this witness. These estimates ranged from 7.3 for a 27 km rupture on the SCOZD to 7.8 for a 62 km rupture on that zone. (See Intervenors' Proposed Finding No. 55; Slemmons, Tr. 6242, 6243 and 6269 for examples).

124. The Intervenors also elicited from Dr. Slemmons the estimate, postulating a rupture of 22% of a fault length of 190

km for the OZD, that the mean plus one standard deviation would yield an estimate of M_S7.6 (Slemmons, Tr. 6265).

125. The Board does not disagree that, as the Intervenors present in their proposed findings, many numbers in excess of M_S7.0 are present in the record. However, these numbers are the result of adding one standard deviation to the mean value, an approach the witness, Slemmons, declined for good reasons to use. (Tr. 6230-6232, 6265, 6270). In Slemmons' opinion, the data base from which the standard deviation had been derived was already overly conservative (Tr. 6265).

126. Dr. Slemmons compiled world-wide data summarizing observations of total fault length and rupture length as a means for relating these facts to the maximum magnitude earthquake that might occur on a given fault. He arrived at 22% as the mean rupture length to be expected. That value had a standard deviation of 7.45%. The Slemmons' method contains built-in conservatism. The Board adopts in the next paragraph Applicants' Proposed Finding No. 183 for the clarity with which it presents the Slemmons' method.

127. "The value of 22% of total fault length used in the evaluation of maximum magnitude has been derived from earthquakes ranging in magnitude from 8.25 to 5.9. For faults with a total length of more than 1000 km, the percentage is around 25-30%. In the length range 600-1000 km, the average percentage of the largest observed rupture-to-fault-length approaches the mean value of 22%. Finally, for faults in the

range of interest to the OZD, the percentage value is in the range 15-16%. The standard deviation for the value 22% is 7.45%. Therefore, for faults with a length similar to the OZD, 22% may already be an overly conservative value for assessing rupture length. (Slemmons, Staff Exhibit #1-DBS, Table E-14; Tr. 6285)." (These same facts also appear in Staff's Proposed Finding No. 77).

128. Dr. Slemmons used only the largest percentage rupture reported for each fault to obtain the average rupture length, which also adds conservatism to his estimate. In addition, had he chosen to average the percentage rupture of only those faults of less than 400 km length he would have obtained a percentage between 15 and 16 as a mean value. That approach would have then yielded the value of about 22% as the mean plus about one standard deviation, while 30% would have represented the mean plus two standard deviations. If we assume a 240 km fault length for the OZD and use Slemmons' equation (SER, Appendix E, pp. E10-E11) to compute the magnitudes for 15%, 22% and 30% rupture, we arrive at magnitudes of 6.75, 7.0 and 7.2, respectively.

129. The Board notes, too, that Dr. Slemmons indicated that his 22% rupture length may already be too conservative (Tr. 6267) and he objected to blindly applying standard deviations throughout his data (Tr. 6268).

130. Dr. Slemmons noted that his world-wide data base showed that for faults with a length of more then 1000 km it is

possible to have earthquakes of M_S8 or greater. In the range of 400 to 600 km, the maximum values observed have decreased to 7 to 7.5. Lastly, for faults comparable to the OZD, the values are around 7 or below (Slemmons in Table E-16 of Staff Exhibit No. 1; Tr. 6266-67).

131. The Board places confidence in a final statement elicited from Dr. Slemmons just before he was excused. In response to the question as to Dr. Slemmons' confidence in his estimates of the maximum magnitude earthquake to be assigned to the OZD, Dr. Slemmons responded, "I have high confidence in the magnitude of 7 due to the fact that I, in my opinion the two methods -- two independent methods, slip rate and my table on page E1[6], strongly support a magnitude of about seven." (Tr. 6323).

132. The Intervenors have consistently pursued the hypothesis that rupture of the full length of the OZD (240 km) and its proposed extensions into Baja California (420 km) is possible. Such ruptures, based upon the approach used by Dr. Slemmons in his 1977 paper, might yield earthquakes of $M_S8.6$ and $M_S8.9$ (mean plus one standard deviation values). (Intervenors' Proposed Findings of Fact Nos. 42-43).

133. We have earlier reviewed the nature and geologic record of the OZD and its proposed extensions into Baja California. We have rejected the concept that the OZD extends into Baja California and we have concluded that the OZD is made up of three relatively discrete segments. Slemmons' approach

(SER, E-11-12), included consideration of rupture of the full length of each segment, events that seems highly unlikely in view of the geologic history and present tectonic setting of the OZD. The approach he preferred was to base his estimate of the SSE on a 22% rupture of the OZD, an approach he considered to be already overly conservative. (Tr. 6267). We regard Intervenors' Proposed Findings Nos. 42 and 43 as inappropriate applications of the Slemmons' method which have no value in assisting us to determine the maximum earthquake to be planned for at the San Onofre site.

134. We concur with the Applicants' and Staff's conclusions that M_S7 is an appropriately conservative maximum magnitude earthquake to be planned for at the San Onofre site, based on the fault rupture length method.

135. The Staff, in its Proposed Findings Nos. 93-107 reviews "Other Methods for Determining Maximum Magnitude." Those methods include fault displacement, degree of deformation, historical seismicity, surface displacement and fault area. We have already made findings on historical seismicity. We concur with the Staff that the other methods listed cannot be usefully applied to the OZD. The Staff's findings on these other methods are significant in that they, along with the other methods used, represent a broad and multifaceted approach that adandons no possibly useful approach without thoughtful consideration.

136. The Board agrees with Dr. Slemmons that, "The studies for the SONGS site are accurate, represent state-of-the-art

methods and form an adequate basis for evaluating the seismic potential of the OZD." (Staff Exhibit No. 1-DBS at E-17).

137. In summary, we have, in essence, rejected the thrust and purpose of the Intervenors Proposed Findings of Fact and adopted those of the Staff and Applicant. We have found, based upon the geologic and seismic characteristics of the OZD, including its length, that an M_S7 earthquake is an appropriately conservative maximum magnitude that could occur on the OZD. It is, within the meaning of the regulations, the safe shutdown earthquake for the San Onofre site.54/.

54/ In making the SSE determination, the Board is not required to make any period-of-recurrence finding. This is in contrast to the "operating basis earthquake" (OBE), a much less severe event and the "strongest earthquake considered likely to occur during the plant's operating lifetime." Pacific Gas and Electric Co., supra, note 8, at p. 7. See App. A, III(d). The element of likelihood builds into the OBE determination a probability judgment that a particular magnitude earthquake will occur near the site in a brief geologic time interval. Such judgments can be made about relatively small OBE's because they typically occur much more frequently than SSE's, providing more data on which to base a statistical prediction. The OBE for San Onofre was determined at the construction permit stage and is not an issue in this proceeding.

In a recent Commission order in this case involving emergency planning issues, Commissioner Ahearne expressed his view that an SSE is "a once in thousands of years event." Memorandum and Order dated December 8, 1981, Additional Views of Commissioner Ahearne. Such a recurrence period may describe SSE determinations generally. It would then be relevant to a rulemaking on the subject of emergency planning and natural disasters, a context in which detailed, site-specific information is not necessary. We want to make it clear, however, that the record on the site-specific seismic issues in this case

(Continued on following page)

54/ (Continued from previous page)

does not support a thousands of years or, indeed, any specific period-of-recurrence for the San Onofre SSE. No party made any attempt to prove a period-of-recurrence for the SSE of M_S7 postulated on the OZD by the Applicants and the Staff.

Apparently, some useful research is being done on periods-of-recurrence based upon the geologic record of particular faults. For example, we were told that trenching across the Southern San Andreas fault has yielded evidence of the times and magnitudes of past earthquakes and predictions that a great earthquake (M_S8 or above) will probably occur there about every 150 years. Testimony of Dr. Clarence Allen, Tr. 4868-69. However, it is impossible to use any direct observation techniques, such as trenching, on the underwater OZD. This problem, coupled with the short instrumental and historic record and the limitations of seismic profiling, suggests to us that no very firm conclusions could be drawn about periods of SSE recurrence on the OZD. The testimony of the Applicants' principal witness in this area supports this view. Dr. Perry Ehlig rejected the idea that specific numerical recurrence values could be assigned to SSE's, in the manner of the Reactor Safety Study, WASH-1400. Tr. 993-997. An Intervenor witness, Dr. Anderson, discussed on cross-examination relationships between recurrence intervals, magnitudes and slip rates, suggesting a long recurrence interval for the OZD. However, he had performed no specific studies of the OZD. Tr. 4914-39.

Even if one could establish a long geologic period of recurrence for an SSE on a particular fault, in order to have an incremental assurance of safety from proof of this nature one would also need to know that the last SSE on that fault occurred only a short geologic time ago. Otherwise, as Dr. Ehlig testified, one must assume that an SSE can occur "at any time." Tr. 993. The record here does not establish when (or whether) an SSE of M_S7 last occurred on the OZD.

C. Evaluation of Strong Ground Motion.

1. Introduction. Having established that the occurrence of a maximum magnitude earthquake of $M_S 7$ is consistent with the geologic and seismic features of the OZD, we must determine whether an appropriate relationship exists between that magnitude and the peak horizontal ground acceleration (PGA) determination of 0.67g made at the time of the construction permit. That PGA value served as the anchor point for the design spectrum for the plants.

2. The Board recognizes that this portion of Contention 4 and Contention 1, also directed in major part to the determination of strong ground motion,[55] cover different time periods; Contention 1 covers only those matters occurring after issuance of the CP, while Contention 4 has no time limitation. We believe that maintenance of that time distinction in these findings would be unnecessary and artificial. Therefore we combine in this section discussion of the strong motion evidence presented under both issues.[56]

55/ Contention 1 reads as follows: "Whether as the result of ground motion analysis techniques developed subsequent to issuance of the construction permit or data gathered from earthquakes which occurred subsequent to issuance of the contruction permit, the seismic design basis for SONGS 2 & 3 is inadequate to protect the public health and safety."

56/ Other evidence adduced under Contention 1, and a related matter, are addressed in Part III F of this opinion.

3. Witnesses for the Applicants on this portion of Contention 4 were Mr. Lawrence H. Wight, Dr. Gerald A. Frazier, Dr. I. M. Idriss, and Dr. Robert L. McNeill; on Contention 1 they were Dr. Stewart W. Smith, Dr. Gerald A. Frazier, Dr. I. M. Idriss, Dr. Shawn Beihler, and Dr. Robert L. McNeill. Witnesses for the Intervenors were Dr. James N. Brune, Dr. John Anderson, Dr. Clarence Allen, and Dr. David Boore. Staff witnesses were Dr. Leon Reiter and Mr. A. Thomas Cardone. The Board called Dr. J. Enrique Luco.

4. The following quotation from the SER presents useful background for the basis of the specification of 0.67g and its use in the development of the response spectrum for the plants:

> In the seismological review conducted for the Construction Permit (CP) of the San Onofre Units 2 and 3 site, the staff relied primarily upon the evaluation provided by the National Oceanic and Atmospheric Administration (NOAA). [NOAA took the position that:]
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> > "An acceleration of 2/3g, resulting from a strong X intensity (MM) event, (should) be used to represent the ground motion from the maximum earthquake likely to affect this site. However, the accelerogram may contain a few peaks between 2/3 and 3/4g during the 2/3g interval. These accelerations could result from an earthquake occurring within a few miles from the site. Also, it must be assumed that a similar earthquake could occur at any point along this zone of deformation."
>
> The staff agreed with the NOAA evaluation and on this basis approved the earthquake design bases (anchor points) of

0.67g and 0.33g for the Safe Shutdown Earthquake (SSE) and the Operating Basis Earthquake (OBE) as being appropriately conservative. The FSAR refers to the SSE as the Design Basis Earthquake (DBE). The response spectra used in conjunction with the above acceleration values were developed from a scaled, smoothed, and modified set of real time histories. SER, §2.5.2.1.57/

5. As Staff observes (SF 115) and Intervenors echo (IF 96, in part), "[d]etermination of ground motion in the near field of large earthquakes is a difficult and problematic task. ... Since the earthquake assumed to occur on the OZD is also assumed to result from a rupture tens of kilometers long and at least 10 km wide (deep), estimation of ground motion at a distance of 8 km from the fault can be clearly considered a 'near field' problem." (SER 2.5.2.4)

6. That there have been relatively few well recorded "large" earthquakes ($M_S \geq 6$), in tectonic and geologic settings similar to the San Onofre site was not controverted; at issue was whether the data base that has been assembled from such large earthquakes (including certain ones from other parts of the world) includes a sufficient number and range of recordings

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57/ As noted above at page 7, the "design basis earthquake" and "safe shutdown earthquake" are synonymous phrases, although the latter is the prescribed technical term under 10 CFR Part 100, App. A. The Applicants and their witnesses frequently use the phrase "DBE spectrum" in their presentations; we use the phrase "design spectrum" to denote the same concept.

in the near field to allow a reasoned determination of the adequacy of the seismic design basis for San Onofre Units 2 and 3.

7. Applicants presented extensive testimony directed to empirical evaluations of strong motion data and to the use of models to predict near field accelerations. Intervenors, while presenting no studies of their own,58/ emphasized their belief that the number of large earthquakes and the information that has been gleaned from them is too limited to allow confidence in evaluations and predictions by any and all of these means. (Brune, written testimony, pp. 3-5) Dr. Clarence Allen, a subpoenaed witness for Intervenors, expressed the view that, while not optimal, there is adequate information. (Allen, Tr. 4665) All witnesses who commented on the extent of the data base would welcome more data.

8. The Board notes that it is indeed seldom that a true researcher feels that he has no need for additional data in his field of investigation. We take note also of the record before us which reflects more than willingness on the part of investigators to incorporate new information into their data bases and to test their theories and assumptions against them. Although there is a sparsity of near-field data, the records from such events as the 1979 Imperial Valley earthquake (IV-79)

58/ Dr. Brune was the only witness for Intervenors who filed written testimony on these contentions; Drs. Anderson, Allen, and Boore appeared under subpeona. Dr. Boore is one of the authors of USGS Open File Report 81-365, which was used extensively in Intervenors' cross-examination of Applicants' witnesses. Dr. Boore's testimony with respect to this report is discussed below, beginning at ¶ 27.

have done much to improve the situation. (Allen, Tr. 4682; Reiter, supplemental testimony at 3, following Tr. 5566) We agree with Dr. Allen's opinion -- that, although the available information is not optimal, it is adequate.

9. There is a relative abundance of data recorded at distances greater than 20 km from a fault rupture, but simple extrapolation of these data to the near field is not straightforward.[59/] Empirical evaluations and, more recently, theoretical models for predicting strong ground motion at various distances have become practical as a result of the development of large digital computers. These techniques are relatively new and there have been few events to try their assumptions. (Brune, written testimony, p. 40)

10. As the Staff states, "As of this time, no consensus with sufficient detail exists within the seismological community that would allow the exclusive use of theoretical models in order to estimate ground motion in the near field. In the face of the problems (not necessarily the same) associated with either the empirical or theoretical approaches in estimating near field ground motion, it is the Staff's position that the most appropriate way to arrive at an estimate involves the pursuit of both approaches and a conservative comparison." (SF 117; SER § 2.5.2.4) The Board agrees with this Staff position.

59/ See the discussion of magnitude saturation at pp. 141-147, below.

11. In order to test the appropriateness (and the possible conservatism) of the value of 0.67g for the PGA, the Applicants contracted several independent studies which approached the question of strong ground motion from the standpoints of both empirical evaluations and theoretical modeling of earthquake phenomena. These we discuss in order.

2. Empirical Evaluation of Strong Ground Motion--Analyses from Similar Earthquakes.

12. Applicants' witness Lawrence H. Wight made use of regression analysis[60/] to test various empirical and physical models. His carefully selected data base originally consisted of "192 horizontal peak ground acceleration (PGA) recordings from 22 earthquakes, as well as source, travel path, and site characteristics such as magnitude, closest distance to the fault rupture surface, site geology, instrument type and location, and size of structure" [in which instruments were located]. (A. Ex. 11, p. 1-1) The selection criteria for this

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60/ Regression analysis is a statistical analysis, now usually performed by a computer program, whereby sets of data are fitted to an assumed functional relationship (e.g., straight line, polynomial, exponential, Legendre, hyperbolic) among the components of each set of data; the coefficients of the terms in the assumed relationship are determined analytically. Goals are to test the appropriateness of the assumed functional relationship by minimizing the variance between observed and calculated values. Should this variance be considered excessive, the process can be repeated using a different functional relationship. One of the simplest forms of regression analysis is the least squares fitting of data to a curve. Mr. Wight discussed regression analysis as applied to his determination of PGA at Tr. 1625-1627.

data base statistically tested and eliminated data irrelevant to this site and resulted in inclusion of records whose quality was certain and whose distance to the rupture surface was adequately defined. Mr. Wight considered that this data base was suitable for ground motion predictions at the San Onofre site (Wight, Tr. 1579) and that it could be used with confidence for this purpose for the following reasons. (1) The average distance between the event and the recording instrument was about 11 km, although the data include recordings in the range between about 3 and 50 km. (Wight, written testimony, p. 7; A. Ex. 11, p. 2-4) Multiple regression analyses were made with magnitude and distance as variables. (2) The analyses included reverse-fault ground motion, which is approximately 23% higher than the corresponding motion from strike-slip faults, thereby introducing conservatism into the results. (Wight, op. cit., p.11) (3) The recordings were predominantly obtained from modern-type strong motion instruments in the free field or at the ground level of low buildings situated on recent alluvium; this selection criterion excluded recordings of old earthquakes for reasons detailed at Applicants' Exhibit 11, p. 2-8. However, the magnitude range of these old earthquakes (5.5 to 6.5) were well represented in the data base. (4) The predominant depth of the earthquake fell within 5 to 10 km. Mr. Wight's data base is described at Applicants' Exhibit 11 beginning at 2-4; Appendices A and B of that Exhibit give additional details.

13. A functional form of a relationship among M_S, distance, and PGA was selected that would allow flexibility to fit the data with minimal variance. The coefficients of this relationship allowed testing near-source attenuation of peak acceleration, possible saturation of PGA with very small distances, dependence of peak accelerations near to the rupture surface on magnitude, by employing expressions for the coefficients based on physical phenomena. Nonlinear regression techniques were used to quantitatively evaluate the coefficients. (A. Ex. 11, pp. 2-9)

14. Sensitivity analyses were made to determine the "robustness" of the predicted PGAs with respect to the data base and the various assumptions incorporated in the analyses, with the following results: (1) Variations in the predicted PGAs, using different functional forms of the relationships by which the data were fitted, were less than 15%. (A. Ex. 11, p. 3-1 and Table 3-1) (2) Variations in the constraint on the far-field decay rate[61/] over the values suggested by the literature demonstrated "remarkable insensitivity" (less than 7%). (Id., p. 3-3) (3) Inclusion of geology type as an independent variable resulted in only a few percent variation in the predictions for all magnitudes of interest. (Id., p.3-5)

61/ Far-field decay rate is the rate at which energy propagated through the ground is attenuated (diminished) at distances well removed from the rupture surface.

(4) Removal of the data of the 1979 Imperial Valley (52 components) and the 1971 San Fernando (44 components) earthquakes from the data base resulted in essentially no change in the predicted PGA for the site. (Id., p. 3-5 and Table 3-3)

15. These analyses of the data base led tc a median and 84th percentile prediction of 0.33 and 0.52g PGA at San Onofre as a result of an M_S7 event on the OZD. (Wight, written testimony, p. 7; A. Ex. 11, p. 1-2)

16. Subsequent to the completion of this study, the data base was expanded to 229 accelerograms by adding the recordings from five more earthquakes from other data made available and from new recordings. Inclusion of these data in the analyses "simply tightened [the] conclusions regarding ... ground motion predictions." (Wight, written testimony, pp. 8-10)

17. The Board finds that Mr. Wight's empirical regression analysis approach to determination of peak ground motion at San Onofre has substantial probative value. Although more data in the near field might give us greater confidence in the results, we believe that the data and the manner of its resolution provide a solid basis for the conclusions reached.

3. PGA and Response Spectra.

18. The peak ground acceleration is simply that of the ground at a specific location; the ground motion at that same location exhibits a spectrum of motions resulting from the influence of the several types and magnitudes of waves (and their velocities through intervening materials) produced by rock

breaking. Therefore the selection of the PGA is only the beginning of the process whereby appropriate design criteria can be established to protect a structure. The spectrum of strong ground motion that may occur at the selected site must be established; this is the instrumental spectrum.

19. Traditionally, the design spectrum is derived from the instrumental spectrum by taking into account the site geology and the characteristics of the structure to be erected such as embedment, dimensions, structural materials, and the like. In typical engineering practice, the design spectrum is lower than the instrumental spectrum because of the transfer of energy between structure and ground. (McNeill, Tr. 2641)

20. Finally, the manner in which the structure will respond to the forces acting on it should be determined: will it sway, twist, break? The portions of each of these spectra that are important to a specfic project are structure-dependent; for example, components of ground motion having frequencies greater than about 2 Hz are important to power plant safety. (SER, § 2.5.2.4) Consequently, analyses should concentrate on correlations of those frequencies rather than of low frequency motion and isolated high frequency peaks. (SER, § 2.5.2.4) Perusal of the transcript does not inspire confidence that accurate designation of the type of spectrum being addressed was

always made; most of the written testimony is apparently more definitive, as we would expect.[61/]

21. As noted above, the magnitude of the event that would produce these spectra was not specified at the CP stage. It therefore remained to be demonstrated at the OL stage that the spectra to which the plants were designed would not be exceeded by the spectra that could result from an M_S7 event on the OZD.

22. Prior to 1979, M_S6.5 had been adopted by the Applicants as a working hypothesis as a reasonable maximum earthquake (consistent with the geologic and seismologic features of the OZD) for the purpose of confirming the adequacy of the design spectrum. This work was done under the direction of the Applicants' witness, Dr. Idriss. Subsequently, for additional conservatism, the results of the initial analysis were scaled upward to M_S7. (Idriss, written testimony, p. 8; Heath, written testimony, pp. 16-17) The approach adopted for estimating the characteristics of ground motion resulting from an M_S6.5 earthquake was in many ways similar to that described above in Mr. Wight's work. However this earlier work was carried on independently and for the purpose of developing

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61/ Some of this apparent confusion may stem from the fact, attested to by Dr. McNeill, that the spectrum to which San Onofre was designed was based on the actual ground motion derived for the site, i.e., the instrumental spectrum, not reduced to account for the response of planned structures. See ¶¶ 59 and 60 below.

spectra specific to the San Onofre site. The two investigators made different selections from the available data for their data bases. For instance, Dr. Idriss used recordings from earthquakes of only about M_S6.5, while Mr. Wight included some much smaller earthquakes in order to increase near-field data. Mr. Wight included data from some earthquakes outside the United States, while Dr. Idriss restricted his data to the western United States; however, both restricted their data bases to similar-to-site geology.

23. "The development of site-specific empirical attenuation relationships was accomplished by the selection of earthquake recordings screened according to source factors [approximate magnitude 6.5], travel path [accelerograms recorded in the Western United States], and local site conditions appropriate to the San Onofre site [accelerograms recorded at sites having subsurface conditions similar to those at San Onofre]. A regression analysis of peak acceleration and response spectral values for the selected accelerograms was then performed to derive these relationships. ... The results of the ... screening process led to the selection of 56 accelerograms obtained during seven earthquakes in the M_L range 6.3 to 6.5 and the M_S range 6.3 to 6.7" with 46 of the records coming from earthquakes of M_S6.6. (Idriss, op. cit., pp. 8-9; see also SER § 2.5.2.4.1) By means of the site-specific attenuation relationships established through regression analyses of these data, instrumental spectra were developed for

25 individual periods in the range of 0.04 to 2 seconds. The mean and 84th percentile instrumental peak accelerations determined for M_S6.5 are 0.42g and 0.57g, respectively. Comparison of the 84th percentile instrumental spectrum derived using recorded data with the design spectrum showed that that spectrum exceeds the derived instrumental spectrum at all periods. (Idriss, op. cit., p. 12; A. Ex. 13, Fig. 10)

24. As mentioned above, in 1979 the maximum postulated earthquake magnitude was increased from M_S6.5 to M_S7 for additional conservatism. Because there are not as many data for magnitude 7, a scaling law was sought whereby the results of the analyses for M_S6.5 could be reliably extended to M_S7. (Idriss, Tr. 1707) This was prior to the 1979 Imperial Valley earthquake. (Idriss, Tr. 1709) The procedure used for scaling the 84th percentile instrumental peak acceleration and response spectrum is described in Applicants' Exhibit 18. The estimated 84th percentile instrumental peak acceleration for an M_S7 was 0.63g.[62/] (Idriss, written testimony, p. 13) (The mean PGA was not scaled to M_S7.) Comparison of the 84th percentile instrumental spectrum with the design spectrum (see Idriss, op. cit., pp. 13-14, Figs. IMI-A and B) shows that the design spectrum exceeds the former for both M_S6.5 and M_S7 at all periods.

62/ Inspection of Dr. Idriss' written testimony and exhibits indicate that the mean was not scaled to M_S7.

25. The Intervenors' witness, Dr. Brune, expressed his reservations about regression analyses of earthquakes, primarily because of the limited data base. As a scientist, he would prefer to have more data. (Brune, written testimony, p. 54; Tr. 4447-60). However he acknowledged that, if "one feels that it is important, for other reasons, to come up with some prediction curves, one has to do the best one can with the limited data." (Brune, Tr. 4460). Dr. Brune had not performed an independent evaluation of the regression analyses presented in the hearings. (Brune, Tr. 4466-67).

26. The Board finds that the separate empirical study directed by Dr. Idriss lends further support to the adequacy of the design spectrum. It is significant that two, independently conducted, site-specific studies reached consistent results in their ground motion predictions.

4. USGS Open File Report 81-365.

27. USGS Open File Report 81-365, authored by D.M. Boore and W.B. Joyner, is the latest in a series of reports on continuing research by these USGS scientists.63/ Dr. Boore appeared as a subpoenaed witness for the Intervenors and testified on the differences between this report and its successor, which had been submitted to the Bulletin of the

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63/ Open File reports of the USGS are preliminary reports, not subjected to peer or agency review in the usual sense, published in order to make information available to other researchers in a timely fashion. (Reiter, Tr. 5565)

Seismological Society of America (BSSA). This report was referenced in the cross examination of several witnesses by the Intervenors. Dr. Boore was of the opinion that the imminent publication of the paper in BSSA would make Open File Report 81-365 obsolete, (Boore, Tr. 4755) although he characterized most of the revisions (differences) as "cosmetic." (Boore, Tr. 6543) Possible exceptions to that statement are Dr. Boore's statements (Tr. 4754) that the revision predicts a mean value for PGA for an M_S7 event about 2% lower than does the original; the mean-plus-one standard deviation would be about 4% lower: also, the equation on which regression was done was changed. (Boore, Tr. 4758) Because of the importance attached to this USGS Open File Report by Intervenors, we comment in some detail; for the sake of brevity, we refer to it and to the revision as OFR 81-365,64/ using, however, only the revised manuscript.

28. This paper reports the results of a regression analysis of data from earthquakes that have occurred in western North America. The equation to which the data were fitted has a magnitude-independent shape because it requires fewer parameters. (Boore, Tr. 6544) In translation, the equation to which the data were regressed did not allow for saturation of PGA with distance in the near field.

64/ The revised manuscript was admitted into evidence as Intervenors Exhibit 28. The Open File Report was not admitted.

29. In the following discussion, the Board adopts, as edited and either in whole or in part, Staff's Proposed Findings 163-165 and Applicants' Proposed Findings 239, 241-243 and 245 pertaining to OFR 81-365.

30. The following points have been identified as significant criteria for evaluating regression analysis studies: (1) the data base should include information from earthquakes in the distance and magnitude range of interest; (2) the functional form assumed for the regression should not be biased or constrained; (3) all other things being equal, the regression with the lowest standard error is preferable. (Brune, Tr. 4461-65) In the regression analyses for San Onofre, values of PGA below 2% g are irrelevant. (S. Smith, Tr. 3263) (AF 239)

31. Included in the assumptions used in OFR 81-365 are: (1) the measure of source strength is moment magnitude. This new magnitude scale was originally developed to reflect the energy release of truly great earthquakes (greater than magnitude 8); (2) the shape of the attenuation curve (decrease of peak amplitude with distance) is magnitude independent; within the range of data ($5.0 \leq M \leq 7.7$ for peak accelerations and $5.3 \leq M \leq 7.4$ for peak velocity) it is assumed that the relative rate of peak attenuation with distance is the same for all magnitudes; (3) within the range of data it is also assumed that there is no saturation with magnitude at close distances to the fault; there is a simple log-linear relationship between peak acceleration (or peak velocity) and magnitude at all

distances; this assumes, for example, that the relative proportional increase in peak acceleration at a distance of 5 km is the same when magnitude is increased by 0.5 units regardless of whether one is considering M 5.0 or M 7.0. (Reiter, supplemental testimony at 6) (SF 163)

32. It is Staff's position that this report should not be used to assess the adequacy of the design ground motion for San Onofre because the authors themselves indicate that their results are not necessarily applicable to near field sites like San Onofre. The authors state "For distances less than 40 km from earthquakes with M greater than 6.6 the prediction equations are not constrained by data, and the results should be treated with caution." (I. Ex. 28 at 17) (SF 165) In Mr. Wight's study discussed above, the data base was restricted to recordings 50 km or less from the fault rupture; Dr. Boore included data recorded as far away as 200 km. This resulted in inclusion of accelerations as low as 0.2g, which were excluded as irrelevant to San Onofre by Mr. Wight.

33. Applicants argue in a similar vein that the statistical analyses presented in this publication are irrelevant to San Onofre because the USGS study is controlled by recordings at large distances from the rupture rather than by near-field data; because the model assumptions do not allow for magnitude saturation, i.e., it is assumed that the attenuation curves for all earthquakes have the same shape; and because the weighting procedures used result in minimizing the influence of

the relatively few recordings at near distances so that the analyses are controlled by low accelerations at large distances. (S. Smith, written testimony, Contention 1, at 4-6) (AF 241)

34. Testing the model of this paper with raw data shows that the model fails to predict the data at close distances for magnitudes near 6.5. (S. Smith, Tr. 3271) These inconsistencies include an 84th percentile that essentially envelopes all the data for magnitudes near 6.5. For magnitude 5, the median of the computed attenuation relationship falls below all the data. Therefore extrapolations to larger magnitudes probably overestimate PGA, making the predicted PGA values in the near field not useful for San Onofre. (Idriss, Tr. 1738; McNeill, Tr. 4023) (AF 243)

35. Using Equation 1 of the Boore and Joyner paper, the mean and 84th percentile PGA values for a magnitude 7 earthquake at a distance of 8 km are 0.46 and 0.83g, respectively, (Boore, Tr. 6559) Dr. Boore suggests reducing these values by a factor of 1.13 for comparison with Campbell's results,65/ (Boore, Tr. 6560) by which they become 0.41 and 0.73g, respectively. For a magnitude 7.5 earthquake at 8 km, Dr. Boore predicts a mean and 84th percentile of 0.54 and 0.98g,

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65/ Dr. Kenneth W. Campbell appeared as a rebuttal witness for Applicants. He had performed regression analyses comparable to those of Dr. Boore, also not for the purposes of this proceeding, and testified with a critique of the applicability of Dr. Boore's results to San Onofre. (Tr. beginning at 6749) respectively, also reduced by 1.13 for comparability. (Boore, Tr. 6613) When Boore and Joyner exclude from their analysis data beyond 50 km (as recommended by S. Smith, Tr. 3263), the mean and 84th percentile values for PGA become 0.31 and 0.57, respectively, for M 7 at 8 km. (Boore, Tr. 6609) (AF 245)

36. For statistical analyses, the model should be selected that reflects the known physics of the process and whose results are chiefly controlled by the data rather than by assumptions in the model. The model of OFR 81-365 is not the most appropriate one for near-field accelerations of a large earthquake, as the authors themselves appear to concede. In any event, in view of the results in the preceding paragraph, application of the Boore and Joyner model to San Onofre does not produce results significantly at variance with the design spectrum developed for use there. (AF 242)

5. Theoretical Modeling.

37. Computer modeling of the physical processes of earthquakes is a relatively recent development and was used in this case as an independent (of empirical methods) approach to judging the adequacy of the seismic design spectrum. This method attempts to correlate observed earthquake phenomena with their possible physical causes through mathematical descriptions and computer simulations. (Frazier, Tr. 6395) Dr. Gerald A. Frazier discussed the development and refinements of his models and presented the results of their application to the San Onofre site. The Board combines and adopts the Proposed Findings of

Staff (#131-153) and of Applicants (#251-261) in the following findings, as indicated.

(a). Method.

•38. The great potential of theoretical models for predicting strong ground motions is that extrapolations to geometric circumstances or site conditions for which little data exist can be made. (Frazier, Tr. 3327-28, 3538; Brune, written testimony, pp. 38, 43) The earthquake model should be viewed as a highly sophisticated method for extrapolating site-specific ground motions from recorded past earthquakes. Because of the degree of sophistication that includes rupture physics and wave mechanics, fewer data are needed to make reliable extrapolations than from conventional methods. (Frazier, Tr. 3327-28; A. Ex. 22, pp. 1-1, 1-2) The modeling studies performed for San Onofre complement empirical studies performed by Mr. Wight and Dr. Idriss. (Frazier, Tr. 6395-96) (AF 251) The basic objective of the modeling studies has been to predict ground motions at the San Onofre site that would result from a large earthquake hypothesized to occur along the OZD by modeling the physical process of previous earthquakes. (Frazier, written testimony, p. 4; Tr. 6395) (AF 252, SF 121)

39. In the initial stage of model development, computer methods were developed for simulating earthquake rupture and wave propagation in order to synthetically produce ground shaking over the frequency range 0-20 Hz. Next, strong motion recordings of past earthquakes were used in conjunction with

earthquake physics to calibrate rupture parameters in the computer model. The calibrated model was then tested for simulating ground motions for additional earthquakes, and the resulting model was then used to predict motions at the San Onofre site due to several hypothesized earthquake ruptures along the OZD. (Frazier, written testimony, p. 4) (AF 253)

40. The parameters used in the modeling procedure allow characterization of a specific fault slippage along a specific rupture surface in a specific earth structure. This involves characterization of rupture kinematics, rupture extent and orientation relative to the site and geologic structure (Frazier, written testimony, pp. 6-7). All but one of the key parameters are set according to site-specific conditions or robust generic formulae common to all earthquakes (Frazier, Tr. 3316). That one parameter, the initial slip velocity V_0, has been calibrated from near-field recordings of earthquakes. The considerable effort that went into the assignment of values for this parameter has been described in detail. (Frazier, written testimony at 8; A. Ex. 22; Tr. 3328, 3350-52) A value for V_0 of 800 cm/sec ($\pm$ 20%) was determined independently for all earthquakes modeled to date, including the 1940 Imperial Valley, 1966 Parkfield, 1933 Long Beach, 1971 San Fernando, and 1979 Imperial Valley earthquakes. (Frazier, written testimony at 8, 9; Tr. 3357, 6419) (AF 254)

41. In the model, the initial slip velocity characterizes the violence or intensity of the fracture process as the rock

initially fails (Frazier, Tr. 3354) and therefore controls the high frequency components of strong ground motion such as peak acceleration. (Frazier, Tr. 3355) Dr. Frazier concludes (written testimony at 9) that, because an essentially constant value of V_0 was required to match the high frequency recordings from the above large earthquake, the production of high frequency seismic waves per square kilometer of rupture surface is independent of earthquakes magnitude and static stress drop. This earthquake property he considers physically reasonable because the initial slip velocity directly relates to dynamic stress drop (the rapid change in stress at the crack tip as gouge materials undergo initial brittle fracture). (Frazier, loc. cit.) It is his opinion that the initial slip velocity is probably a constant for all earthquakes, down to magnitude zero and up to magnitude 8. (Frazier, Tr. 3357, 6419) (AF 255)

(b) Criticisms of the San Onofre Models, and Responses.

42. The modeling studies have undergone considerable review. (Frazier, Tr. 3361, 3421) Dr. Brune offered a critique in his written testimony. First, he states that the values for standard deviations in the TERA/DELTA model do not represent the kind of standard deviations expected from real data. (Brune, written testimony at 40) Focusing is one of a number of physical processes that lead to dispersion or scatter in recorded accelerations. (S. Smith, Tr. 3258) Because such phenomena are being simulated in the computer model, it is not

appropriate to add such scatter to modeling results. If such effects are not treated properly in the model, they should be referred to as inaccuracy, not as statistical scatter. (Frazier, Tr. 6405, 6406) Dr. Frazier notes further that a more appropriate way to compare the scatter in modeling results with that in recorded data is by comparing the range obtained for San Onofre from modeling various offshore rupture configurations; this scatter varies over about a factor of two, which is less than we see in real earthquakes. (Frazier, Tr. 6407)

43. Second, Dr. Brune states that the attenuation parameter Q has not been adequately investigated. (Brune, op. cit. at 41) Dr. Frazier responded that uncertainties in Q do not significantly influence San Onofre predictions and therefore do not relate to the reliability of the model predictions. He does not know what the value of Q should be for this site, but considers it an interesting research problem. He expects that, were he to double the value of Q in the present model and recalibrate against data, the predicted motions at San Onofre would decrease a little from their present values. (Frazier, Tr. 6400, 6408, 3379-80) Dr. Luco, who had also suggested doubling Q, did not disagree with Dr. Frazier's expectation of the possible result. (Luco, Tr. 5049) Dr. Frazier noted that both Drs. Luco and Brune referred to the modeling studies for their appraisal of this parameter. (Frazier, Tr. 6400; Luco, Tr. 5046) Dr. Brune notes that he has not completed any

independent studies of the parameter Q. (Brune, Tr. 4422) (AF 257)

44. Third, Dr. Brune states that it is difficult to infer what the effective value for dynamic stress drop is. (Brune, written testimony at 41) In his rebuttal testimony, Dr. Frazier presented a detailed discussion of earthquake stresses, stress drops and the relations among them and initial slip velocity. (Frazier, Tr. 6408-20) Dr. Frazier contends that effective stress drop is a difficult problem, of theoretical interest only, and inappropriate in attempting to deal with real data because of its non-physical implications. (Frazier, Tr. 6410) He considers dynamic stress drop to have a one-to-one relationship with initial slip velocity, V_0, which is a parameter in his model. He has attempted to estimate dynamic stress drop from the intitial slip velocity and gets about 500 bars, to which he attaches only order of magnitude accuracy. Frazier, Tr. 6419) Values of the initial slip velocity are established empirically from strong motion recordings in southern California. (Frazier, Tr. 3356-57, 6419) Considerable evidence indicates that PGAs are not directly related to conventional (static) stress drop. (Frazier, Tr. 6418, 3420, 3552-53) (AF 258)

45. Fourth, Dr. Brune, referencing Dr. Luco, states that the TERA/DELTA model does not adequately predict the accelerations observed in the IV-79 earthquake at stations a few kilometers from the fault, being too low by approximately a

factor of two. (Brune, op, cit. at 42) Dr. Brune stated that he did not independently make this assessment. (Brune, Tr. 4425) He then stated that the results presented in Dr. Frazier's testimony are not low by a factor of two. (Brune, Tr. 4426) Dr. Frazier's testimony with respect to actual comparisons between computed and recorded accelerations for IV-79 indicate good agreement for distances near 8 km, which are of primary interest for San Onofre. (Frazier, written testimony, Contention 1, at 23; Tr. 3377, 3607, 3370) (AF 259-260)

46. Regarding uncertainties in the physics of earthquakes, Dr. Frazier notes that the relevant question is "Has the modeling been done in a consistent manner?" Each time the model has been updated or improved and new results calculated for San Onofre, the resulting values are all comparable. The reason the values are similar is not because all of the physics in the model is 100% correct, rather, the results are similar because the modeling matches real data at distances appropriate for San Onofre. (Frazier, Tr. 3478, 3451) Dr. Frazier concedes that there are gaps in the knowledge of earthquake phenomena and that some comments have led to improvements in the model while others, although interesting, are primarily of scientific interest. He considers the model adequate for the practical purposes intended. (Frazier, Tr. 6399, 6403, 6407, 3378, 3450, 3467, 3476-78) (AF 261)

47. The Board also heard testimony from Dr. J. Enrique Luco, who appeared as a Board witness, concerning his review of the Applicants' modeling studies. Dr. Luco has served as a consultant to the Staff in its review of the TERA/DELTA modeling. (Luco, Tr. 4977) Intervenors' Exhibits 19, 20, and 21 relate to his testimony. (SF 149)

48. While Dr. Luco expressed his views concerning the appropriateness of certain of the parameters in the study, he was emphatic in his position that he was "not recommending a particular value of g for design." (Luco, Tr. 5010) It is also worthy of note that Dr. Luco's recommendation of a value of 0.8g (Luco, Tr. 5007-08, 5010) is for purposes of defining a free field or instrumental spectrum. (Luco, Tr. 5014) (SF 150)

49. Dr. Luco acknowledged that it is possible to reduce the design spectrum from the free-field spectrum, but he objected to doing it at the beginning of an analysis. (Luco, Tr. 5021-22) (SF 152)

50. Dr. Luco was involved in the origin and validation of the TERA/DELTA computer program (Luco, Tr. 5038) and continues his work in this area through development of his method of study of earthquake phenomena via computer analysis (Luco, Tr. 5038 et seq.). He maintained that his view of the TERA/DELTA modeling has changed little over the time of his letters of comment on it, (I. Exs. 19, 20, and 21; Luco, Tr. 5028, 5043) and expressed preference for his approach. (Luco, Tr. 5046) Nevertheless, Dr. Luco believes that the "general approach" is "of high value in

estimating the strong motion characteristics at a site." (I. Ex. 19 at 1; Luco, Tr. 5094) Thus, for comparative purposes, the modeling approach serves a useful adjunct to empirical studies. (See SER § 2.5.2.4.5) (SF 153)

(c) San Onofre Predictions.

51. A suite of postulated earthquakes was examined in the modeling approach to isolate particular rupture configurations that produce the strongest ground shaking at San Onofre. The various conditions that were compared included different fault locations, rupture directions, fault length, hypocentral depth, depth to the fault bottom. amd depth to the fault top. (Frazier, written testimony at 16-17; A. Ex. 22) (AF 262)

52. The worst case fracture represented an M_S7 with rupture orientation so as to maximize ground motion at the site. The results indicate that the design spectrum is conservative in that it exceeds the predicted instrumental spectrum at all periods of interest using 2% damping. (Frazier, written testimony at 14-16, Figs. GAF-A through GAF-D (AF 264)

(d) Board Findings.

53. Because earthquake modeling of the kind done for San Onofre is a relatively new and controversial technique, this board is not prepared to endorse it unequivocally. Until there is greater experience and refinement of these techniques, we think it would not be prudent (although perhaps possible under a "preponderance of the evidence" approach) for a licensing board to make definitive determinations about some of the very

technical questions that have been raised by the critics -- unless such determinations are necessary to decide the case, a situation that does not obtain here.

54. In light of these considerations, we make no specific findings, for example, about the proper value of "Q" or the implications of dynamic stress drop for modeling studies. Only further research will produce the "truth" about these matters. But we can reach these general conclusions. First, it is particularly significant that the results of the modeling studies were validated against near-field recordings of five important California earthquakes in the distance range relevant for San Onofre. (Frazier, written testimony, p. 17). In addition, we were impressed with the level and intensity of intellectual effort devoted to these studies by Dr. Frazier and his colleagues. Moreover, although critics raised some interesting questions, these appear to relate in the main to refinements in methods, not fundamental flaws. As the Staff points out, the results of the Applicants' modeling studies support the conservatism both of the SSE and the empirically derived design spectrum. (SER § 2.5.2.4.2) We therefore believe we can take these studies into account as bolstering our determinations about the adequacy of the San Onofre design spectrum.

55. The Board reiterates its concurrence with the Staff that the most appropriate way to arrive at an estimate on strong ground motion is through a conservative comparison of the

results of different methods of determination. The table below summarizes the PGA results reached for San Onofre by the different methods discussed above. We observe that all estimates lie appreciably below the 0.67g anchor point to which San Onofre was designed, except for the Boore estimates. When the Boore estimates are adjusted appropriately for distance, they are also compatible with the anchor point.

Estimated PGA at San Onofre
for an M_S7 Event on the OZD

Investigator	PGA for Instrumental Spectrum (g)	
	Mean	84th Percentile
Wight	0.33	0.52
Idriss	a	0.63
Boore	0.46[b]	0.83[b]
Frazier	0.31[c]	a

[a]We do not find this value in the record.

[b]These values result from inclusion of recordings at distances greater than 50 km. When recordings beyond 50 km are excluded, the resulting values are 0.31 and 0.57.

[c]See A. Ex. 21, p. 5-11.

6. Development of the Design Spectrum.

56. Applicants' witness Dr. Robert McNeill was directly responsible for and actively involved during 1971 and 1972 in calculation of the design spectrum for San Onofre Units 2 and 3. Much of Dr. McNeill's testimony was directed to bridging the gap between the seismologist who deals with an instrumental free

field response spectrum and the designer, who needs a design spectrum. (McNeill, written testimony at 18; Tr. 2748)66/ Dr. McNeill's written testimony (at p. 8) includes a lucid discussion of the technical terms in this area.

57. "The shape of the [design] spectrum was derived by mathematically propagating virtually all of the strong motion recordings then available through the profile of the San Mateo Formation. [T]he resulting instrumental spectra at the site ground surface [were then calculated and enveloped]. For this purpose, the dynamic properties of the San Mateo Formation were determined by both field and laboratory tests." (McNeill, written testimony, p. 18.)

58. "The instrumental spectrum shape was anchored to a zero period acceleration [ZPA] of 0.5g. ... At that time (1972), the maximum magnitude on the OZD had not been determined, but it was recognized that design for a very large, nearby earthquake

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66/ The Intervenors objected to the admission of the testimony of Dr. McNeill and Mr. Lawrence Wight, and also to portions of the testimony of Dr. Idriss on the grounds that it is not within Contention 4. They argued that that contention is concerned only with the geology and seismology of the site, and that it does not extend beyond determination of free field accelerations to the next step in the process -- construction of design spectra for the facility. The Board ruled that contention 4 does extend to the testimony in question insofar as it concerns design spectra considerations. The contention expressly refers to the "seismic design basis" of the facility, which plainly includes design spectra. Apart from that, some of the testimony in question, particularly that of L. Wight, is concerned primarly with free field accelerations, not design spectra. See Tr. 1589-1612, 1696-98.

would be conservatively appropriate. For that reason, and in consideration of the state of the art of predicting ground motions and structural response at that time, the following modifications were made to the 0.5g site instrumental spectrum to add extra conservatism: (i) the ZPA was increased to 0.67g, and the entire instrumental spectrum was scaled up to that value; (ii) the acceleration amplification ratio was increased by about ten percent; (iii) the short-period turning point was decreased from 0.05 second to 0.033 second." Id., pp. 18, 19.

59. Dr. McNeill described the factors entering into the consideration of soil-structure interaction and the manner in which structures of various size and situation respond to vibrations. (McNeill, written testimony, pp. 13-15; Figs. RLM-H and RLM-I) For example, he pointed out that the dimensions of large structures are larger than the wave lengths of the short-period waves and, therefore, do not respond fully to them. An embedded structure responds less than a surface instrument because the motions at depth may be less than those at the surface. All these considerations serve to lower the short-period end of the design spectrum. (McNeill, loc. cit.)

60. Probably the greatest conservatism lies in the use of this instrumental spectrum directly for design. No allowances were made for wave-passage, incoherence, mass, depth-of-embedment or other effects which cause the motions governing structural response to be less than that recorded by free-field instruments. Furthermore, no allowance was made for the extra

strengths which are provided for in the structural design. (McNeill, written testimony, pp. 18-19) The design form of the design spectrum is shown in Fig. RLM-L of Dr. McNeill's written testimony.67/

61. There is no significance for design in a single observation that exceeds the 84th percentile. There is intrinsic scatter in the data that must be taken into account by looking at the dispersion. (Idriss, Tr. 1747) Some values of PGA will exceed the instrumental response spectrum (Brune, Tr. 4230).

62. The Board concurs with Applicant and Staff that significant conservatisms were introduced at each stage of the development of the design spectrum. The Board is impressed with the evidence of the attention to detail and the conservatism manifest in the establishment of the design basis for San Onofre Units 2 and 3. We note the testimony of Staff witness Dr. Reiter to the effect that he considers the facility, one of at least 30 that he has reviewed (Reiter, Tr. 5585), to be probably the most conservatively designed. (Reiter, Tr. 5597-98)

67/ It was necessary to derive an equivalent instrumental spectrum for the plants since Dr. McNeill had used the conventional instrumental free-field spectrum as the design spectrum. This derived instrumental spectrum is shown in Fig. RLM-P of Dr. McNeill's written testimony.

7. Relationship Between Vertical and Horizontal Accelerations

63. Since acceleration is a vector, it can be resolved into three mutually perpendicular components. In the context of this hearing, most of the emphasis was placed on the horizontal components, in almost all cases the larger one. However, the vertical component was not ignored.

64. A view based on observations and held by many seismologists apparently for some time is that the vertical component of strong motion would be 2/3 the horizontal component. (Reiter, Tr. 5860) It is not clear from the record whether this ratio is intended to apply to the larger horizontal component or to some sort of an average of the two; however, in light of our findings below, this is of little relevance for our purpose.

65. Analysis of the data from large earthquakes since 1973 has shown several instances of nonconformance with this assumption, notably in the 1979 Imperial Valley and in the 1980 Mammoth earthquakes in which some stations showed the vertical component equal to or larger than the horizontal components. (See, for example, Anderson at Tr. 4648; Frazier, testimony, Contention 1 at 15 et ff.) Because the design spectrum for San Onofre is anchored at 0.44g vertical acceleration (2/3 of the PGA of 0.67g), Dr. Brune feels that "we cannot be sure of the degree of conservatism involved in the vertical acceleration of 0.44g" (Brune, testimony at 63); he views these recordings of

the vertical component greater than 2/3 the horizontal as further evidence of our lack of understanding of earthquake phenomena. (Brune, op. cit., at 62) Although Dr. Brune expressed concern about exceeding the 2/3 ratio, he did not attach any specific significance to such an exceedance from the standpoint of the design of the plants. (Brune, Tr. 4224-25, 4228-29, 4238) These areas, he acknowledged, are beyond his expertise. (Brune, Tr. 4224, 4231)

66. Several explanations have been offered of these high vertical recordings (Brune, ibid.; Frazier, 68/ testimony Contention 1, at 15 to 21; Anderson, Tr. 4649) but the matter remains speculative at this time. Of greater present importance is the question of their possible impact on the adequacy of the design basis of San Onofre. Dr. McNeill, who had derived the spectra used for design, testified that the 2/3 ratio has no significance for him but that the values of acceleration do. (McNeill, Tr. 4024) He discussed the impact of events since 1973 on the design spectrum for San Onofre by comparing their spectra. Referring to his written testimony for Contention 4, Figs. RLM-Q and RLM-R, it is apparent that the design spectra, horizontal and vertical, lie above the IV-79

68/ Dr. Frazier considers the "large vertical acceleration recorded at Station 6 (1.74g later corrected to 1.52g) during the 1979 Imperical Valley earthquake ... an enigma" and offers extensive comment on it. (Testimony, Contention 1 at 19 ff.)

spectra at all periods for relevant distances. (McNeill, Tr. 4009)

67. Further, the design of San Onofre Units 2 and 3 assumes conservatively that the significant ground motion from all components occurs at the same time; the assumed duration of this motion, including repetition of high peaks of acceleration, is much longer than that recorded at IV-79 (80 sec vs. less than 15 sec). (SER, § 2.5.2.4.6) The duration of strong motion is important because of the damage it can do to structures.69/ Dr. Reiter observed that the high vertical accelerations recorded during IV-79 did not correlate with damage and that the high-frequency vertical spikes, which did not occur at the same time as the maximum horizontal motions, seem to be of little importance. (Reiter, Tr. 5881)

68. In summary, the Board feels no concern over the fact that the traditionally expected 2/3 ratio between vertical and horizontal accelerations has been exceeded in some recent recordings; the adequacy of the design criteria for the plants has not been affected.

69/ Dr. McNeill described the possible importance of duration at Tr. 4012-16. In response to a Board question, Dr. McNeill stated that at the time he derived the spectra for these plants there was no specification of M_S7 at 8 km, and the intent was to design conservatively. Events since the design was established indicate, in his opinion, that the spectra, the time history, and the duration of the time history are extreme; he further stated that, if he were to do the design again, with the many more records for guidance, the design constraints would be much less severe than they are. (McNeill, Tr. 4017)

8. Saturation of Peak Ground Acceleration.

69. The concept of "saturation" of peak ground accelerations in the area near the fault rupture surface, the so-called "near field," is controversial among seismologists. In the case of moderate earthquakes of magnitude ranging from, say, M_S5 to 6, there will be a roughly proportional increase in peak ground acceleration ("PGA") accompanying increasing magnitude. However, if the Applicants' thesis is correct, that proportional increase in PGA will diminish -- i.e., the curve plotting PGA's will begin to "flatten out" -- above magnitude 6. And above $M_S6.5$, further increases in magnitude will not be accompanied by any significant increases in PGA -- i.e., PGA becomes "independent" of magnitude in the near field area close to the fault. As described by Dr. Frazier, one of the Applicants' witnesses on this point, when saturation occurs at the larger earthquake level, "the sensitivity of peak ground acceleration (PGA) on earthquake magnitude diminishes with increasing magnitude and with decreasing distance." (Frazier, written testimony, p. 18-21).

70. The saturation concept, if established for the anticipated PGA in this case, would buttress the adequacy of the San Onofre design basis. It would mean, in effect, that a PGA significantly higher than that to be expected from an $M_S6.5$ earthquake would not result, even from earthquakes of M_S7 or $M_S7.5$. On the other hand, it would not mean that earthquakes of such higher magnitudes might not cause greater damage. For example, the higher magnitude earthquakes can cause ground

motion of much longer duration, even though PGA measurements may be about the same. Nevertheless, proof of the saturation concept here would add a significant element of conservatism to the Applicants' case. S. Smith, Tr. 3285-87.

71. There is general agreement that measurements of some waves caused by earthquakes saturate at certain magnitude levels. Thus, the surface wave magnitude method of measurement is based on relatively long-period 20 second surface waves. According to Dr. Frazier, these waves saturate at about $M_S8.3$. M_L and body wave measurements are based on shorter waves with a period of about one second. Both of these measurements saturate at values equivalent to about M_S7, so that earthquakes larger than M_S7 nevertheless do not register above 7 on these scales. Frazier, written testimony, p. 18. The Intervenors generally accept these saturation phenomena and the magnitude levels at which they tend to occur. Brune, Tr. 4995-4500.

72. The Intervenors' chief witness of this point, Dr. Brune, expressed his general agreement with the proposition that PGA would saturate, but only "at some high [and unspecified] magnitude" on the M_S scale. Tr. 4482. Furthermore, the Intervenors' findings of fact refer to the possibility of PGA increasing up to $M_S7.5$. IF 126. Thus, the crux of the disagreement between the Applicants and Intervenors is whether

saturation will occur at some point between M_S6.5 and 7.5.70/

73. Having established these parameters of disagreement, we look to the proof adduced by the Applicants and the Intervenors. The Staff offered no proof and proposed no findings on the saturation phenomenon.

74. In their proposed findings of fact, the Applicants rely primarily on certain testimony of Drs. Smith and Fraizer. Dr. Smith testified that "the data clearly shows that above magnitude six and a half, the peak ground acceleration is essentially independent of magnitude." Tr. 3240. In support of his position, he referred to data from five specific earthquakes, to a recently published paper, and to the Applicants' Exhibit 11. Id. He asserted that the most recent paper published by Hanks and McGuire on strong ground motion supported his position that PGA saturates at M_S6.5. Tr. 3242-43. However, this paper, entitled "The Character of High-Frequency Strong Ground Motion," was not introduced into evidence. Dr. Smith had not carried out any independent research, beyond reviewing data over the years. Tr. 3245.

75. Dr. Frazier also endorsed the saturation phenomenon, but from a theoretical, rather than an empirical, perspective. His reasoning proceeded from the demonstrated saturation of 20

70/ Consideration of larger earthquakes from the "saturation" perspective is not warranted because there is no substantial evidence in the record indicating the possibility of such an earthquake on the OZD.

second and one second waves at M_S8.3 and 7, respectively, to the hypothesis that waves around 5 H_z (0.2 second) "would be expected to" or "should" saturate at about M_S6.5. Frazier, written testimony, pp. 18-19. Seemingly implying some disagreement with Dr. Smith, Dr. Frazier indicated that the saturation of high-frequency waves is not well documented because of the difficulty of measuring such waves at long distances.

76. The Intervenors rely upon Drs. Brune and Boore for the proposition that PGA does not saturate with magnitude, or at least that it has not been shown to saturate in the range of M_S6.5 to 7.5. Dr. Brune reviews aspects of some current literature on saturation and concludes that "the question of magnitude saturation cannot be solved by debate over the present data set, but must await accumulation of more data." Brune, written testimony, p. 60. Dr. Brune's arguments rest largely upon the recent Hanks and McGuire article, the same article in which Dr. Smith found support for his quite different views on saturation. Dr. Brune also relied on a recent unpublished paper by C.H. Scholz. Neither of these articles is in evidence. Since the data and assumptions underlying the conclusions of these articles are unavailable to us, we cannot attribute evidentiary weight to the views Dr. Brune bases solely upon them, other than to acknowledge that they may raise interesting questions on this subject. It is Dr. Brune's independent view that we do not have enough data to establish whether near field PGA saturation occurs with large earthquakes.

77. Dr. Boore of the U.S. Geological Survey testified concerning saturation largely on the basis of the most recent revision of an article he wrote with Dr. Joyner which was recently submitted for publication to the Bulletin of the Seismological Society of America. This article is in evidence as Intervenors' Ex. 28. Although this study did not focus primarily on the question of near field saturation, the authors did note that their data showed "no tendency for ... peak acceleration ... to saturate with magnitude." They further noted that --

> Although it might be argued that peak acceleration should saturate for the same reason that the body-wave magnitude scale saturates, we are not aware of any careful analysis supporting this argument. We consider the question open. I. Ex. 28, p. 17.

Dr. Boore testified that he and Joyner had chosen to use a regression curve having the fewest number of parameters; and since their data did not demonstrate the saturation phenomenon, they had used a magnitude-independent curve. He stated that he was "not really aware "of a saturation level associated with PGA, but indicated his belief that saturation might be found with great earthquakes of magnitudes M_W8 to 9. Tr. 6588-96.

78. If the foregoing fully described the record on saturation, we might conclude that the evidence is in equipoise. We would have about equal and not very strong cases for and against the phenomenon, coincidentally supported by four exceptionally well-qualified experts, two on each side. In that event, the issue would go to the Intervenors, because of the Applicants' failure to prevail by a preponderance of the

evidence. However, we believe that the Applicants Exhibit 11, not cited to us for the saturation phenomenon, tilts the scales in the Applicants' favor to a limited extent.

79. We have earlier made favorable findings concerning Applicants' Exhibit 11, sponsored by Lawrence Wight. See ¶¶ 12-17, above. That study included conclusions that PGA saturates both with increasing magnitude and decreasing distance from the fault rupture surface. More importantly, the study includes a description of the underlying data and how it was selected and analyzed. The results from a saturation perspective are clearly evident in Figures 4-1 to 4-4. For example, Figure 4-2 shows a marked bending downward of the median curves, reflecting a slower increase in PGA with decreasing distance from the fault. Similarly, Figure 4-4, which normalizes data to 8 km, shows the median curve of PGA flattening with increasing magnitude. The Wight results are also substantiated by the testimony of Dr. Frazier on the 1979 Imperial Valley earthquake, which we note although it was not cited to us for the saturation phenomenon. Frazier, written testimony on contention 1, p. 13, and Figure GAF-H. See also written testimony of I.M. Idriss, p. 12 and A. Ex. 18.

80. The Wight study is very helpful, but it does not carry the day entirely for the Applicants. First, as has been frequently noted, more near-field data from large earthquakes are needed to test the saturation hypothesis fully. Beyond that, the Wight data does not provide a clear demonstration that saturation is virtually complete at M_S6.5, that increases in

magnitude beyond that will not be accompanied by significant PGA increases. The Wight tables indicate that saturation begins between M_S6 and 6.5, and that it increases through M_S7. However, the tables also suggest that smaller but significant PGA increases could occur above M_S7, particularly considering the lack of data at such magnitudes.

81. We conclude that PGA probably does begin to saturate to some extent within 10 km of the fault between M_S6 and 6.5, and that saturation probably continues thereafter with increasing magnitude and decreasing distance from the fault rupture surface. The record contains no sufficient basis for concluding when or whether saturation becomes complete. This qualified finding lends some slight support to the adequacy of the San Onofre design. However, given the meager and rather confused record on saturation, we do not ascribe substantial significance to the phenomenon.71/

9. Effects of Focusing on Peak Ground Acceleration.

82. As stated by Dr. Brune:

> Focussing of energy in the direction of source propagation is a phenomenon that has been known and observed in nature for many years. In seismology, the effect has been termed directivity and has been observed for many earthquakes, ... most recently in the Livermore earthquake

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71/ Apparently the record in the Diablo Canyon case contained more persuasive proof of near field PGA saturation. The Appeal Board there strongly endorsed the concept. See Pacific Gas and Electric Co. (Diablo Canyon Plant), ALAB-644, slip op., pp. 42-52. If saturation had turned out to be a pivotal issue in this case, we might have sought further evidence on the question. Since the result is not affected by this factor, there was no occasion to pursue it further.

> ... the Santa Barbara earthquake ... and the Coyote Lake earthquake. Written testimony, p. 32.

Earthquake focusing results from time compression of signals, similar to the familiar Doppler effect one hears as a train or helicopter passes. Dr. Frazier provides the following illustrative example:

> Focusing for earthquakes can be understood by considering a unidirectional fracture that ruptures due north and emits seismic waves for a duration of 10 seconds. Because of the approaching rupture, an observer in the near field and north of the source experiences strong shaking for a duration less than 10 seconds, say 6 seconds. The fact that 10-seconds-worth of seismic energy arrives within 6 seconds tends to increase the amplitudes of ground motion in the direction of rupture focusing. Conversely, an observer in the near field, south of the source, experiences strong ground shaking for a duration longer than 10 seconds which tends to decrease the amplitudes of motion in the direction of rupture defocusing.

83. The phenomena of focusing and saturation are opposites from a safety standpoint. That is, saturation would diminish the PGA one would otherwise expect and the consequent hazard to a facility; by contrast, focusing would result in a higher PGA toward a facility and would increase the hazard.

84. There was no dispute among the witnesses that focusing is a real, observed phenomenon. The dispute centered on how much higher PGAs might be expected to result from focusing.

85. The Applicants' witnesses, Drs. Smith and Frazier, took the position that, other things being equal, the maximum spread between the low (or "defocused") PGA and the focused PGA would be approximately a factor of 2, and that the spread between the median PGA and focused PGA would be approximately a factor of 1.5. For example, if the median PGA were .3, the

focused PGA might be about .45, and the defocused PGA would be about .22. These figures are borne out by data derived from the best instrumented earthquakes for testing the focusing phenomenon -- Parkfield, Livermore, Santa Barbara and Coyote Lake. Dr. Brune, the chief witness for the Intervenors, agreed with the results derived by the Applicants from these earthquakes. Tr. 3255-58; Frazier, written testimony, pp. 12-13; Tr. 4367.

86. In addition to these data, Dr. Fraizer testified that his modelling study incorporated focusing effects. He noted that the model tended to overemphasize focusing effects of PGA due to localized irregularities associated with actual earthquakes. As noted previously, the PGAs predicted by his study for San Onofre are well within present design parameters. Written testimony, p. 10.

87. Dr. Brune testified that focusing can lead to PGAs in the direction of rupture "several times higher" than in the opposite direction. He was reluctant to quantify that estimate further, but suggested that about 5 times higher was a posssibility. Tr. 4365. He did not suggest any theoretical reason why this would prove to be the case. Dr. Brune pointed out, however, that there is no case of a well-instrumented large earthquake (M_S near 7) that might clearly illustrate the maximum potential effect of focusing. Id.

88. The Intervenors cite a recent article (Intervenors' Ex. 17) by their witness, Dr. Boore, which included some data analysis from two 1980 earthquakes in the Livermore Valley. In

the article, Dr. Boore states that the results of their analysis "are most easily interpreted as the result of directivity" (focusing), but he does not state how much directivity is indicated. Ex. 17 at p. 2295.

89. In their proposed finding 111, the Intervenors quote Dr. Boore in his direct examination, where he refers to certain comparative data in the article and to a "factor of ten" change in that data. The Intervenors go on to state that "Dr. Boore's best interpretation of the data from the Livermore earthquake is that directivity effects the peak accelerations by a factor of 10." This is a serious misstatement of the record. Dr. Boore did not say anything of the sort. On a page of the transcript not cited by the Intervenors, their Counsel specifically asked Dr. Boore --

> Does the directivity observed in the Livermore earthquake indicate a factor of up to ten increased ground accelerations in the direction of rupture?
>
> Dr. Boore answered --
>
> Not necessarily ... The data are available, and I don't recall -- I don't think they showed that much change. This kind of a factor of ten increase is -- if you had two events and they were propagating in different directions, then the actual variation of acceleration in the event can be on the order of the square root of ten. Tr. 4749-51.

In concluding on this subject, Dr. Boore would only say that the data from the Livermore earthquakes showed directivity in that particular earthquake, resisting promptings from counsel to make a broader statement. Tr. 4765-66. Other testimony from Drs. Smith and Frazier places this Livermore data in a clearer perspective and indicates that it is not seriously inconsistent with other available focusing data. Tr. 3255-58; 3556-58. Dr. Brune also appeared to question whether the Boore article demonstrated a high degree of focusing at Livermore. Tr. 4367.

90. Intervenor witness Dr. Anderson testified concerning certain PGA readings he had obtained from the 1980 Mammoth Lake M_S6.2 earthquake. At three stations located at different points on a 10 km radius of the estimated epicenter, the readings were .72 and .55g, .27 and .35g, and .20 and .10g. He suggested that focusing was a possible explanation of the different readings, but that he had only preliminary data insufficient to make any exact determination of the cause. Tr. 4626-27.

91. The 1979 Imperial Valley M_S6.9 earthquake generated more strong motion recordings than any other strike-slip earthquake to date. Dr. Frazier testified that these data were consistent with those previously derived for the Parkfield and Coyote Lake earthquakes, providing further evidence "on the limited effects that rupture focusing has on increasing peak accelerations." Frazier, written testimony, issue 4, p. 13, issue 1, p. 13. Dr. Brune conceded that the Imperial Valley earthquake had not produced a focusing phenomenon multiplying PGAs by 5. Tr. 4368. He suggested, however, that this may not have occurred "possibly because the source was not an approximate uniform rupture." Brune, written testimony, p. 33. That suggestion was not further explored.

92. An additional consideration, not explicitly developed in the record, leads us to largely discount focusing as a

significant hazard in this particular case. Increased PGAs resulting from focusing are highest directly in the path of the spreading rupture. Thus, our focusing concerns would be greater if the San Onofre facility stood directly in the path of a major fault. But the OZD, the controlling structure, is oriented orthogonally to the facility, about 8 km offshore. Dr. Smith was apparently referring to a similar situation in the Santa Barbara earthquake, where Santa Barbara was "off to the side" from the fault, and higher PGAs occurred elsewhere. Tr. 3258.

93. In summary, we conclude that the focusing phenomenon is not a serious safety concern, at least in this case. All of the available evidence indicates that where focusing does occur, the resulting differences in high and low PGAs will be about a factor of 2, and that lesser differences will obtain between median and high PGAs. Moreover, there are no major active faults in the site vicinity "focused" -- i.e., aimed at -- the site. Furthermore, the Intervenors' concerns about focusing are based in the record on little more than its possibility, and an alleged lack of sufficient data. They have failed to advance a plausible theory supporting these concerns.

94. We find, in conclusion and considering all of the factors discussed in this Section III C, that a 0.67 PGA predicated upon the occurrence of an M_S7 earthquake on the OZD about 8 km from the site represents a conservative anchor point for the design spectrum of the San Onofre facilities.

D. Newly-discovered Geologic Features.

1. Introduction. Contention 3 states that:

> Whether the seismic design basis for SONGS 2 & 3 is inadequate to protect the public health and safety as a result of discovery subsequent to issuance of the construction permit of the following geologic features: (1) ABCD features at the site; (2) features located at Trail 6, Target Canyon, Dead Dog Canyon, Horno Canyon, and "onshore faults E & F"; (3) such other features as the parties may agree are relevant to the seismology of the SONGS site or with respect to which intervenor Friends of the Earth makes a threshold showing of relevance.

Both the Applicants and the Staff presented testimony and exhibits concerning the various features named in this contention. (J. Smith, written testimony, pp. 1-19; P. Ehlig, written testimony, pp. 1-4; A. Exs. 25-27; SER Sections 2.5.1.3, 2.5.1.6 and 2.5.1.8). One Intervenor witness (M. Legg, written testimony, pp. 8-10) briefly addressed the ABCD features, but the Intervenors propose no findings based on that testimony and apparently do not rely on it.72/

2. Although the contention contemplated that the parties might agree upon, or one party might prove, the

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72/ Our independent review of this testimony indicates that it is not entitled to significant probative value. Its thrust -- that the ABCD features are "favorably oriented" for slip in the present stress regine -- was blunted by the witness' inability to say what kind of fault orientations would not be" favorably oriented." M. Legg, written testimony, pp. 8-10; Tr. 5242-5245. Furthermore, the witness conceded that he had not personally done any field study of the ABCD features. Tr. 5252.

relevance of additional geological discoveries, that did not occur.73/

3. The proposed findings of the Applicants and the Staff on contention 3 are basically consistent, although each party tends to rely more on its own evidence. Thus, this contention

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73/ Early in the hearing, the Board Chairman was contacted informally by Mr. David W. Phifer, a local resident who indicated that he had significant geological information about the San Onofre area. The Board granted Mr. Phifer a specially scheduled limited appearance in which he presented his interpretations of certain geologic features as previously unknown active faults. Tr. 1418-1432. Thereafter, the Applicants conducted field investigations and lodged a report with the Board on Mr. Phifer's information, concluding that his active fault interpretations were incorrect and that his information was not significant to the seismic design of San Onofre. The Staff, on the basis of their own field investigations and review of the Applicants' report, concurred in those conclusions. Tr. 6024. The Intervenors acknowledged that they had no evidence that would justify further pursuit of Mr. Phifer's views in this case and that they did not intend to call him as a witness. Tr. 6090-6092. In these circumstances, the Board saw no reason to pursue the matter any further.

After the record was closed, Mr. Phifer submitted additional information about the San Onofre area and his geological interpretations of it, to the Commission, the President and other officials, and the media. The Applicants prepared a second report dated November 25, 1981 on features it had not previously discussed; the Staff concurred with the Applicants on December 5, 1981. Once again, we saw no basis for this Board to take any action on Mr. Phifer's information.

The Staff introduced evidence and proposed findings (SF 223-224) concerning two cracks discovered near the Cristianitos fault since construction permit issuance. Since no threshold showing was made as a predicate for considering these features, we have made no findings considering them.

is essentially uncontested, except for a few findings proposed by the Intervenors.

2. <u>ABCD Features</u>.

(a) <u>Discovery and Investigations</u>.

4. In 1974, following issuance of the construction permits, anomalous geologic features in the San Mateo formation were discovered at the site during excavation of Units 2 and 3. These features were designated the "A and B" features by the Applicants. They are referred to variously as "joints," "shear zones" and "minor faults." The Staff requested the Applicants to perform a detailed study of these features in order to assess the possibility of ground rupture under the reactors. (SER 2.5.1.3; S. Ex. 9, p. 1; A. Ex. 25, p. 1; J. Smith, written testimony, pp. 2-3).

5. Shortly thereafter, two additional features labelled the "C and D" features were discovered and reported to the NRC Staff. The Applicants undertook an investigation of these features as well. (SER. 2.5.1.3; A. Ex. 26, pp. 1-2).

6. We adopt the Applicants' overall description of its investigations at the site, AF 350:

"The investigations of the A, B, C, and D features at the site were extensive and detailed. They included review of pertinent geologic literature, review of aerial photographs, geologic mapping at Units 1, 2 and 3 of SONGS, excavation of 19 backhoe trenches, drilling of seven borings to a depth of 25 feet, detailed logging of all backhoe trenches and pertinent excavations, microscopic and petrographic studies, theoretical analysis regarding the mechanics of their origin, detailed mapping at two areas outside the SONGS site and inspection of two other localities. The investigations involved approximately 215[74] man-days, and were reviewed on several occasions by representatives of the NRC, USGS, and ACRS. (A. Ex. 27, pp. 3-4; S. Ex. 9, pp. 2-3).

7. A and B features were found at various elevations around the site, indicating that they extend to depths of perhaps a few hundred feet into the sandstone San Mateo formation on which the site is located. Because of their good exposure in both horizonal and vertical views in and around the site, it was not necessary to investigate them to greater depths. (J. Smith, Tr. 2693-2694).

8. The Applicants also conducted extensive investigations off site, but in the nearby vicinity, for further evidence of ABCD features. The A and B features were found in several off-site areas in the San Mateo formation, demonstrating that these features are not unique to the site. The features in two of these areas were studied in detail, including the use of drilling and trenching techniques. (J. Smith, Tr. 2672-74, 2772; A. Ex. 25, pp. 4, 23; S. Ex. 9, pp. 9, 29).

74/ The Applicants' exhibit states that 295 man-days were involved for investigations and report preparation. We assume that the 215 days refers only to investigations.

9. Searches were conducted off site for additional examples of C or D features, but no additional examples were found. (A. Ex. 26, pp. 8, 13).

10. The Applicants did not perform any seismic reflection profile investigations of these on-shore ABCD features because such minor features cannot be adequately detected by that technique. Trenching, which was done extensively, is the preferred method for determining offset and age dating. (T. Cardone, Tr. 6676-78; J. Smith, Tr. 2718-20).

11. The Intervenors attempted through cross-examination to impeach the adequacy of the Applicants' investigations of the ABCD features. These efforts tended to disregard what had been done, and to call for further investigations without any showing that something significant might be accomplished. The Board was impressed with the thoroughness of the Applicants' investigations, particularly as reflected in Applicants' Exhibits 25, 26, and 27, and finds that any further investigation of these features would not have been useful. (See, e.g., cross-examination by G. Barlow of J. Smith, Tr. 2714-17, 2720-23; and T. Cardone, Tr. 6677, 6713-14, 6724-26).

(b) Description of ABCD Features.

12. The San Mateo Formation of Pliocene or Mio-Pliocene age is well exposed along the sea coast, and underlies the San Onofre site. The formation consists predominantly of massive, light-brown to light-gray sandstone with scattered interbeds of gravel. The sandstone forms steep canyon walls and

nearly vertical cliffs along the sea coast. (S. Ex. 9, pp. 4-5). We adopt the Applicants' proposed findings 380-382, 385-392 in the following eleven paragraphs.

13. "The A and B features at the SONGS site are light gray or white, slightly resistant ridges in the tan San Mateo formation. The ridges are a fraction of an inch wide and collectively comprise a zone 1-6 inches wide, averaging about 2-4 inches." (A. Ex. 25, pp. 15-17).

14. "The A and B features are discontinuous joint-like shears that intersect in a conjugate relationship. They are nearly vertical, and linear or broadly curvilinear in plan. Type B features decrease in width and eventually disappear in the eastern half of the site, and the Type A features decrease in width or disappear in the southern part of the site." (A. Ex. 25, p. 3).

15. "The individual elements of the A and B features present a stepping or intertwined appearance that consistently indicates right- or left-lateral displacement. The absence of the intertwining and stepping arrangement of the elements where the features are observed in vertical excavations indicates that slip on the features occurred horizontally rather than vertically." (A. Ex. 25, pp. 15-16).

16. "The A and B features are straight in plan and section and they are resistant to brushing in the more easily eroded sandstone because of the slight amount of crushing and

compression that occurred along them during their formation." (J. Smith, written testimony, p. 5).

17. "Under the microscope, the A and B features can best be described as a crush-breccia with a very closed framework. The cementing agent is not clay or calcite, but a weak binding of fine sand or silt-size grains." (A. Ex. 25, p. A-2).

18. "Feature C consists of a sinuous zone of thin (1/8 to 1/4 inch) white resistant ribs that are very similar to the A and B features." (A. Ex. 26, p. 7).

19. "The D feature consists of a sinuous pattern of hairline planar fractures containing little or no evidence of crushed grains and no evidence of compaction It is quite different from the ABC features because of its lack of linearity and its lack of resistance to erosion by brushing. The orientation of the D feature is very similar to that of bedding in the San Mateo formation. Displacement on the D feature is in a reverse sense, with the northern part being up. Displacement ranges from as low as 1/8 inch to a maximum of 2-3/4 inches. The direction of slip is south, parallel with or along the line of the A features." (J. Smith, written testimony, p. 7-8; A. Ex. 26, pp. 8-9).

20. "In contrast to the A, B, and C features, the D feature is usually apparent after light brushing of the sandstone because the planar surface erodes slightly more than the surrounding formation, leaving a thin line in the sandstone. While feature D has a distinct surface, that surface contains no

evidence of gouge, cementation, crushing, or extensional separation." (A. Ex. 26, p. 8).

21. "Features A, B, and D are plainly shears, but A and B are more highly anastomosed and have a greater total displacement across them than the D features. In addition, grain crushing is more evident on A and B so that in brushing, these features appear in relief, whereas feature D exhibits lesser resistance to abrasion than the adjacent material. The resistance to brush erosion of features A and B is related to the greater cohesion of the fine grain sheared debris that exists there than along feature D." (A. Ex. 26, p. 14).

22. "Petrographic examination of samples of the D feature disclosed an abundance of voids and empty fractures which suggest that deformation did not take place repeatedly or was not intense enough to cause filling of the void spaces." (A. Ex. 26, p. A-3).

23. "AB features, viewed in a vertical exposure rather than in plan, are very innocuous looking. They represent essentially a single white line within a tan sandstone, and very little note was taken of them during the early mapping." (J. Smith, Tr. 2687).

(c) Location and Evaluation of ABCD Features.

24. We adopt as proposed the Staff's proposed findings 198 (in part), 199-203, part of 204, and 205-207,75/ in the following ten findings, except for the insertion of findings 31 and 32.

25. "The Type A shears strike between north and N 10°E, and the Type B shears strike approximately N 50°W." (S. Ex. 9 pp. 8, 28).

26. "The Type A shear zones, which occur in four principal strands, converge northerly in the site area. Their northerly and southerly extent has not been determined. No Type A features were located that were more than thirty to forty feet in length and were not interrupted by Type B features. Therefore, no Type A features were found that traversed the San Onofre site as a single, through-going feature." (J. Smith, Tr. 2769-71).

27. "The absolute end of the Type A features could not be found because of the thickness of saturated beach sand which precluded further trenching, but the decreasing progression of the width of the Type A features indicates that they were dying out as they approached the sea cliff. The Type A features are from four to six inches wide in the central part of the site and

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75/ Applicants' proposed findings 393-439 cover the same ground in greater detail. We did not note any significant inconsistencies between these two sets of findings. We preferred the Staff's less detailed approach because these matters are substantially uncontested.

thin-out to approximately 3/4 to 3/8 of an inch at the sea cliff." (J. Smith, Tr. 2702-04).

28. "Six strands of the Type B shears are exposed in the site. These continue beyond the site to the northwest, but all visible strands of this set terminate in the southeasterly direction within the site excavation." (S. Ex. 9, pp. 8-9, 28; J. Smith, Tr. 2703).

29. "No effort was made to find the vertical depth of the A and B Type features. A good exposure of the features was obtained in both horizontal and vertical aspects at the site. In addition, these are minor features so there was no particular reason to search for their full depth. However, the features were found some 200 to 300 feet above sea level in area 3 so it is anticipated that they extend to that depth within the San Mateo formation." (J. Smith, Tr. 2693-2700).

30. "Where the two sets of shear zones intersect, each offsets the other. The maximum total displacement at their intersections and across clay inclusions has been observed not to exceed 4 inches. The sense of displacement is consistently left lateral for the Type A shears and right lateral for the Type B shears, indicating the development of a conjugate set of shears zones." (S. Ex. 9 at 9, 29).

31. Pleistocene marine and non-marine deposits have been recognized in the site vicinity. The primary Pleistocene terrace deposit is a series of crudely stratified mixtures of brown to gray-brown sand, silt, and clay with scattered lenses

and layers of gravel, cobbles and boulders. This unit represents both marine and non-marine terrace materials deposited over wave cut benches. At the site, the terrace materials have been deposited on a broad, gently sloping coastal plain that is extensively developed along the San Onofre coast. The thickness of these materials ranges from 30 to 50 feet. (S. Ex. 9, p. 5).

32. Age dating of California coastal terraces can be done by various methods, including dating of shell materials through thorium-protactinium disequilibrium determinations and inferences based on regional terrace elevations. Through a combination of these methods, the Staff developed an estimate, which we accept, that the terrace deposit in the vicinity of the San Onofre site is about 100,000 years old. (S. Ex. 9, pp. 6-7).

33. "Wherever the shear zones are observed in an exposure with overlying terrace deposits, they are truncated by the terrace deposits. This relationship indicates that the shear zones [were] formed within the San Mateo Formation prior to the deposition of the overlying terrace deposits. Thus they can be assigned a minimum age of 70,000 to 120,000 years[76/]

76/ This range is consistent with the 100,000 year estimate in finding 32, above. The record contains several other age estimates for these terraces. See S. Ex. 9, pp. 6-7, finding 47, *infra*. The important thing for our purposes is that all of these estimates greatly exceed 35,000 years, a critical test for whether a fault is capable. 10 CFR Part 100, App. A, III(g).

based on the age of terrace deposits which overlie the eroded surface of the San Mateo Formation." (S. Ex. 9, pp. 9, 29; A. Ex. 25, p. 28.

34. " The shear zones form a conjugate set consistent with the application of regional compressive forces in a northwest-southeast direction and in the opinion of the NRC Staff, the shear zones resulted from these wide spread northwest-southeast compressional stresses." (S. Ex. 9, pp. 9-10, 29; A. Ex. 25, p. B-3, 4).

35. "The shear zones were not created by movement on the Cristianitos Fault which strikes North-South, approximately 3000 feet inland of the San Onofre site. The Cristianitos fault is a normal fault and its last movement was from ten to four million years ago under an extensional environment, whereas the A and B Type features are the result of a compressional evironment. Therefore, it is not possible for a structural and tectonic relationship to exist between the Cristianitos fault and the Type A and B features." (T. Cardone, Tr. 6638, 6646-47; S. Ex. 9, pp. 10; A. Ex. 25, p. 28; J. Smith, Tr. 2697-98).

36. "The A and B Type features are not surface expressions of a deep seated shear zone. They are only surface expressions of themselves and they exist in the San Mateo formation because of the characteristics of that formation. They are not parallel to the Cristianitos fault--or to any other known fault. In addition, the A and B Type features have a sense of motion that

is not compatible with motion on the Cristianitos fault." (J. Smith, Tr. 2697-98).

37. The C feature extends approximately 60 feet through one excavation cut-slope northeast of Unit 3. The strike of feature C is N 50°W to N 60°W and it dips between 5° and 19°NE. Feature C has not been observed to intersect the Type A, B or D features, or the terrace deposits. (S. Ex. 9, p. 14; A. Ex. 26, p. 8).

38. The C feature consists of thin, white resistant ribs approximately 1/8 to 1/4 of an inch wide. The C feature has the crushing and gouge characteristics of the A and B features, indicating a contemporaneous origin. In addition, the C feature has other properties similar to the A and B features, further strengthening the concept of contemporaneous development. (S. Ex. 9, p. 14; A. Ex. 26, pp. 7, 18).

39. The D feature consists of a sinuous pattern of individual hairline fractures which continue across the excavations for Units 2 and 3, but terminate in the north and west cut-slopes of the Unit 2 excavation. This feature, unlike the A, B and C features, has a distinctly planar surface and contains no gouge, cementation, or crushed material. (S. Ex. 9, pp. 14-15; A. Ex. 26, pp. 8-9; written testimony of J. Smith, pp. 7-8).

40. Displacement on the D feature is in a reverse sense. The displacement ranges from a minimum of 1/8 inch to a maximum of 2-3/4 inches. The direction of slip is south, parallel to

the A features. The D feature strikes approximately N 70°W and dips between 15° and 20°NE. (S. Ex. 9, pp. 14-15; A. Ex. 26, pp. 9-10; written testimony of J. Smith, p. 8).

41. The age of feature D can be determined by its relationship to the A and B shear zones. (It does not intersect the C feature.) When the D feature intersects those features, they are offset in a reverse direction with the notable exception of the terrace deposits. This means that the D feature is younger than the A and B shear zones, but older than the terrace deposits. (S. Ex. 9, p. 15; A. Ex. 26, p. 11).

(d) Intervenors' Proposed Findings.

42. Under the heading of "Relationship of the ABCD Features to the CZD and OZD," the Intervenors propose seven findings, IF 202-208. Several of these proposed findings have record support, viz.: the strike of Feature A is parallel to the trend of the CZD (Tr. 2658); the CZD is north-south treading (Tr. 2437); and the Cristianitos Fault is north to slightly northwest trending (Tr. 2656). But standing as they do, alone and unexplained, these proposed findings have no apparent relationship to the issues in this case and we decline to adopt them. The burden is on the proponent of a finding to link it with other findings and with the issues in the case, unless such relationships are obvious or readily inferable from the context. We are aware in this connection of the Intervenors' proposed conclusion of law that the CZD "could be related" to the A and B features. Like many geological speculations, this

one is conceivable. However, the proof in this case is that the CZD does not project onshore and that the A and B features do not project offshore, at least not very far. See FF Nos. 27, and 28. The Intervenors also suggest in their conclusions that the Applicants should have performed further studies of the A and B features after the "discovery" of the fault "known as the CZD" to determine structural and tectonic relationships between them. As described herein, the investigations of all these features were exhaustive. See FF 6-11.

43. The Intervenors' proposed finding 205 -- that the strike of Feature B is parallel to the general trend of the OZD -- is not fully supported by the record. The witness stated that there were "significant deviations" from that parallel relationship. Tr. 2659. In any event, this proposed finding also stands unexplained and out of a meaningful context.

44. The implication of Intervenors' proposed finding 206 is that the A features extend out to sea toward the CZD and may intersect it. As noted in finding 27, above, the decreasing width of the A features toward the ocean indicates that they die out in that direction. Thus the only direct evidence in the record is contrary to the idea that the A features intersect the CZD at sea. (J. Smith, Tr. 2702-04).

45. The matters proposed in the first sentence of IF. 207 have been found in our finding 8. The A and B features were discovered during excavation at the site and some of them are

located under Unit 2. (SER pp. 2-35; Ex. JLS-N following the testimony of Jay Smith).

46. The Intervenors' proposed finding 208 about 50 shears in a nearby quarry is supported by the record. (Tr. 2681). Again, however, we do not adopt it because it stands unexplained and out of context.

(e) Significance of ABCD Features.

47. The evidence shows that the ABCD features are minor features and that there has not been any significant displacement on them for a very long time. The Staff supports a minimum age of 70- to -120,000 years, which we believe to be a conservative estimate. Beyond that, the Applicants cite evidence suggesting that the A and B features might have been created some 800,000 or even millions of years ago. (A. Ex. 25, p. 27, B-3; S. Ex. 9, pp. 10-11).

48. As noted above, these features are variously referred to as "joints," shears" and "faults" and combinations of these terms, such as "joints displaying small amounts of mutual shear displacement." AF 421. Whether these features were of a tectonic or non-tectonic origin is debatable. In any event, in view of their relatively slight displacements and the long periods of time since any displacement, we believe that it makes no practical difference what label is affixed to them, or what their exact origins were. (J. Smith, written testimony, pp. 9-11; Tr. 2897-98).

49. The ABCD features are not "capable faults" within the meaning of 10 CFR Part 100, Appendix A, III(g). They have no significance for the safety of San Onofre.

3. <u>Features at Trail 6</u>.

50. The features at Trail 6, first noted in 1977, are small vertical offsets of the contact between the bedrock and the marine terrace deposits exposed in the seacliff approximately 3 miles south of San Onofre. (J. Smith, written testimony, pp. 12-13).

51. Geologic units in the vicinity of Trail 6 are sandstone of the Monterey formation, overlying marine and nonmarine terrace deposits, landslide deposits, and colluvium. (J. Smith, written testimony, p. 13).

52. Large landsides are common along the San Onofre coast where the Monterey formation is exposed to wave erosion. The offsets at Trail 6 exist within the boundary of a large (6 acres) landslide displaying many of the features common to massive movement in response to gravity. (J. Smith, written testimony, p. 14).

53. At the request of the NRC Staff, the Applicants performed a detailed geologic investigation, including trenching, to study the offsets and to determine their relationship to the landslide. They were requested to trench along the trend of the offsets to where they intersect the failure plane along which the landslide slumped. (SER § 2.5.1.6, paragraph 2).

54. These investigations, which included detailed mapping, sea cliff exposures, trenching and observation, support the conclusion that the Trail 6 offset features are the result of a landslide. They were not caused by faulting and are not part of a fault. (J. Smith, Tr. 2856). In particular, displacement of the bedrock/marine terrace deposit contact by the offsets terminates at the landslide rupture surface; the displacement does not extend beyond the limits of landsliding. Therefore, we conclude that the Trail 6 offset features are the resut of landsliding and have no significance to the seismic design of San Onofre. (SER § 2.5.1.6, paragraph 4; testimony of J. Smith at 14-15; T. Cardone, Tr. 6727).

4. Features at Horno and Dead Dog Canyons.

55. Horno and Dead Dog Canyons are located approximately five miles southeast of the San Onofre site. Offsets in the bedrock/marine terrace contact were discovered near the mouth of these canyons. Investigation of these offsets by the Applicants included geological mapping, examination of aerial photographs, and examination of sea cliffs and canyon walls. No evidence of faulting was found. These investigations established that the offsets were caused by seacliff failure and seaward landsliding. (Testimony of J. Smith, p. 16; Tr. 2760-61). The Staff agrees with the Applicants' conclusions. (T. Cardone, Tr. 6728-29).

56. Based upon the Applicants' investigations and the NRC Staff's review, we find that the offsets at Horno and Dead Dog

Canyons were the result of seaward landsliding, and are of no safety significance to the San Onofre site.

5. <u>Features at Target Canyon</u>.

57. We adopt the Applicants' proposed findings 451 - 456 on these features, in the following findings:

58. "The stage 5e marine platform and overlying deposits are offset a small amount by narrow shears in Target Canyon, approximately 6-1/2 miles southeast of SONGS." (J. Smith, written testimony, pp. 16-17).

59. "Offsets of the stage 5e platform were observed at seven localities within an area measuring 2,000 feet by 1,000 feet in Target Canyon. Bedrock shears coincident with the offsets strike between north-south and north 15° east, and dip in the range 26° to 90°. Displacements of the marine platform are no more than 14 inches vertically, and are generally less than 12 inches. The displacements are chiefly normal dip-slip, with minor apparent horizontal and reverse slip on some shears." (J. Smith, written testimony, p. 17).

60. "Displacements in Target Canyon die out about 17 feet below the adjacent ground surface, ending in nonmarine deposits several tens of thousands of years old that overlie marine terrace deposits 125,000 years old." (J. Smith, written testimony, pp. 17-18).

61. "The offsets in target Canyon have no association or alignment with any faults landward or seaward, and their zonal distribution is poorly developed. Assuming they represent a

shear zone, projection toward the north along their strike would take them toward distinct and continuous strata in the San Onofre Breccia formation that are not faulted." (J. Smith, written testimony, p. 18).

62. "The association of the offsets and their shears with conjugate sets of fractures adjacent to a buried ridge of San Onofre Breccia suggests an origin related to differential compaction of the overlying softer sediments. The gradual dying-out upward of the displacements tends to support this possibility, rather than that of a fault origin. Offsets of fault origin would be more likely to have displacements indicating abrupt episodic movements." (J. Smith, written testimony, p. 18.)

63. "The weight of the evidence from investigations of offsets in Target Canyon favors a nontectonic origin for them. In any case, the offsets are small, tens of thousands of years old, and have a different orientation from most faults in the region. Furthermore, they are more than five miles from SONGS, and even their projection beyond known locations would be tangent to a five-mile radius drawn around SONGS. Accordingly, they are not significant to the site." (J. Smith, written testimony, pp. 18-19).

6. Faults E and F.

64. We adopt the Applicants' proposed findings 457-460 and 462-465 on these features in the following findings:

65. "Fault E lies from about 500 to 5,000 feet east of the Cristianitos Fault on the south flank of the San Onofre mountains. Fault F lies about 2,000 feet east of fault E." (P. Ehlig, written testimony, p. 1).

66. "Faults E and F strike about north 15 degrees west, nearly parallel to the Cristianitos fault." (P. Ehlig, Tr. 2899-2900).

67. "Faults E and F have subparallel trends striking nearly north-south, but they dip steeply toward each other. Their displacement is small (300-400 feet for Fault E and about 25 feet for Fault F) and chiefly normal dip-slip." (P. Ehlig, written testimony, pp. 2-3).

68. "Although Fault E might appear to join the Cristianitos fault if projected in planview, it dips in the opposite direction from the Cristianitos, so the two faults diverge at depth. Therefore, Fault E is not a branch of the Cristianitos fault." (P. Ehlig, Tr 2904-2905).

69. "Faults E and F are secondary features probably associated with early deformation at the start of the Cristianitos fault development. However, they do not join the Cristianitos on the surface or at depth." (P. Ehlig, Tr. 2903-2904).

70. "Throughout the area of Faults E and F there is no topographic expression of faults. Where marine terrace platforms with or without terrace deposits exist there is no evidence that they are offset by faulting. These platforms are

very old, probably a few hundred thousand years." (P. Ehlig, written testimony, p. 3; Tr. 2940-2941).

71. "The age of the E and F faults is imprecisely known but displacement is younger than about 14 or 15 million years old, the age of the Monterey Formation adjacent to the fault. Both faults lack physiographic expression and show no evidence of cutting the coastal terrace. Fault E passes beneath the remnant of a wave cut terrace bench at an elevation of about 350 feet without displacing the bench or an overlying soil unit. The bench is probably a few hundred thousand years old, thus suggesting that fault movement ceased by Late Pleistocene time." (P. Ehlig, written testimony, p. 3).

72. "Faults E and F were most likely formed in an east-west extensional tectonic regime 4 to 10 million years ago, and they thus do not fit the present north-south compressional regime. They have had no movement in the past several hundred thousand years. They are not capable faults and, thus, are not significant to SONGS." (P. Ehlig, written testimony, p. 4).

E. <u>The Cristianitos Zone of Deformation (CZD)</u>.

<u>1.</u> <u>Introduction</u>. Contention 2 states that:

> Whether characterization of certain offshore geologic features as a zone of deformation, referred to as the Cristianitos Zone of Deformation (CZD), or whether any additional information about the CZD which became available subsequent to issuance of the construction permit render the seismic design basis for SONGS 2 and 3 inadequate to protect the public health and safety.

The evidence concerning the CZD was based upon two lines of investigation. These concerned studies of onshore and offshore features of possible relationship to the CZD. The evidence includes the research conducted, geologic characterizations, varying interpretations of the nature of the CZD, its relationship to the OZD, and its age based upon stratigraphy and both onshore and offshore platforms and terraces.

2. Eight witnesses testified on various of the foregoing aspects of the CZD. The Applicants witnesses were Dr. David G. Moore and Dr. Roy Shlemon (Moore, written testimony, pp. 37-50; Shlemon, written testimony, pp. 7-10). The witnesses for the Staff were Dr. H. Gary Greene, Mr. James Devine and Mr. Robert Morris, U.S. Geological Survey (USGS), Dr. Michael Kennedy, California Division of Mines and Geology and Mr. A. Thomas Cardone (Greene and Kennedy, SER, Appendix F; Morris, Devine, Greene and Kennedy, SER, Appendix G; Cardone, SER, Section 2.5.1.12). Dr. Kennedy also testified for the Intervenors, as did Mr. Mark Legg (Legg, written testimony, pp. 10-12).

3. The Staff set forth in its Proposed Findings No. 254-255 certain helpful historical information based upon

material contained in the SER. We adopt those findings for their historical perspective and repeat them as the following Findings Nos. 4 and 5.

4. "A number of offshore seismic reflection surveys were performed by the Applicants and by others in the vicinity of the site over the 10-year period beginning with the development of the safety analysis for the construction permit. The purpose was to investigate the structural features offshore. (SER 2.5.1.12)."

5. "On May 8, 1980, the Staff requested that a comprehensive review be made by the USGS of all marine geophysical data relevant to the character and recency of faulting along the offshore extension of the Cristianitos fault in the vicinity of the San Onofre 2 and 3. This request was concerned specifically with a proposed structural relationship between the Cristianitos zone of deformation (CZD) and the OZD. The NRC requested that this review be made jointly by H.G. Greene of the USGS and M.P. Kennedy of the California Division of Mines and Geology, because of the extensive joint research effort then underway by Greene and Kennedy on aspects of the structural geology of the southern California borderland. Their review and a subsequent report were completed on July 18, 1980. Their report, "Review of Offshore Seismic Reflection Profiles in the Vicinity of the Cristianitos Fault, San Onofre, California" appears as Appendix F to the SER. (SER 2.5.1.12; SER, Appendix F)."

6. Greene and Kennedy had coined the name "Cristianitos Zone of Deformation" simply because the Cristianitos fault is nearby. The name was not chosen to imply a relationship with the Cristianitos Fault. (Tr. 2139-40).

7. The Review of Greene and Kennedy identifies the seismic reflection profiles they used, those which were new to them, their methods of interpretation of the data, a discussion and their conclusions (SER, Appendix F).

8. The conclusions reached by Greene and Kennedy are set forth at SER, Appendix F at F7-F8 and we repeat them here.

> "Interpretation of marine continuous seismic-reflection profiles in the vicinity of SONGS and concentrated along the projected, offshore trace of the Cristianitos fault indicates to us that two structural zones of deformation are present in this area. The first and most well defined zone is a segment of the "OZD," a recognized Quaternary fault zone (Greene and others, 1979; Hileman, 1979; Legg and Kennedy, 1979). The second is less well defined but nevertheless exhibits characteristics similar to those of the "OZD." This second zone, the "CZD," consists principally of a highly fractured and faulted asymmetrical anticlinal structures."
>
> "The "CZD" and associated folds to the east combine to form a broad structural zone (up to 3 km in width) which projects onshore to the north. The southeast end of the "CZD" could become incorporated with a major syncline of the "OZD". However, the structural relationship of the "CZD" with the "OZD" is unconfirmed because of a "data void" (Plate 1)."
>
> "The age of most recent faulting along the "CZD" is unknown. All seismic profiles examined show that faults associated with the "CZD" end at or near the surface of an apparent wave-cut platform that is overlain by acoustically transparent sediment. Nowhere within the "CZD" is there evidence of seafloor displacement."
>
> "It is our conclusion that a structurally deformed zone consisting of correlatable <u>en echelon</u> faults and folds, many extending into shallow subsurface strata

(probably Neogene in age), is present along the expected ofshore extension of the "CZD." The seismic reflection data reviewed here show that a fairly continuous fault zone extends south to southeastward offshore from SONGS to within 1 km of the "OZD," where a projected connection is possible."

2. <u>Data Voids and the Relationship of the CZD and OZD</u>.

9. The Review of Greene and Kennedy also included a paragraph explaining the term "data void" which appears on Plate 1 of Appendix F of the SER. We quote that paragraph below.

> "Areas in which good quality data are lacking or the density of seismic profiles are insufficient to map and correlate structures at a scale of 1:24,000 are designated as "Data Voids" (Plate 1). It must be emphasized that the notation "data void" does not mean that no data are avilable, only that we felt the data are insufficient for correlation with confidence between lines. The data in some areas are of sufficient quality to permit the extension of geologic structures by inference across expanses mapped as data voids; in such cases, these structures are mapped as inferred or questionably inferred." (SER, Appendix F, p. F5; also see Tr. 3134).

10. As a further explanation during the hearings, Dr. Greene stated that, "as we use the term 'data void,' it represents basically two things. One thing is that either there is a lack of data there, no lines have been run in that general vicinity, or that lines have been run in that vicinity, but they were not of good enough quality to be usable for our mapping. In other words, due to perhaps the shallowness of the water, the lithology, the types of rocks that existed on the sea floor, you did not get a good reflection profile, and so you could not use that to develop your structural picture." (Tr. 2136). (Also see Tr. 2283-86, 2288, 2300-01).

11. As indicated above, the significance of and reason for the appearance of the term "data voids" on Plate 1 (SER, Appendix F) was extensively explored in the hearings. Dr. Greene stated that seismic profiling for the San Onofre area was "the greatest density of track lines that I've ever dealt with as far as an area of this size." (Tr. 2282). Dr. Kennedy agreed that it was an, "extremely tight series of tracks." (Tr. 2282-83). Further, Witness Kennedy indicated that even with more profiling in the areas marked data voids there was no way to predict that good mapping could be accomplished in those areas. (Tr. 2624-2628).

12. Drs. Greene and Kennedy were not complaining about a general lack of data. Rather, at times, there wasn't a specific line that went through a spot they were particularly interested in. (Tr. 2286).

13. The data void problem affected determination of whether there is a relationship between the CZD with the OZD. Concerning that Dr. Greene stated, "profiles did not cross the intersection, per se." (Tr. 2285).

14. Greene and Kennedy also submitted an Addendum to their July 18, 1980 Review which was transmitted to the NRC by Dr. H. William Menard. The Addendum was prepared as a result of their review of new data collected for the Applicants in June 1980 by NEKTON Inc. That Addendum appears at pages G8-G11 of SER, Appendix G. Included in this Addendum is the statement, "Although no seismic lines collected by NEKTON in the June 1980

survey actually cross the proposed CZD-OZD intersection of Greene and Kennedy (1980) the CZD can be extended by way of this data (June 1980 NEKTON data) to an area where we interpret it to merge with a snyclinal fold and adjoining fault associated with the OZD." (SER, Appendix G).

15. The conclusion reached by Greene and Kennedy in this Addendum is as follows:

> "The CZD merges with or is truncated by the OZD in the area offshore from SONGS (plate 1). Generally faults within the CZD with few exceptions (plate 1) displace shallow stratified sedimentary rock that lies beneath a younger poorly stratified sediments. The June 1980 NEKTON data support the conclusions reported previously by Greene and Kennedy (1980)." (SER, Appendix G, p. G11).

16. The Intervenors introduced, as their Exhibit No. 4, a letter dated August 11, 1980 from Dr. James Davis, the Chief Geologist of the State of California and Dr. Michael Kennedy to the NRC Staff. That letter indicated that it was their "tentative conclusion that the structure termed 'Cristianitos zone of deformation' (Greene and Kennedy, 1980) does extend offshore from the present-day coastline in the vicinity of SONGS and connect with the OZD." That letter also requested that the NRC instruct the Applicant to evaluate the seismic potential of the Cristianitos fault based upon the structural relationship outlined in the Greene and Kennedy 1980 report. (Intervenors Exhibit No. 4; see also Intervenors' Proposed Finding of Fact No. 160).

17. The Intervenors in their Proposed Findings of Fact cite Staff Witness Cardone's testimony that the Staff had not

requested the Applicant or the USGS to do any further research since the NRC had received the Greene and Kennedy "Review" and the Davis and Kennedy letter. (Intervenors Proposed Finding of Fact No. 161, 162; Tr. 6513-6518).

18. Witness Kennedy was questioned about the Davis and Kennedy letter and what response if any there had been to it. The Witness stated that subsequently the State received the information it had requested and that their request had been responded to. The material received was the work of Applicants' Witness Dr. David Moore, and that material satisfied the request of the State. (Tr. 2469-74; Tr. 2513-14).

19. The Intervenors do not acknowledge Mr. Cardone's statements that no further research was asked for because none was needed or felt necessary by the Staff (Tr. 6513-6519).

20. Subsequent to the Greene and Kennedy, 1980 Review and the Greene and Kennedy "Addendum," the USGS submitted to the NRC a "Review of Geologic and Seismologic Data Relative to the San Onofre Units 2 and 3 Operating License Application." This Reivew was conducted by Mr. Robert H. Morris and Mr. James F. Devine with assistance from Dr. H. Gary Greene and Dr. Joseph S. Andrews. This Review included consideration of a complete summary of the Applicant's analysis of the geological and seismological data for Units 2 and 3, as well as both the original 1980 Review of Greene and Kennedy and their Addendum (SER, Appendix G).

21. Intervenors in their Proposed Findings of Facts, do not cite a conclusory paragraph in the USGS Review which stated, "The USGS, in general, concurs with the conclusions stated by the applicant and its consultants regarding the history and age of last movement of the Cristianitos Fault, its relation as one of several faults of the CZD of Greene and Kennedy, and its apparent lack of potential for movement in response to movement on the OZD." (SER, Appendix G, p. G4).

22. The existence of the so-called data voids of Greene and Kennedy were acknowledged in the SER and that fact is noted by the Intervenors in their Proposed Findings Nos. 150 and 152. (See SER, p. 2-46; SER, Appendix F).

23. Witness Greene was asked whether additional profiling would allow better mapping of the possible faulting in the areas labeled "data voids." He responded that this could not be answered specifically because of the definition of data void. (Tr. 2407-08; Tr. 2413; also see Tr. 2439-40).

24. The Board believes the Greene and Kennedy "data voids" are of little significance in relation to the seismic safety at San Onofre but it has not relied solely on the foregoing material in reaching this decision. Earthquakes are generated on faults and, where faults have branches, movement on the main fault can be transmitted to the branch. Thus, the possible extension of the Cristianitos fault to the SCOZD could be important in the seismic considerations affecting San Onofre 2.

We repeat in the following finding the results of the NEKTON survey designed to explore this possibility.

25. "A seismic reflection profile survey was conducted by NEKTON, Inc. for the applicant to provide higher resolution in the shallow offshore strata to help determine whether or not the Cristianitos fault projects toward the OZD. The report (Nekton, 1980) concludes:

(a) The Cristianitos fault does not project enough seaward (i.e., south-southeasterly) to be identified in the survey area. Where the fault may be projected to occur, there is no evidence of its existence. Nekton concluded that along its offshore projection, displacement diminishes and the Cristianitos Fault dies out, possibly in a number of lesser faults and small folds. It does not connect to the OZD.

(b) The OZD was mapped parallel to the coastline for 8.8 kilometers in the central and northern oceanside survey area. In the central part, at least two branches of the fault occur and their width is limited. To the north, it broadens to a zone of deformation up to 0.6 kilometers (0.4 miles) wide. The OZD is not present in the Dana Point survey area.

(c) Other faulting offshore - a number of minor faults are interpreted to be present offshore in the survey area. Minor faults in the area are short in length and occur below a Pleistocene erosion surface in Tertiary age beds.

(d) Fault movement - none of the minor faults shows evidence of movement following the period of erosion which developed the Pleistocene erosion surface. Eighteen kilometers south of San Onofre, the OZD shows evidence for at least two periods of probable movements. Movements during one period have displaced the Pleistocene erosion surface and the movements during the other period appear (locally) to displace terrace deposits of probably Holocene age." (SER, p. 2-47).

26. In reviewing the record before us, the Board has been impressed with the amount and high quality of the investigations carried out by the Applicants of both the onshore and offshore areas of the San Onofre site. In their Proposed Findings, neither the Staff nor the Intervenors fully covered the rich record. The Staff chose to rely primarily upon its review as presented in the SER, while the Intervenors (Nos. 147-171) do not arrive at a conclusory finding, nor do they assert how those findings relate to Contention 2. Their findings are individually based on the record, but no context is provided to aid the reader. Collectively their findings are presented largly out of context, presumably with the intent of showing that both the Christianitos Fault and the CZD may be interpreted as capable fault structures. The record does not support that conclusion, nor was that conclusion reached by the Intervenors in their findings. On the other hand the Applicants presented a detailed account of their studies and conclusions in their Proposed Findings of Fact. We have reviewed the underlying record and find that the Applicants' Proposed Findings are fully supported by it. We adopt the Applicants' Proposed Findings

Nos. 470-479, 481-495, 499-525, and 526 (in part), and and repeat them in the following findings.

3. <u>History of Offshore Investigations</u>.

27. "Since the late 1960's, more than 2500 km of seismic reflection transects have been utilized by the Applicants to investigate the offshore geology of SONGS. About 1500 km of deep-penetration common-depth-point (CDP) seismic reflection data were used in regional studies, along with several hundred kilometers of higher resolution Sparker data. Most of the remaining transects have been concentrated on or near the San Onofre Shelf and upper Continental slope. Altogether, the geophysical studies of the geologic structures offshore of SONGS have extended for more than 100 km to the northwest and southeast of the plant site, and seaward across the shelf to the deep basins of the southern California Continental Borderland. The most detailed of the geophysical investigations were conducted close to SONGS, with most transects confined to a 15 km by 30 km area on the continental shelf which parallels the coastline between San Mateo Point and Oceanside, hereinafter referred to as the San Onofre Shelf. (Moore, written testimony, p. 7; Figure DGM-C)."

28. "The submarine topography off southern California comprises an irregular terrain of basins and submarine ridges bordered along the coastline by a narrow continental shelf that varies from less than a kilometer to a few tens of kilometers wide. The San Onofre Shelf is oval in shape and varies in width

from 6 km in it northern end, to more than 9 km in the central area, narrowing again to about 6 km in the southern end near Oceanside. The narrow shelf here has a very gentle slope of about 10 meters per kilometer from the shoreline out to the 100 meter contour, near the shelf edge. The steep basin slope beyond the shelf edge has a declivity of over 260 meters per kilometer and extends down to the basin floor at a depth of about 800 meters. The greatest concentration of geophysical data is largly confined to the shelf area because of the adjacent topography and the nature of the strata underlying the shelf. The shelf edge is a natural barrier to the collection of useful geophysical data because of its steepness and the numerous sea gullies that have incised it to form a highly irregular topography. All of the geological structures important for SONGS 2 & 3 lie landward of this steeply sloping terrain and on the San Onofre Shelf. (Moore, written testimony, pp. 4-6; Figures DGM-A, DGM-B)."

29. "Detailed examination and interpretation of a very large amount of relatively close spaced seismic reflection profiling data have provided information to construct a tectonic map of the San Onofre Shelf and have allowed interpretation of the structures in that area with a high degree of confidence. The greatest number of seismic transects and those having the closest spacing were concentrated in the shelf area south and southeast of SONGS where the data are of good quality, and they reveal a relatively complicated structural situation with well

determined stratigraphic units. Collectively, more than 1000 km of seismic profile transects are contained within the San Onofre Shelf area with a line density of about 2.5 km per sq. km and an average line spacing of about 400 meters." (Moore, written testimony, p. 7, 9 and 49; Figure DGM-C).

30. "Because of the extraordinary line density of the seismic profile transects, Staff witness, Dr. G. Greene, (USGS) stated '[There was] no lack of general [offshore] data' (Greene; Tr. 2286). He went on to conclude that the track line spacing in this investigation is '... the greatest density of track lines that I've ever dealt with ....' (Greene; Tr. 2282)."

31. "Several different surveys were run during the last 10-15 years. Exhibit 36, DGM-L shows that the major structural features of the region were detected in a very rough way by the earliest reconnaissance survey done by Marine Advisers in 1970. Dart core and bore hole samples of the sea floor were also taken to provide ages for the seismic stratigraphy seen in the recorded sections. The position of the survey track lines and bottom samples are shown in Figure DGM-C. The most recent surveys, the Woodward-Clyde (1978) and Nekton Survey (1980), data are important to the offshore investigations because of their high quality, resolution, and close spacing of transects which show major structural elements of the San Onofre Shelf in considerable detail. They also provide a high degree of confidence in correlating geological structures from one line to the next. The Nekton survey lines were specifically positioned,

and data were collected in 1980 to cover the area south of the Woodward-Clyde survey where an offshore projection of the Cristianitos fault had been postulated to intercept the South Coast Offshore Fault within the South Coast Offshore Zone of Deformation. (Moore, written testimony, pp. 8-9, 35; Tr. 2982)."

4. Offshore Geology--Relationship of the CZD and Cristianitos Fault.

32. "As shown by these surveys, a great thickness of rock strata underlies the near surface erosional and depositional features of the San Onofre Shelf. All of these strata were originally deposited horizontally or gently sloping, and they have subsequently been variously warped in places into folds or broken by faults as the region has been subjected to compressional, tensional, or shear forces. When mapped and age dated, these rocks and their structural features indicate the tectonic history of the region. The most conspicuous and consistent features of the offshore shelf are those associated with the South Coast Offshore Zone of Deformation (SCOZD), on the western and southwestern edge of the Shelf. The SCOZD has been assumed to be one of the zone of folds and faults referred to as the Offshore Zone of Deformation (OZD) that includes the Newport-Inglewood Zone of Deformation (NIZD) to the north and the Rose Canyon Fault Zone (RCFZ) to the south. (Moore, written testimony, pp. 10-13; Figure DGM-E)."

33. "The most important element of the SCOZD is the South Coast Offshore Fault (SCOF) which occurs as a single trace in the southernmost part of the area and as a double trace in the central part, extending to the northwestern part of the shelf as a less well-defined single trace. Over most of this length, the SCOF is associated with the crest or near the crest of a large anticline or anticlinorium designated the San Onofre Shelf Anticline (SOSA). Only in the southernmost part of the shelf where the SOSA dies out, does the SCOF continue as a single trace unassociated with folding. The SOSA and its eastward flanking syncline are much larger features than the very gentle folds to the east.77/ (Moore, written testimony, pp. 13, 39)."

34. "Flanking the SOSA on the northeast is the San Onofre Shelf Syncline (SOSS), a very broad and conspicuous asymmetrical fold on all seismic profiles that cross it. SOSA and SOSS show remarkable continuity along the central part of the outer San Onofre Shelf, where they are continuous for more than 9 km, or over 30,000 feet. Other folds pairs occur to the northwest and are similarly oriented to the SCOF, but they do not have the continuity of those to the south. (Moore, written testimony, pp. 13-14)."

77/ The Board notes that the "gentle folds" indicated here are part of Greene and Kennedy's CZD.

35. "The principal structural features of strata beneath the San Onofre Shelf are shown on Figure DGM-E. This structural map (DGM-E) is designed to display the amplitude or magnitude of folding as well as continuity of the major features and to contrast the age of faulting in the different parts of the area. (Moore, written testimony, pp. 11-12)."

36. "In summary, the principal structural features on the San Onofre Shelf are the SCOF and the intimately associated SOSA and the SOSS. The folds in this zone are very long and continuous, whereas the principal features to the east are much smaller, shorter and discontinuous. The longest fold east of the SCOZD is only about 1/5 the size of the SOSA of the SCOZD. (Moore, written testimony, pp. 14-15)."

37. "The use of the term Cristianitos Zone of Deformation (CZD) implies that offshore structures within that zone are somehow related to the Cristianitos fault, an implication not supported by the seismic data. The Cristianitos fault is a discrete, single, normal fault resulting from east-west extension and, thus, is by nature a tensional feature. On the other hand, the faults and folds of the CZD are typical compressional features. Also, the faults of the CZD are shallow and generally do not extend downward to any great depth in the section as would be expected of an extensional feature such as the Cristianitos fault. (Moore, written testimony, p. 45, Tr. 2997; J. Smith, Tr. 867-868)."

38. "Much detailed profiling has been done along a projected seaward extension of the Cristianitos fault to test its postulated connection with the SCOF. Careful examination of seismic lines closest to the Cristianitos fault and across its offshore projection do not reveal any feature which could be interpreted as an extension of the Cristianitos fault beyond about 6,000 feet (2,000 meters) from the shoreline. Faults occurring farther seaward along a projection of the Cristianitos fault have displacements that are opposite to that of the Cristianitos fault, and which are much too deep and old to be associated with the fault. The faults nearest such a projected offshore trend have been inactive for a period greatly predating the opening of the Capistrano Embayment and activity on the Cristianitos fault. (Moore, written testimony, pp. 44-45, 48; J. Smith, written testimony, Contention 4, pp. 21-32, 37; Tr. 840-846, 870-873)."

39. "Additionally, the northerly trending zone of gentle folds and associated faults east of the SCOZD and west of the Cristianitos fault, i.e., the CZD, does not form a connection between the SCOZD and the onshore trace of the Cristianitos fault. (Moore, written testimony, p. 37). Instead, faulting along the SCOZD contrasts strongly in terms of amount and continuity as well as age of faulting with that along the so-called CZD (Moore, written testimony, p. 37). The CZD is largely associated with the Miocene Monterey formation. Southeast of this zone and inshore are a number of relatively

minor folds and associated faults, which are associated with deeply buried older formations. (Moore, written testimony, p. 14)."

5. Stratigraphy of the Offshore Area.

40. "The stratigraphy of the offshore are n the vicinity of SONGS, which is a very important aspect of Applicants' studies, has been interpreted in the context of the evolution of the Capistrano Embayment and the Cristianitos fault, and has been based on extensive detailed geologic mapping done for the Applicants and extending inland several miles. Offshore stratigraphic units have been identified by correlating data from borings and dart cores with seismic reflection profile data. (Moore, written testimony, p. 15; Tr. 2965-2967)."

41. "The oldest unit recorded offshore, and the unit that serves as effective acoustic basement, is believed to be the San Onofre Breccia which, because of its poor bedding, and lack of conerent internal reflectors produces a fuzzy appearance in the profiling records. It also underlies the sea floor off Dana Point at the northern boundary of the region. Consequently, data quality in this area is reduced significantly. South from Dana Point and approaching San Onofre, the relatively simple and nearly-horizontal bedding nature of the San Mateo and Capistrano formations make close spacing of seismic reflection profile lines unnecessary because, in areas of very simple structure, close-spaced traverses do not yield significantly greater information than wide-spaced lines. Early reconnaissance lines

supplied ample data for identifying major structures in that area. (Moore, written testimony, pp. 6, 15, 18; Figure DGM-F; Tr. 3008-3012)."

42. "Farther southeast of the northerly-trending structures east of the SCOZD there are deeply buried faults in the San Onofre Breccia overlain by undisturbed Monterey formation. (Moore, written testimony, p. 43)."

43. "Overlying the San Onofre Breccia is the Monterey formation which has a very characteristic seismic signature of many stong, continuous, repetitive reflectors with very little scattering or defraction. Seismic profiles of the Monterey formation almost anywhere along the California coast show the characteristically well-developed bedding and its typical response to tectonic compression by formation of well-developed anticlines and synclines. Offshore San Onofre, older and younger units of the Monterey formation rocks have been mapped with an angular unconformity being clearly expressed between the two. The most pronounced folding has taken place at depth beneath the youngest Monterey unit. (Moore, written testimony, pp. 18-19; Figures DGM-C, DGM-G, DGM-H, DGM-I)."

44. "The Capistrano formation overlies the younger Monterey unit and is less well bedded than the Monterey formation. Several borings in the vicinity of the plant were also used to identify the Capistrano formation. The age of the Capistrano formation was determined to be about four to ten million years old showing a Delmontian Late Miocene age.

(Moore, written testimony, p. 20). The pinching-out in places of the Capistrano formation against the Monterey formation indicates that some degree of folding took place in the SCOZD during the time the Capistrano formation was being deposited. In the northern part of the San Onofre Shelf, the Capistrano formation is relatively undeformed by faulting and folding except in the immediate vicinity of the SCOZD. The Capistrano formation and the younger unnamed Plio-Pleistocene unit overlying it disappear southward on the San Onofre Shelf. Onshore the Capistrano formation is sharply terminated on the east by the Cristianitos fault. On the San Onofre Shelf, however, the seismic stratigraphic unit identified with the Capistrano formation is less-sharply limited on the east and south. This is supportive of the lack of evidence for the Cristianitos fault on the San Onofre Shelf, and, hence, a less sharply defined easterly termination of the Capistrano formation. In summary, it is apparent that the SOSA and SOSS are by far the most prominent features on the shelf and that the area of gentle broad folding to the east is, with a few exceptions, of a much lesser amplitude and a different character. (Moore, written testimony, pp. 20, 39-40; Figures DGM-F, DGM-G, DGM-H, DGM-I)."

45. "Offshore, a relatively-thick stratigraphic unit of Plio-Pleistocene age underlies younger Pleistocene terrace deposits. The unit is acoustically transparent and generally without good internal reflectors, suggesting it is soft and

poorly stratified. This younger stratigraphic unit can be clearly differentiated from the older bedrock formations by correlation and by the presence of an intervening well-defined unconformity that appears on the seismic profile records. The intensification of the folding as indicated by the configuration of this and lower unconformities between the formations increases with depth and is most striking beneath the youngest Monterey formation unit. Folding in the Capistrano and younger units is relatively mild and, in fact, disappears in the northern part of the offshore area, north of Woodward Clyde line 841. (Moore, written testimony, pp. 20, 37-39; Figure DGM-H)."

6. Relationship of the SCOZD to the CZD.

46. "The features now characterized as the CZD have been known to people associated with the site for some period of time, were discussed back in the construction permit days, and were identified quite some time ago, before the Greene and Kennedy study (Devine, Tr. 6115). Much of the data on the structure of the offshore area in the vicinity of SONGS were generated several years ago by Marine Advisers and Western Geophysical. In 1970, Marine Advisers mapped several minor folds and faults in the vicinity of the CZD, but gave these features another name. (Moore, Tr. 4065-70; Exhibit No. 36, DGM-L). In addition, in 1978, Woodward Clyde Consultants mapped a zone of minor folds and faults in the same general vicinity as the features mapped by Greene and Kennedy who, in 1980, assigned the name 'Cristianitos Zone of Deformation.' These features,

mapped several years ago by the Applicants in the area of the CZD, have been shown to be several discontinuous faults of unknown strike on the shorter sections. (J. Smith, Tr. 829, 830, 864; Moore, Tr. 2982, 4069, 4084)."

47. "The youngest and most continuous faulting on the San Onofre Shelf is confined to the SCOF of the SCOZD. There is a striking difference in continuity and intensity of faulting between that of the SCOF and the relatively small and discontinuous faults associated with the folding to the east. The SCOF at some locations extends to the sea floor and through the Plio-Pleistocene sedimentary unit, thereby confirming the relatively recent activity on this fault. Throughout much of its length the SCOF is a dual-trace fault or a broad fault zone. In the northwestern part of the shelf, the SCOF appears to be dying out or becoming less distinct, and the SOSA and SOSS are becoming discontinuous. Toward the southeastern end of the shelf the SCOZD clearly changes its expression from that of a very large, complexly-faulted anticline to a single fault across which well-bedded Monterey Formation reflectors are juxtaposed against a zone of incoherent or fuzzy reflectors suggestive of San Onofre Breccia. (Moore, written testimony, pp. 40-42)."

48. "The SCOF is best developed along the outer edge of the central part of the San Onofre Shelf where there is a change in trend of the fault from northerly to northwesterly. Along this change in trend, the fault is closely associated with the SOSA, and it is probable that the folding is a direct result of

strike-slip faulting resulting from compression accompanying the change in direction. The faulting in the anticline is well developed and extends from the sea floor or near the sea floor to depths as great as surveying equipment is able to penetrate. In contrast, the north-trending folds of the CZD east of the SCOF are associated with largely intraformational faulting within the flexures. This is explained by recognizing that a thick sedimentary section of Monterey-type lithology can develop very high pore pressures and consequently low shear strength if bent even slightly. When gently or broadly folded this type of sediment typically develops many small folds or flexures along the crests of larger anticlines. The flexures are of a scale difficult to detect with seismic profiling equipment and, thus, often produce a record resembling a zone of disturbance or deformation, but which is not clearly related to faulting. Intraformational faulting has limited upward and downward extent, and commonly develops in association with this minor folding superimposed on larger broad folds as illustrated in Woodward Clyde profiles 836, 839 and 841 of Figure DGM-H. (Moore, written testimony, pp. 42-32)."

49. "Greene and Kennedy's postulated connection of the CZD and the SCOF relies on the existence of a narrow band of fault-bounded deformation trending southeast at an angle to the main body of folding in the CZD. Dr. Moore interprets this deformation instead to be a deeply buried small anticline, and a nearby adjacent "fault" to be a misinterpretation of

seismic-signal crossovers on a relatively steep-sided flank of the asymmetric SOSS. (Moore, Tr. 3074). Even if this fault and a connection with the SCOF existed, the area of the postulated connection is overlain by clearly unfaulted strata of probable Late Miocene age, requiring the conclusion that there has been no movement on the faults for at least 5-6 million years. Therefore, these questionable faults and their purported connection with the OZD have no real significance. (Moore, written testimony, pp. 46-47; Tr. 3075)."

50. "Regarding a postulated connection between the SCOF and the CZD, it is also important to distinguish between connections of faults rather than of so-called zones of deformation. The orientation and continuity of faults is the key issue, inasmuch as only movement on faults can cause earthquakes. Folds are of great geologic interest in determining tectonic history, but are not associated with earthquake generation. Faulting in the CZD is the result of compressional forces related to folding. Faults of the CZD do not displace the Pleistocene erosional surface and, therefore have not moved for thousands of years according to data based on the ages of the terraces. (Shlemon, written testimony, pp. 9-10). Therefore, Greene and Kennedy's postulated near connection of the CZD and the SCOF relies on questionable and difficult interpretation of deep faults in the records. However, unfaulted probable late Miocene strata overlying this area make it clear that movement on these questionable features

has not occurred since Miocene time. (Moore, written testimony, pp. 45-46, 48-49; Tr. 3074-3075, 3079)."

51. "The closest approach of faults of the CZD to the SCOF is approximately 10,000 feet (or 3.6 km) when measured along a projection of the onshore Cristianitos fault. This interpretation cannot support a postulated connection between the SCOF and the faults of the central shelf area. (Moore, written testimony, p. 46)."

7. Quaternary Studies.

52. "Once the regional and local stratigraphy and structure have been determined, it is necessary to evaluate and assign the ages to the various features. From the regional studies it is clear that broad tectonic uplift has been occurring for hundreds of thousands of years in the western United States, including the California coastline and the SONGS region, as indicated by elevated wave-cut platforms. While this uplift may indicate the existence of tectonic stress, it does so on a broad continental scale rather than a local scale, and would include the 25 to 40 mile region surrounding San Onofre. (Shlemon, Tr. 3177-3180; SER, Section 2.5.1.8)."

53. "Applicants have investigated the broad chronological framework of the entire San Onofre region, on land and offshore, in order to extrapolate and determine the age of features offshore. The results of these investigations are contained in Exhibits #28, RJS-1, #29, RJS-2, and #30, RJS-3. These investigations showed the Quaternary stratigraphy in the San

Onofre area to be rather remarkable and perhaps the best exposed on the entire west coast of the United States. (Shlemon, Tr. 3168)."

54. "Dr. Shlemon's investigations for the Applicants involved collecting and interpreting all relevant literature dealing with the Quaternary geology of the area. He also mapped marine and fluvial terraces and collected samples as appropriate to determine the age, continuity and deformation of marine platforms and their overlying sediments. Investigative procedures included measuring and describing soil profiles; collecting and interpreting water-well logs; obtaining and interpreting uranium-series, amino-acid, and radiocarbon dates; and associating terrace ages with the Quaternary marine isotope stage chronology. (Shlemon, written testimony, p. 6). In support of both Dr. Shlemon and Dr. Moore, dart core and bore hole samples of the sea floor were also taken to provide ages for the seismic stratigraphy seen in the recorded sections. (Moore, written testimony, p. 8)."

55. "The gently sloping surface of the San Onofre Shelf is interrupted by several erosional wave cut platforms that mark former sea levels which fluctuated in response to glaciations during the Pleistocene epoch. These wave cut platforms truncate underlying strata of Miocene age and are covered by younger sediments laid down as the sea fluctuated to new levels. (Shlemon, Tr. 3189-3194; Exhibit #28, RJS-1, p. 32; Figures 6, 7). These platforms and the younger covering sediments are not

displaced and their ages therefore provide a minimum date for any faulting that may have occurred in the vicinity of the San Onofre Shelf. (Moore, written testimony, pp. 9-10; SER, Section 2.5.1.12)."

56. "An analysis of the worldwide marine isotope chronology shows that there have been some 17 to 20 major fluctuations of sea level within about the last 700,000 years, caused mainly by glacial (low stand) and interglacial (high stand) alternations (Shlemon, Tr. 3190-3194; Exhibit #28, RJS-1, p. 32). A well documented high stand of sea level, referred to as substage 5e, took place about 125,000 years ago and is recorded onshore by the almost continuous, unbroken platform exposed in the seacliffs. Previous high stands of sea level are also recorded by other elevated marine platforms found throughout the Camp Pendleton area. Younger fluctuations of sea level are recorded by submerged platforms offshore San Onofre. (Shlemon, written testimony, p. 10; Tr. 3135; SER, Section 2.5.1.12)."

57. "Several submerged platforms exist on the San Onofre Shelf. The ages of these platforms range from about 5,000 years to at least 40,000 years and possibly as much as 80,000 years old. (Shlemon, written testimony, pp. 9-10, Figures RJS-A, RJS-B; SER, Section 2.5.1.12). Seismic profiles in this area show that no faults displace these platforms and that there is no deformation or faulting within the overlying covering sediments with the possible exception of an area at the northern

part of the SCOF of the SCOZD. Confidence in the absence of faulting of the offshore platforms and overlying deposits is provided by the strong contrast of seismic reflectors between the younger sedimentary cover and the underlying Miocene-age rock. Nowhere east of the SCOF does displacement on the San Onofre Shelf extend upward into the Pleistocene erosional unconformity. (Moore, written testimony, pp. 21-22; SER, Section 2.5.1.12)."

58. "The terrace platforms offshore San Onofre are dated by radiocarbon of organic matter from younger covering sediments and by association with the worldwide marine isotope stage chronology. One of the platforms was probably cut during isotope stage 3 about 35,000 - 40,000 years ago, and another during a preceding high stand, possibly isotope stage 5a, about 80,000 years ago or during a minor intermediate age level. (Shlemon, written testimony, pp. 9-10, Figures RJS-A, RJS-B; Exhibit #28, RJS-1, Figures 6, 7). The older sediments covering the platforms are in the order of 20,000 to 40,000 years old. The younger sediments probably range in age from about 20,000 to 2,000 or 3,000 years old. The contact between these covering sediments is well defined on the seismic profiles. (Shlemon, Tr. 3170-3177). There is high confidence in the radiocarbon dates of 8,500 to 13,000 years for the youngest sediments covering the offshore terraces, because the dates are stratigraphically consistent and are not likely to be contaminated by younger organic matter. Although there are

always some uncertainties in isotopic dating techniques, in most cases errors in the San Onofre samples favor a younger age, so that the dates obtained are minimal. (Shlemon, Tr. 3195-3197)."

59. "Radiocarbon dates and world wide sea level fluctuations (Flandrian transgression) indicate that the youngest offshore cover was deposited since the last 17,000 or 20,000 years. The underlying older cover was deposited prior to about 20,000 years ago. Conservative extrapolation suggests that the entire sequence of sediments covering the marine platforms offshore San Onofre are at least 35,000 to 40,000 years old. (Shlemon, Tr. 3182-3187)."

60. "The folds and faults of the so-called CZD have not had movement since Miocene time (Moore, written testimony, pp. 48-49). In addition, it is known that without exception the wave-cut platforms are not displaced. (Kennedy, Tr. 2455; SER, Section 2.5.2.12). Therefore, faults of the CZD have had no movement for at least about the last 80,000 years and possibly not for several million years."

61. "Nine marine terraces were identified onshore in the San Onofre area. The Terrace 1 platform, investigated for at least 10 kilometers south to the Target Canyon area and 17 kilometers north to Dana Point, is the lowermost platform in the San Onofre onshore region and is traced almost continuously in the sea cliffs from about 10 km south of San Onofre to Target Canyon. It can be discontinuously traced northerly some 17 km

to Dana Point. (Shlemon, written testimony, p. 7; Exhibit #29, RJS-2). Although there are places where streams have eroded the platform or have covered it, the platform is almost continuously exposed over this distance, and the SONGS sea cliff area is one of the best exposures on the west coast (Shlemon, Tr. 3134-3137). Excellent exposures of the sea cliff and the Stage 5e platform and 125,000 year old terrace deposits are observed unbroken from the northern end of the San Mateo flood plain north of SONGS, to south of SONGS (Shlemon, Tr. 3181)."

62. "Assurance of no displacement of the fluvial and marine terrace deposits is obtained either through direct observation or by projection of surfaces across unexposed areas. In the case of San Onofre and San Mateo Creeks, the exposures are sufficiently continuous such that resolution of vertical displacement by these methods is in the order of three to four feet. (Shlemon, Tr. 3203-3204). However, Terrace 1 is not exposed for approximately 7,200 feet north of the SONGS site where it is covered by younger fluvial materials or has been removed by erosion (Shlemon, Tr. 3137-3142). There are, however, other dateable geomorphic markers and stratigraphic units, including the San Mateo formation, to cover these minor gaps. (Shlemon, Tr. 3146; Exhibit #25, JLS-1, Drawing 2)."

63. "River terrace deposits laid down by ancestral San Mateo and San Onofre Creeks, dated at about 60,000 to 70,000 years old, have been observed in valley walls and found to be undisplaced where exposed from the coast upstream some 2 or 3

miles (Shlemon, Tr. 3152-3143). In addition, interpretation of water well logs from the lower San Mateo Creek area discloses a general continuity of buried gravels, indicating no displacement in the vicinity of the projected CZD (Shlemon, Tr. 3249). These logs show buried gravels of part of an ancient (glacial) channel of San Mateo Creek (QC-2), about 17,000 to 20,000 years old, preserved some 100 feet below sea level at the present coast line (Shlemon, Tr. 3149). The modern floodplain deposits of San Mateo and San Onofre Creeks are flanked by fluvial terrace deposits (Q 4) and related soils in the 40,000 - 60,000 year-old range, and are undisplaced (Shlemon, Tr. 3200-3202, 3204, 3162). Additionally, these deposits are well exposed in other localities adjacent to SONGS including sea cliffs, and road and railroad cuts (Shlemon, Tr. 3156-3158)."

64. "In addition to dates based on terrace development and the worldwide isotope chronology, absolute dates on sediments in the San Onofre area were derived from radiocarbon analysis, uranium-series methods, and amino-acid techniques. The age ranges for these techniques overlap sufficiently to provide confirmation of the various dates obtained. In essence, Quaternary sediments at San Onofre, both onshore and offshore, have been dated by multiple methods including geomorphic and isotopic techniques. All methods yielded generally consistent results (Shlemon, written testimony, pp. 8-10; Exhibits #28, RJS-1; #29, RJS-2; Tr. 3199-3200)."

65. "At San Onofre, Terrace 1 is overlain by about 60 feet of nonmarine deposits containing several buried paleosols, excellent stratigraphic markers to determine the age of the deposits and the last movement of any fault in the area. (Shlemon, Exhibit #28, RJS-1) Several age dating techniques demonstrated that Terrace 1 is about 125,000 years old. Terrace 1 clearly passes unbroken over the Cristianitos fault as exposed in the seacliffs (Ehlig, Tr. 1103; Shlemon, written testimony, p. 8; Shlemon, Tr. 3190-3194, 3212; Exhibit #28, RJS-1, pp. 57-109; SER, Sections 2.5.1.8, 2.5.1.12) The absolute ages of the older and higher marine terraces at San Onofre are unknown; but, based on the marine isotope stage chronology, range from about 250,000 to almost a million years old, and these terraces are also not displaced. (Shlemon, Tr. 3190-3194, 3212)."

66. "No evidence for the postulated CZD has been found onshore at San Onofre. Examination of the sea cliffs between San Mateo and San Onofre creeks and between San Onofre Creek on the north and the Cristianitos fault on the south show no faults in either the Tertiary San Mateo formation nor in overlying 125,000 year old marine terrace and approximately 60,000 year old fluvial deposits (Shlemon, written testimony, pp. 10; Exhibit #30, RJS-3, Figures 5, 5a, 6)."78/

78/ The Board adds Shlemon, Tr. 3160, 3204-3209 to this Finding.

67. "The sea cliffs and river valleys bordering San Mateo and San Onofre Creeks have also been inspected to determine if there may have been displacement of various geomorphic features and formations along any conceivable projection of the CZD. There is no deformation or displacement of the 4-10 million years old San Mateo formation nor of the younger marine and fluvial terrace deposits (Shlemon, Tr. 3204-3205). Therefore, from geomorphic expression and continuity, there is no evidence for faults or folds of the CZD extending onshore at San Onofre (Shlemon, Tr. 3208-3209)."

8. Summary and Conclusions.

68. "All seismic profiles examined show that faults associated with the CZD end at or below the surface of an apparent wave-cut platform that is overlain by acoustically transparent sediment. Nowhere within the CZD is there evidence of a seafloor displacement. The CZD dies out to the north and has essentially disappeared within the area of the close-spaced Woodward-Clyde lines. Marine Advisers line S-26 farther north also shows no evidence of CZD folds, but homoclinally seaward-dipping beds. No faults of consequence extend onshore from the CZD offshore, [according] to analysis of the offshore data. (SER, p. F-8; Moore, Tr. 2969-70, 3082-83)."

69. "The only capable fault within five miles of the SONGS site is the SCOF which is an element of the SCOZD. (Moore, written testimony, p. 49)."

70. "The onshore Cristianitos fault does not extend seaward for more than about 2,000 meters, and it does not have a connection or other structural relationship with the SCOZD. (Moore, written testimony, p. 49)."

71. "Faults on the San Onofre Shelf that nearly coincide with the onshore trend of the Cristianitos fault are confined to horizons deep within the section and do not extend into the younger Monterey formation. They cannot be related to the much younger movement on the Cristianitos fault. (Moore, written testimony, p. 49; Tr. 3079-80)."

72. "Other faults east of the SCOZD in the CZD are associated with gentle folding and are largely intraformational. Most of them do not extend deep into the section or upward to the sea floor, and they do not have the intensity or continuity of deformation comparable to the SCOF. (Moore, written testimony, p. 50)."

73. "Last displacement on faults of the CZD offshore SONGS occurred in Miocene time, about 5-6 million years ago (Moore written testimony, pp. 45-49)."

74. "Wave-cut platforms offshore San Onofre range in age from about 5,000 to possibly 80,000 years old, based on association with the marine isotope stage chronology and on stratigraphic relationship to overlying marine sediments dated by radiocarbon. Neither the offshore platforms nor overlying sediments are displaced by the CZD (Moore, written testimony,

pp. 46-47; Shlemon, written testimony, pp. 8-10; SER, Section 2.5.1.12)."

75. "The first marine terrace onshore, Terrace 1, is dated by uranium-series, amino-acid, faunal association and soil-stratigraphic techniques as about 125,000 years old (substage 5e). This terrace (platform) is an almost continuous stratigraphic marker in the San Onofre area crossing unbroken over the Cristianitos fault as exposed in sea cliffs (Shlemon, written testimony, p. 8; Tr. 3182; SER, Sections 2.5.1.8, 2.5.1.12)."

76. "Nine older terraces onshore at San Onofre are dated by association with the marine isotope chronology, and range in age from about 250,000 to almost a million years. None of these are known to be offset. (Shlemon, Figures RJS-A, RJS-B; Exhibit #28, RJS-1, Figures 5, 6)."

77. "Fluvial terraces bordering San Onofre and San Mateo Creeks, in the order of 60,000 years old, are traceable from the coastline some 2 or 3 miles upstream. Within the resolution of field measurements these terraces are not displaced by any onshore projections of the CZD (Shlemon, Tr. 3160; Exhibit #30, RJS-3, Figures 5, 5A, 6)."

78. "No evidence has been observed for displacement of the 125,000 year old marine platform, the 60,000 year old fluvial terraces, or the underlying Tertiary bedrock (San Mateo formation), in areas adjacent to SONGS where the CZD might be

projected onshore (Shlemon, written testimony, p. 10; Exhibit #30, RJS-3, Figures 5, 5A, 6)."

79. "Certain offshore features characterized as a zone of deformation and referred to as the CZD are not structurally related to either the Cristianitos fault onshore or to the SCOF offshore. (Moore, written testimony, p. 50). Therefore, neither characterization of the offshore features as a zone of deformation or any additional information about this zone of deformation which became available subsequent to the issuance of the construction permit renders the seismic design basis for SONGS 2 & 3 inadequate to protect the public health and safety."

80. We earlier raised the matter of the data voids reported by Greene and Kennedy. In consideration of the full record, we find those data voids of little significance in determining the seismic safety at San Onofre. A truly massive investigative effort was mounted by the Applicants, which has been critically reviewed by the Staff and the USGS, to explore the CZD and it relationship to the OZD and the Christianitos fault. These studies, involving both the onshore and offshore features, have determined in a most professional fashion the geologic stratigraphy, tectonic history, and age of the critical features of interest. The record strongly supports the conclusion that the faults associated with the CZD are inactive. The Board concludes that the questions posed in Contention No. 2 have been laid to rest.

F. Small Earthquakes After the Construction Permit.

1. Trabuco Canyon Earthquakes. The two largest earthquakes near the site since issuance of the construction permits occurred within a few minutes of each other in January 1975 several kilometers west of the Cristianitos Fault. The magnitudes of these earthquakes were M_L3.8 and 3.3. In June and July of 1977, five small earthquakes, the largest of which was M_L2.8, occurred in Trabuco Canyon about 2.5 km north of the 1975 events. The Applicants presented expert testimony and exhibits [79/] to demonstrate that these earthquakes were not associated with the Cristianitos Fault and have no safety significance for San Onofre. (Biehler, written testimony)

2. The Applicants and the NRC Staff agreed that these small earthquakes were of no safety significance. The Intervenors presented no direct case and proposed no findings on these events. Accordingly, the findings proposed by the Applicants and Staff are uncontested.

79/ Dr. Sean Biehler, the Applicants' witness, had prepared an extensive report on the 1975 events which had been submitted to the NRC Staff. This report was admitted into evidence, without objection, as Applicants' Exhibit 31. This Exhibit includes in Figure 1 and Appendix B some earthquake data antedating issuance of the construction permits in 1973. The Intervenors pointed to this data in support of their later efforts to introduce similar data to prove the seismicity of the Cristianitos Fault. (Tr. 4602-03). The Applicants argued that their pre-1973 data was offered only to show the thoroughness of their investigations. (Tr. 4609). The Board might well have excluded the pre-1973 data if a timely objection had been made to it. In any event, we did not consider it for any purpose.

3. Using refined velocity models, the Applicants placed the hypocenters of the two 1975 events too far west to be on the Cristianitos Fault. Moreover, these events did not have a style of faulting similar to the Cristianitos Fault. The Applicants concluded that the events appeared to be associated with a fault which parallels Trabuco Canyon. Depth estimates for both events ranged from 2 to 4 km. A field survey in the area did not locate any ground surface rupture. (SER § 2.5.1.7, 2.5.2.2; Biehler, written testimony, pp. 4-8).

4. Because of the small magnitudes of the 1977 earthquakes, there was insufficient data to determine the focal mechanisms of these events. However, there is no evidence to indicate that these small earthquakes are associated with the Cristianitos Fault or other known faults in the area. (SER § 2.5.2.2; Biehler, written testimony, pp. 8-9).

5. The Board finds on the basis of the uncontradicted evidence that these small earthquakes are unrelated to the Cristianitos Fault and have no safety significance for the San Onofre site.

2. Offshore Earthquake Swarm.

6. Between November 6 and 9, 1981, after the record in this case was closed, a swarm of small earthquakes occurred offshore about 12 km SSE of the San Onofre site. The largest earthquake detected was M_L 3.0; the swarm totaled twenty small earthquakes, including eleven in the magnitude range M_L 1.2 to 1.8. The Applicants notified the NRC Staff of these events and thereafter filed two technical reports establishing the swarm

location as accurately as possible and answering various questions about its significance. The NRC Staff notified the Board and parties of these developments and served copies of the reports. (Reports of Sierra Geophysics, Inc., about Earthquake Swarm transmitted to NRC Staff on November 18 and 30, 1981).

7. The Board thereafter issued on Order calling for comments on the swarm to determine what impact, if any, it might have on the pending decision. The parties were specifically asked to comment, among other things, on whether the Applicants' reports should be included in the record and whether the swarm constituted good cause to reopen the record for further hearings. (Board Order of December 10, 1981).

8. Comments were received from all parties. We are incorporating those comments and related papers, as described in the footnote,[80/] in the record. It is unnecessary, therefore, to restate the parties' positions in any detail.

9. The basic question is whether the case should be reopened for further hearings on the possible significance of the swarm to the seismic safety of San Onofre. The only reason to consider reopening is the swarm location near the point where

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80/ The following documents are ordered included in the record: Applicants' Reports transmitted November 18 and 30, 1981; NRC Staff Review of Applicants' Reports dated December 8, 1981; Board Order dated December 10, 1981; Comments by Intervenors (December 15), Applicants (December 21) and the Staff (December 22); Letter from Dr. Brune to the Board Chairman dated December 18, 1981. The parties divided on whether these papers should be included in the record. We include them because that will not prejudice any party and could facilitate possible appellate review of the matter.

Greene and Kennedy have postulated a merger of the OZD and CZD. If the swarm seemed to prove, or might lead to proof, that the CZD contains significant capable faults (contrary to the findings we make in this decision) then presumably we should reopen t. explore it further. But the swarm, while relevant to those questions, does not prove capability of the CZD, and there is little reason to believe that further investigation and hearings because of the swarm might lead to any better knowledge of the CZD.

10. The available evidence, although less than conclusive, indicates that the swarm was less likely to have been associated with the CZD than the OZD, an active fault where swarm activity is not unexpected. This is suggested both by the fault plane resolutions for the largest events and the strike/slip sense of motion. (Applicants' Comments, pp. 9-10 and Fig. 13.1). Moreover, these small earthquakes occurred probably five-to-eight km below the ocean floor. (Applicants' Report of November 30, 1981, p.2). It seems unlikely that they would have caused surface ruptures of any kind, let alone ruptures large enough to be studied by additional seismic reflection profiling. Thus it appears that no more useful information about the swarm is even potentially available. And given the fairly straightforward nature of the evidence that is available, cross-examination is unlikely to shed more light on this matter. In sum, we conclude that nothing useful would be gained and that the outcome of the proceeding would not be affected by reopening.81/

81/ A Board has discretion to decline to reopen in such circumstances. Public Service Co. of Oklahoma (Black Fox Station), 10 NRC 775, 804 (1979).

V. CONCLUSIONS OF LAW ON GEOLOGY/SEISMOLOGY ISSUES

Upon consideration of the record of the proceeding and in light of the foregoing findings and discussion, the Board concludes that, with respect to the requirements of the Atomic Energy Act of 1954, as amended, and the rules of the Commission relating to seismic and geologic siting of nuclear power plants:

(1) The geologic, seismic, and engineering characteristics of the San Onofre site and its environs have been investigated in sufficient scope and detail to provide reasonable assurance that they are sufficiently well understood to permit an adequate evaluation of the proposed site, and to provide sufficient information to support the required health and safety determinations and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the plant site;

(2) Applicants have taken into account the potential effects of vibrating ground motion that could be caused by earthquakes. The design basis for the maximum vibratory ground motion and the expected vibrating ground motion have been determined through evaluation of the seismologic and geologic characteristics of the site and the surrounding region. Applicants have identified the most severe earthquakes associated with tectonic structures in the region surrounding

the site. Applicants have determined the most severe earthquake that could be associated with the controlling feature at the San Onofre site -- the Offshore Zone of Deformation -- by considering its geologic history and other relevant factors. Applicants then have determined the vibratory ground motion at the site and have designated the earthquake which could cause the maximum vibratory ground motion as the Safe Shutdown Earthquake;

(3) Applicants have met their burden of proof with respect to each of the four geologic/seismic issues admitted into controversy in this proceeding; and

(4) From the standpoint of seismicity of the site and surrounding area, there is a reasonable assurance that San Onofre Units 2 and 3 can be operated without endangering the health and safety of the public.

V. THE LOW-POWER MOTION

A. Contentions In Issue.

When it became apparent that Unit 2 would be completed before the Board could render a decision on a full-power operating license, the Applicants filed a motion pursuant to 10 CFR 50.57(c) for an operating license authorizing fuel loading and initial low-power testing at levels not to exceed 5 percent of rated power.82/ The motion was predicated upon a ruling in the Applicants' favor on the seismic issues (which had already been heard) and a showing to be presented concerning the relatively lower accident risks associated with low-power, compared to full-power, operations. The issue for hearing presented by the low-power motion, as formulated by the Applicants, slightly modified by the Staff, accepted by the Intervenors, and approved by the Board, was as follows:

> Whether there is reasonable assurance of adequate protection to the health and safety of the public during fuel loading and low power testing, considering the risk to the public presented by those activities and the level of

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82/ Alternative Motion of Applicants Southern California Edison Company, *et al.* for an Operating License for Fuel Loading and Low-power Testing, filed August 31, 1981.

> emergency preparedness in place during those activities.83/

In addition to the "comparative risk" contention quoted above, the parties were given an opportunity to propose additional contentions, subject to their making appropriate showings on the requirements for late contentions, if applicable. The Intervenors proposed two contentions, both of which were opposed by the Applicants and the Staff,84/ and one of which they subsequently withdrew.85/ The other proposed issue was:

> Whether Applicants have sufficiently demonstrated that a radiological emergency at SONGS 2 and 3 could not cause a radiological emergency at SONGS 1.

83/ See Tr. 8658, 9226, 9232-33. This issue, although worded somewhat differently, is essentially similar to the issue in the Diablo Canyon low-power proceeding. See Pacific Gas and Electric Co. (Diablo Canyon Nuclear Plant) Partial Initial Decision of July 17, 1981, ¶ 60. See Tr. 8462. This contention, theoretically, at least, incorporated the Intervenors' emergency planning contentions (as required by 10 CFR 50.57(c)) "to the extent [they] are relevant to the activity to be authorized" -- i.e., low-power testing. However, the Intervenors' contentions were focused almost exclusively on the off-site emergency plans. (These contentions are set forth at pp. 1-3 of the NRC Staff's Proposed Findings of Fact of October 29, 1981.) As demonstrated at the hearing, the adequacy of off-site plans is at most a secondary concern in low-power testing.

84/ Intervenors' letter to the Board Chairman, dated September 9, 1981; Memorandum of Points and Authorities, dated September 14, 1981; Applicants' Memorandum in Opposition to Intervenors' Issues, dated September 18, 1981; NRC Staff's Response to Intervenors' Issues, dated September 18, 1981.

85/ See Tr. 9972-73.

This contention was opposed on various grounds, including untimeliness and a lack of sufficient specificity. As to the latter, the Intervenor's memorandum in support of this vague contention was premised exclusively on alleged "connections" between Units 2 or 3 and operating Unit 1, such that an accident in one might cause a "simultaneous emergency" in another.86/ The record as later developed indicated that the units were not interconnected in such a fashion,87/ and the Intervenors apparently now concede at least the lack of any physical interconnection.88/

Apart from physical interconnection, the Applicants suggested without contradiction that under the previously admitted comparative risk issue, questions about the adequacy of personnel at the site for low-power testing, and whether they might have conflicting duties at the other units, would be proper.89/ Beyond these areas, however, neither the sponsoring Intervenors nor anyone else was able to clarify this vague contention.90/

86/ Intervenors' Memorandum of Points and Authorities, dated September 14, 1981, p.4.

87/ Affidavit of Harry Rood, the NRC Staff Project Manager, attached to NRC Staff's Response, dated September 18, 1981; Tr. 9953-54.

88/ See Memorandum cited in note 84, *supra*.

89/ Tr. 9953.

90/ Tr. 9955-56, 9960-61.

On the question of timeliness, the Intervenors argued that their contention was not "new," and therefore that it was not subject to the tests applicable to late-filed contentions. In their view, their contentions related to the "risk probability calculus of low-power" and therefore should be considered a "sub-part" of the admitted issue.91/ It is undeniable, however, that the concept of the operations at Units 1 and 3 somehow affecting emergency preparedness at Unit 2 was raised for the first time by this proposed contention.

We thereafter ruled orally on the record, rejecting the Intervenors' proposed contention, primarily for lack of the specificity required by 10 CFR 2.714(b)92/ The Board noted that "the low-power motion context is not a free opportunity to bring in new contentions. Rather, parties have to satisfy the requirements of contentions generally ... and certain other requirements that apply to late-filed contentions."93/ The Board further held that the

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91/ Tr. 9956-59.

92/ Tr. 10,099-100. The reference in the record was inadvertently to the particularity requirement in 10 CFR 2.714(a), which speaks primarily to standing. Subsection (b) speaks to contentions, and requires that their bases be set forth with "reasonable specificity." The concepts of particularity and specificity are, of course, similar. In any event, the rationale of our ruling is clearly expressed in the record.

93/ Tr. 10,099.

requirements of specificity become more stringent where, as here, a new contention is proffered at the eleventh hour.94/ Applying that standard here, we found that:

> We really don't know what the [interconnection] contention does envision, and we think that it is therefore unfair to the Applicant to admit it, because there isn't any very clear indication of what it is they are supposed to respond to.

In their "Brief on Proposed Findings of Fact ...[on] Low Power Testing" the Intervenors seek, in effect, to reargue the exclusion of this contention, urging that "any study of the risk of operation of Unit 2 at low power must address whether ... risks would be increased by (1) the continued construction of Units 3 and (2) the ongoing operation of Unit 1." Brief at p. 6. We are now told that there are "certain interrelationships between [Units 1 and 2] which could multiply the

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94/ The Board reasoned that:

> We think it important to note in this connection that some of these requirements, in our view, become more stringent as the case progresses. Otherwise, admission of contentions under looser standards would, we think, delay cases and unduly prejudice the Applicants. Specifically, 10 CFR 2.714(a) requires that a proposed contention be set forth with particularity. We think this is a requirement that becomes more stringent with the passage of time and the progress of the case. Because you at this late stage don't have the discovery process in which to develop information and refine a contention, nor do you have the pre-trial negotiation phase to refine contentions, so that when you come in at the eleventh hour, and this is at least the eleventh hour in this hearing, we think you need a very clear and very specific contention in order to satisfy particularity requirements. Tr. 10,099-100.

risk of operation of Unit 2 at low power." Id., p. 7. By way of specifics, Intervenors note, for example, that both units use the "sam fire water system and switching system." These facts were before the Board when it heard argument on the Intervenors' contention; yet they apparently saw no safety significance in them at that time.95/ In addition, the Intervenors point out that the emergency plans for Units 1 and 2 are similar, and that some of the emergency personnel would have responsibilities for both units. Id. The record supports these facts. Indeed, it would be anomolous if there were not similarities in plans for different units on the same site and if some management level personnel did not have duties at all three units. The record also shows that the Intervenors were allowed to and did cross-examine in these areas, and that cross-examination did not reveal any significant safety concerns.96/

The Intervenors claim, for the first time, that "Unit 3 is interconnected with Unit 2." (Emphasis in the original.) It is alleged, without specification, that there are "numerous interconnected systems including control room between Unit 2 and Unit 3." Id. It is the Board's understanding, based upon a

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95/ Tr. 9953. This information was contained in the affidavit of Project Manager Rood; see note 87, supra.

96/ Tr. 11,252-58. The Intervenors also state that the "operating personnel for the two units are the same." Id, p. 7. The page of the record cited in support of this statement does not support it; it seems unlikely that the statement is accurate.

site visit and direct observation, that the control rooms for Units 2 and 3 are adjacent to, but essentially independent of, one another. Except for the Intervenors' unsupported assertion about the control rooms, we are left to speculate about the nature of these alleged "interconnections" and their significance to low-power operations.

The Intervenors also claim that ongoing construction at Unit 3 "could increase the risk of an accident at Unit 2." That proposition is hardly self-demonstrating, and the Intervenors offer no demonstration.

The time for advancing specifics about alleged safety relationships among the three units was when we called for proposed contentions on the low-power motion. We are not obliged at this juncture even to consider these post hoc and largely unsupported justifications for the vague contention we earlier rejected. Nevertheless we have given these belated arguments some consideration and find nothing in them to cause us to reconsider our decision.

B. Comparative Risks -- Low Power Versus Full Power.

The NRC Staff called two expert witnesses, Mr. G. Norman Lauben and Dr. Patrick D. O'Reilly, on the technical aspects of the comparative risks issue. They focused on the significant postulated accidents that could occur at San Onofre Unit 2 and which could affect public health or safety. They testified that

> there are three major factors which contribute to a substantial reduction in risk for low-power testing as compared to continuous full-power operation. First, there

> is additional time available for the operators to correct the loss of important safety systems needed to mitigate relatively high risk events, or to take alternate courses of action. Secondly, the fission product inventory during this time would be very much less than during full-power operation. Third, there is a reduction in required capacity for mitigating systems at low power.97/

The NRC witnesses identified the postulated accidents which are the dominant risk contributors at San Onofre. With reference to those kinds of accidents, the NRC Staff performed a plant-specific relative risk analysis which determined the reduction in risk of public exposure for low-power operation, taking into account the additional time available for reactor operators to take corrective actions and the reduced fission product inventory for operation at 5% power for up to six months. For this analysis the overall reduction in risk to the public was found to be 500 to 10,000 as compared to continuous full-power operation.98/

Mr. Lauben and Dr. O'Reilly testified in some detail about the significance of the increased time that would be available to operators at low power to diagnose and take corrective actions for several possible accidents at San Onofre. For example, their analyses showed that, at low power, for a very unlikely large break loss-of-coolant accident, coupled with emergency core cooling system failure, there would be a minimum

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97/ Lauben/O'Reilly Testimony, p. 2.

98/ Id., p. 3; Tr. 11, 326-27, 11,336-37.

of fifteen hours to take effective remedial action.99/ More credible accidents could be expected to involve substantially longer remedial action times.

The Applicants presented a technical witness on the comparative risk question, Mr. David Buttemer.100/ His testimony was along much the same lines as the Staff witnesses -- that the much lower core fission product inventories present at low power and the resulting slower heat-up rates would provide more than ample time for corrective action. The NRC Staff witnesses were critical of Mr. Buttemer's analyses in several respects, notably in his selections of accident scenarios and in certain of the assumptions he adopted.101/ The Staff testified, however, that despite their differences in approach, Mr. Buttemer's results would be "comparable" to theirs, and that the conclusions under both approaches were "similar."102/

The Intervenors did not present any direct case on the low-power motion. Their cross-examination did not significantly undercut the Staff and Applicants' presentations on comparative risk.

99/ Lauben/O'Reilly Testimony, pp. 5-6; Tr. 11,317, 11,330-31).

100/ Tr. 11,198, et seq. Mr. Buttemer's calculations were contained in an exhibit, A. Ex. 161.

101/ Tr. 11,323-24.

102/ Tr. 11,335-36.

In their post-hearing submission, the Intervenors complain that the comparative risk assessments in the hearing were "generic" and that a "site-specific" analysis of "actual risk" is required for low-power operations. This argument rests in part on alleged risks posed by Units 1 and 3; we have already explained why such matters were not properly considered. Beyond that, however, the Staff's analysis was not based on wholly generic factors. Rather, they focused on operations of a Combustion Engineering pressurized water reactor, including certain engineering features specific of San Onofre, Unit 2.[103/] In addition, our conclusions on risk are based in part on the nature and duration of the activities that will actually take place under the low-power license. To be sure, the hearing did not address site-specific <u>consequences</u> of accidents, normally a component of risk analysis. But there was no need to look at consequences in the circumstances of this case. As will be shown, the emergency plan for the site will meet all requirements for full-power operations. Those requirements already incorporate consideration of the worst credible accidents that could endanger workers on-site at San Onofre. As to protection of the public off-site, the evidence shows that potential off-site consequences from low-power

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<u>103</u>/ Tr. at 11,336-37.

operations do not require <u>any</u> advance emergency planning.104/

We see no need to describe in any greater detail the technical presentations on comparative risk. The Commission itself recently endorsed the general proposition that fuel loading and low-power testing --

> involve minimal risk to the public health and safety, in view of the limited power level and correspondingly limited amounts of fission products and decay heat, and greater time available to take any necessary corrective action in the event of an accident.105/

The Staff's technical presentation in this case reflected substantial research and amply demonstrated the applicability of the Commission's statements to San Onofre Unit 2. Specifically, we find that even in the case of the most serious (and extremely unlikely) postulated accident, there would be some fifteen hours available for diagnostic and mitigative actions before core melt would occur.106/ More time would be available for more credible events. In addition, the fission product inventories produced by low-power operations of limited duration are a

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104/ Some consequence analyses might conceivably be necessary if some lesser, but still significant, risks were posed to the public off-site and off-site plans were incomplete. Such analysis might produce some less stringent set of standards for low-power operations.

105/ Supplementary information accompanying adoption of final rule concerning Commission effectiveness review prior to fuel loading. __ Fed Reg. ______.

106/ This section of our decision does not contain separately numbered findings of fact. The findings are incorporated in the decision.

fraction of those produced at full power. Furthermore, the capacity required for heat removal is reduced at low power. On the basis of these factors, we conclude that low-power operations of Unit 2 at San Onofre, as proposed by the Applicants, will involve substantially less risk to the public health and safety than full power operations.

C. Applicants' Plans for Low-Power Operations and Emergency Preparedness in Place.

The Applicants presented a single witness, Mr. David Pilmer, on this subject. He testified that the on-site emergency plans for Units 2 and 3 would be fully implemented before fuel loading.[107/] He noted that a recent inspection of the emergency plan for Unit 1 had found no items of noncompliance. While the operating personnel for Unit 2 are different, this recent inspection is relevant to the state of readiness for Unit 2, because the key on-site management, supervisory and senior technical personnel that represent much of the on-site emergency response capability are responsible for both units.[108/]

Mr. Pilmer testified that the planning required for emergencies with offsite consequences during fuel loading and

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107/ Pilmer Testimony, p. 1, following Tr. 11,243. Mr. Pilmer is Supervisor of the Health Physics and Emergency Planning Group of the Southern California Edison Co.'s Nuclear Engineering and Safety Section. The Board was impressed with his knowledgable presentation.

108/ *Id.* pp. 2-3.

low-power operations depended upon the activities to be conducted. It is estimated that initial criticality will occur about the eleventh week of the sixteen week fuel-loading and testing program. Prior to criticality, the risk of significant releases of radiation is essentially zero. During the first three weeks of criticality, fission product generation is low. This means that a significant fraction of the fission product would have to be released to the atmosphere -- i.e., a core melt -- to result in significant off-site doses. A core melt is not possible during these activities because of the limited decay heat generation associated with operation at less than 1 percent of rated power.[109] Mr. Pilmer concluded from these considerations that "There can not exist a set of conditions that could constitute a General Emergency ..,." i.e., one threatening the public offsite, during the first fourteen weeks of fuel loading and testing.

The final two weeks of proposed testing require reactor power levels between 3-5 per cent. Mr. Pilmer testified that --

> For the first time the reactor will accumulate sufficient quantities of fission products such that a Class-9 accident sequence, although highly improbable, would be possible ... The necessity for taking protective actions offsite could arise. ... With a time period on the order of a day or so for a Class-9 accident sequence to develop to the point of generating the radionuclide release, minimal offsite planning should be sufficient.

109/ Pilmer Testimony, p. 4.

Mr. Pilmer was asked "what would be the minimum state of preparedness to adequately protect public safety in the event of an accident during the low power testing program?."

He testified that --

> The onsite organization should have received the training and otherwise be properly qualified to carry out all of its responsibilities set forth in the Emergency Plan for SONGS Unit 2 & 3. As a minimum, the means to communicate with offsite authorities is required in the event the accident may produce offsite consequences. However, because of the length of time available, offsite authorities for SONGS are well able to carry out any recommended protective actions even without further detailed procedures or special training.

Mr. Pilmer's view concerning the need for "means to communicate with off-site authorities" in the event of a serious accident was shared by Mr. Brian Grimes, Director of the NRC's Division of Emergency Preparedness.[110/] The Board agrees that this capability is necessary. We turn in this connection to the record developed by the Applicants in their affirmative case on emergency planning. One of the contentions is whether there will be adequate "procedures for notification by Applicants of State and local response organizations."[111/] The Applicants' witness on this point was Mr. Harold Ray, Station Manager at San Onofre. Mr. Ray testified in detail concerning both the procedures for emergency communications (e.g., different messages for different alert levels, who calls

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110/ Tr. 11,355.

111/ Contention 2A.

whom, etc.) and available means of communication.[112] As to the latter, he testified that --

> The SONGS 2 and 3 communications system includes multiple systems and redundancies which ensure the performance of vital functions in transmitting and receiving information between SONGS and involved Federal, State and local response organizations throughout the course of an emergency. These systems include the following:
>
> -- a regular public telephone system;
>
> -- a dedicated public telephone system (The Interagency Telephone System);
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> -- a VHF radio system to Camp Pendleton Marine Corps Base;
>
> -- a UHF radio system to the Pendleton Coast Office of the State Department Parks and Recreation; and
>
> -- a microwave multiplex system to the SCE Energy Control Center and the San Diego Gas & Electric Company Energy Control Center (PAX System).

This testimony was not impeached on cross-examination, nor was any contrary testimony introduced by any other party on this subject. The record clearly establishes, therefore, that the Applicants have sufficient means for notifying off-site response organizations in the event of a serious accident during low-power operations.[113]

112/ Ray Testimony, pp. 16-31.

113/ Decisions on the adequacy of emergency planning for full-power operations will be made at a later date, in the light of the parties' proposed findings of fact and conclusions of law. The existence of a nearly complete record on those issues is, however, a helpful backdrop against which to decide this low-power motion. Without intimating any decision on those full-power issues, it is relevant to the low-power question that, as evidenced by (Continued on following page)

D. Criteria for Emergency Plans at Low Power.

Mr. Pilmer's testimony indicated simple criteria for low-power operations: an on-site plan that meets[114/] current emergency planning requirements, plus the ability to communicate off-site. No off-site planning would be required. Unfortunately, due to the rather convoluted development of emergency planning requirements since the Three Mile Island accident, the question of the proper criteria for emergency planning at low power was a murky one, at least at the time this motion was heard.

To begin with, the present rule itself does not provide separate and less stringent standards for low-power operations. It does include, however, an "escape clause" under which applicants are given an opportunity to demonstrate that a failure to meet otherwise applicable standards is "no significant for the plant in question ... or that there are other compelling reasons to permit plant operations." 10 CFR 50.47(c)(1). We believe that this broad language encompasses the low-power situation, authorizing exemptions from at least

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113/ (Continued from previous page) that record taken as a whole, the emergency plans for the off-site areas are far developed. On this narrow question of the adequacy of communications equipment, we think it is appropriate to resort to the record. We made it clear to the parties that we considered the entire emergency planning record to be before us, as necessary, in deciding the low-power motion. Tr. 11,276.

114/ Arguably, one might exempt an Applicant from on-site requirements that are irrelevant to low-power. We need not reach that question here, because the Applicants meet all current onsite requirements. See p. 236, *infra*.

some of the full-power planning requirements upon an appropriate showing. But the rule does not tell us what an appropriate showing is.

In early 1980, prior to the adoption of the new emergency planning requirements, the NRC Staff and the Federal Emergency Management Agency ("FEMA") saw the need for a separate approach to low-power operations when it became evident that some facilities (like San Onofre) would be ready for low-power operations before full-power emergency plans could be developed and put through the hearing process. They considered it unnecessary to develop specific low-power testing criteria, "in view of the minimal nature of the potential hazard."115/ They accordingly agreed that, as to off-site preparedness to be evaluated by FEMA, it would be sufficient if the facility "is located in a State which had received a concurrence under the previously voluntary concurrence program administered by the NRC and based on evaluation by a multi-agency Federal Regional Advisory Committee."116/ The Staff, in evaluating onsite

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115/ FEMA/NRC Steering Committee Memorandum, dated March 6, 1980, Exhibit A attached to Testimony of John Sears. The decision might also have been influenced by the presumably temporary nature of the problem. When the licensing system is functioning on schedule, one would normally expect full-power emergency plans to be developed and approved well before a facility is ready for low-power operations.

116/ "FEMA/NRC Interim Agreement on Criteria for Low Power Testing at New Commercial Nuclear Facilities," Exhibit B attached to Testimony of John Sears, following Tr. 11,340.

preparedness, would apply then existing Appendix E to 10 CFR Part 50, and Regulatory Guide 1.101.

Following the effectiveness of the upgraded emergency planning requirements in late 1980, the NRC Staff began to apply the new rule, and the NRC/FEMA implementations of the rule in NUREG-0654, to determine the adequacy of on-site plans for low-power operations. The Staff's current approach is to determine whether a plan meets the criteria of NUREG-0654 and, if there are any deficiencies, whether those deficiencies are significant for low-power operations.117/

The Commission has not taken a final position on which of these criteria should be applied. However, following the closing of the record in this case, the Commission proposed an amendment to the emergency planning rule under which no NRC or FEMA review concerning the adequacy of off-site emergency plans would be a prerequisite to issuance of a low-power license. The amendment contemplates that the NRC review of the on-site plan will include an assessment of off-site elements, such as communications, necessary to evaluate the Applicants' response mechanism. Any deficiencies found in the on-site plans would then be evaluated to determine their significance to low-power operation.118/ The approach the Commission has now proposed is fully consistent with the approach we would have adodpted on this record in any case. But as we shall now see,

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117/ Sears testimony, pp. 2-4; Tr. 11,342, 11,353.

118/ See Notice of Proposed Rulemaking Concerning Emergency Planning, dated December 10, 19781, __ Fed Reg. ________.

the state of emergency planning in this case satisfies not only the proposed Commission standard, but also any other reasonable standard that might be suggested.

E. Federal Agency Reviews of Emergency Plans.

1. NRC Reviews. The NRC's initial review of the Applicants' on-site plan was conducted against the newly upgraded requirements in 10 CFR 50.47(a) and the implementing standards in NUREG-0654, on the assumption of full-power operations. The review is described in the Staff's Safety Evaluation Report and Supplements thereto.[119/] The Staff concluded that "the San Onofre onsite emergency plan provides ... an acceptable state of emergency preparedness."[120/]

The Staff called two witnesses at the hearing on low power, Brian Grimes and John Sears, to sponsor the SER in relevant respects and to confirm the ineluctable conclusion that a plan adequate for full-power operations would also be adequate for low-power operations. Mr. Sears reconfirmed the conclusion that the on-site plan for San Onofre fully meets the requirements of 10 CFR 50.47(a) and the standards in NUREG-0654.[121/] He further testified that the plan meets the criteria of former Appendix E, pursuant to the 1980 agreement with FEMA on evaluation of plans for low-power

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119/ SER § 13.3; Supp. I, pp. 22-126-135; Supp. 3 § 13.3.

120/ Supp. 3 at p. 13-4.

121/ Sears Testimony, p. 4 following Tr. at 11,340.

operations.122/ Taking note of the FEMA conclusion concerning the status of the State plan (discussed below), Mr. Sears testified that "the overall state of emergency preparedness for SONGS 2 and 3 is adequate" for low-power operations.123/

Mr. Grimes also testified that the present level of both on-site and off-site emergency preparedness at San Onofre is adequate for low-power operations. With respect to necessary planning levels in off-site areas, he expressed the view that --

> because of the extended time periods available for ad hoc actions in the off-site areas ... no particular pre-planning is required off-site except for the ability to communicate with off-site authorities.

Mr. Grimes went on to add, however, that there would almost necessarily be substantial off-site preparedness in place when an applicant sought low-power operating authority only a short time before planned full-power operations. In that connection, he observed that --

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122/ Sears Testimony, p. 6.

123/ Sears testimony, p. 7. Mr. Sears also expressed the opinion that certain off-site planning deficiencies previously identified by FEMA did not affect his conclusion about the adequacy of preparedness for low-power testing. Testimony, p. 7. We do not reach these questions because we credit the testimony that no advance planning for off-site areas is necessary. See Lauben and O'Reilly, written testimony, p. 9, following Tr. 11,319; Grimes, Tr. 11,343.

> Indeed, that is the case for the San Onofre facility and we believe there are substantial preparedness capabilities exhibited by the off-site authorities.124/

2. FEMA Review. The FEMA position supporting low-power testing at San Onofre was first set forth in a July 1981 memorandum to NRC.125/ FEMA noted first that, as of that time, off-site planning for San Onofre was not, in their opinion, adequate for full power operations. However, pursuant to the 1980 agreement with NRC, FEMA took the position that low-power operations should be allowed because the California State plan had received concurrence under the prior review program. The Staff called a witness from FEMA, Mr. Kenneth Nauman, who testified that the July 1981 memorandum accurately reflected the FEMA position.126/

F. Summary and Conclusions.

The risk associated with fuel loading and low-power testing as proposed for Unit 2 at San Onofre are a small fraction of the risks associated with full power operations. The more credible low-power risks could affect workers at the site, but not the general public off-site. Primarily because of the long lead times between initiation of an accident and possible releases of radiation off-site, there is no need for advance off-site plannning.

124/ Tr. p. 11,341-343.

125/ Memorandum from Robert Jaske to Brian Grimes dated July 17, 1981, S. Ex. 13.

126/ Tr. p. 11,305.

The most appropriate criteria for testing the adequacy of emergency planning for low-power operations is whether the on-site plan meets relevant full-power requirements (forgiving any deficiencies that are insignificant to low power), plus the ability to communicate with off-site authorities. Unit 2 not only meets but exceeds these tests.127/ We conclude that there is a reasonable assurance of adequate protection of the public during the fuel loading and low-power testing proposed by the Applicants. This protection is at least equal to that which will obtain at full power operations upon full compliance with the regulations. We hold, therefore, that the Applicants have demonstrated that any present "deficiencies in the off-site plans are not significant for the plant in question ..." 10 CFR 50.47(c)(1).

In light of this Partial Initial Decision and the underlying record, the Board further concludes that, to the extent relevant to the matters in controversy, Unit 2 will operate in conformity with the application, the provisions of the Act, and the rules of the Commission; that there is reasonable assurance (i) that the activities authorized by the low-power license can be conducted without endangering the health and safety of the public and (ii), that such activities will be conducted in compliance with the rules of the

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127/ The on-site plan meets all full-power requirements. In addition, we take into account in this context the record demonstrating that off-site planning is substantial, encompassing matters well beyond the minimum required ability to communicate.

Commission; and (iii), that issuance of the license will not be inimical to the health and safety of the public.

VI. ORDER

IT IS HEREBY ORDERED, pursuant to the Atomic Energy Act of 1954 and the Commission's rules, and based upon the findings and conclusions set forth herein that the Director of Nuclear Reactor Regulation is authorized, upon making the findings on all other matters specified in 10 CFR § 50.57(a), to issue to Applicants Southern California Edison Company, San Diego Gas & Electric Company, City of Anaheim, California, and City of Riverside, Califoria, a license to authorize the loading of fuel and low-power testing (up to 5 percent of rated power) for Unit 2 of the San Onofre Nuclear Generating Station.

This Order is subject to the following condition: that the Emergency Plan for Units 2 and 3 (A. Ex. 51) will be in effect prior to the first fuel loading activities, including complete implementing procedures and accomplishment of all required training. Satisfaction of this condition shall be evidenced by an NRC inspection and report to the Board. If any deficiencies are found, the report shall include an assessment of their significance to the activities authorized by this Order.

This Order is effective immediately.[128/]

ATOMIC SAFETY AND LICENSING BOARD

James L. Kelley
Chairman
Administrative Judge

Dr. Cadet Hand, Jr.
Administrative Judge

Mrs. Elizabeth B. Johnson
Administrative Judge

Dated at Bethesda, Maryland,

this 11th day of January, 1982.

128/ Appendix C to the Staff's SER addresses the status of unresolved safety issues, as required by the Appeal Board's decision in Virginia Electric and Power Co. (North Anna Staton), 8 NRC 245 (1978). The Staff discusses in some detail a number of such issues that are applicable to San Onofre Units 2 and 3, and explains why the licensing of those units to operate should be allowed before a generic solution to the problem is found. We have reviewed these Staff explanations and find them to be adequate.