UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
Herbert Grossman, Chairman
Dr. Harry Foreman
Dr. George Ferguson

In the Matter of:	)	
	)	
GENERAL ELECTRIC CO.	)	Docket No. 50-70 SC
	)	(Show Cause)
(Vallecitos Nuclear Center -	)	
General Electric Test Reactor,	)	
Operating License No. TR-1)	)	August 16, 1982

Appearances

For the Licensee
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For the NRC Regulatory Staff
Richard G. Bachmann, Esq., Daniel Swanson, Esq., Office of the Executive Legal Director, U.S. Nuclear Regulatory Commission

For the Intervenors
Glenn W. Cady, Esq., Carniato & Dodge; Barbara Shockley; Glenn Barlow (Technical Examiner)

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In the Matter of: GENERAL ELECTRIC CO. (Vallecitos Nuclear Center - General Electric Test Reactor, Operating License No. TR-1)	Docket No. 50-70 SC (Show Cause)

INITIAL DECISION REMOVING SHOW CAUSE ORDER AND APPROVING RESTART

Majority Opinion by Dr. Ge rguson and Dr. Harry Foreman
Administrative Judges[1/]

I. INTRODUCTION

The General Electric Test Reactor (GETR) is a 50 MW (thermal) test reactor used: a) in the production of radioisotopes for medical diagnosis and therapy, and for industrial purposes, and b) in the testing of reactor fuels and materials. The GETR is located at the General Electric Company's (GE) Vallecitos Nuclear Center

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1/ Separate Opinion of Administrative Judge Herbert Grossman, Chairman, dissenting in part and concurring in part, follows the majority opinion.

near Pleasanton, California. GE (the Licensee) was issued Operating License No. TR-1 for the GETR on January 7, 1959. Order to Show Cause, October 24, 1977.

In July of 1977, during consideration of the Licensee's timely application for license renewal, the NRC Staff initiated a review of the geology and seismology of the Vallecitos site. In August of 1977, the NRC Staff met with GE and indicated that additional geological and seismological information would be required to support the renewal application. Subsequently, on August 22, 1977, the Staff received an advance copy of a United States Geological Survey (USGS) Open File Report, No. 77-689, and an accompanying geologic map which indicated that the trace of the Verona fault, previously mapped approximately one-half mile northeast of GETR, came within about 200 feet of GETR. Id. at 1-3.

Between October 10, 1977, and October 20, 1977, the Licensee dug two trenches (known as T-1 and T-2) in order to determine whether or not the Verona fault existed along its mapped trace at the site. An NRC Staff geologist and seismologist, and a representative of USGS visited the site on October 22, 1977, to observe and evaluate the geologic evidence in the trenches. On the basis of this observation and evaluation, the Staff concluded that there was evidence of a fault, and that it might be "capable," as that term is used in 10 C.F.R. Part 100. Ibid.

The NRC Staff also concluded initially that vibratory ground motion at the site would likely be controlled by movement on either the Verona fault or on the nearby Calaveras fault, or on both. The Staff indicated that the most severe earthquake associated with the Calaveras fault would be in the magnitude range of 7 to 7.5, while an earthquake of lesser magnitude, perhaps 6 to 6.5, would be associated with the Verona fault. Of particular significance to the Staff were the possibilities that: a) an earthquake of this magnitude on the Verona fault would be expected to produce offsets of the ground surface of several feet; while b) ground motions at the site could have accelerations of sustained duration in excess of .75g. On this basis the Staff concluded that, since the facility had not been designed to withstand these severe earthquake effects, a potentially hazardous condition may exist. Accordingly, on October 27, 1977, the Acting Director of the Office of Nuclear Reactor Regulations issued an Order to Show Cause which required: 1) that the facility be placed in a cold shutdown condition upon completion of the then existing fuel cycle on October 27, 1977, pending further order of the Commission; and 2) GE to show cause why suspension of activities under Operating Licensing No. TR-1 should not be continued. Id. at 3-6, 8.

The Order to Show Cause provided that within 20 days the Licensee might file a written answer to the Order, and the Licensee or any interested party might request a hearing. On November 11, 1977, the Licensee filed a timely written answer and requested approval to resume operations immediately upon completion of certain modifications proposed in the answer.

In a Memorandum and Order dated February 13, 1978, the Commission, pursuant to Section 191 of the Atomic Energy Act of 1954, as amended (42 USC § 2241), delegated the authority to rule on the requests for a hearing to an Atomic Safety and Licensing Board (Licensing Board or Board). In its Memorandum and Order, the Commission stated the issues on which a hearing might be held, as follows:

ISSUE (1) What the proper seismic and geologic design bases for the GETR facility should be;

ISSUE (2) Whether the design of GETR structures, systems and components important to safety requires modification considering the seismic design bases determined in issue (1) above, and if so, whether any modification(s) can be made so that GETR structures, systems and components important to safety can remain functional in light of the design bases determined in issue (1) above;

ISSUE (3) Whether activities under Operating License No. TR-1 should continue to be suspended pending resolution of the foregoing.

Thereafter, GE submitted additional information to the NRC Staff relating to the geological characteristics of the site. It recommended geologic and seismic design bases, and submitted an analysis to demonstrate that the facility, after modification, would meet those design bases. Upon review by the NRC Staff, GE was advised in the summer of 1978 to perform additional geologic investigations. In response, GE undertook an extensive program of geologic investigations between August and December 1978. In February of 1979, GE submitted a detailed report on these investigations, along with additional information concerning the ability of the GETR to meet the recommended seismic design bases. See Lic. Ex. 1 at 18-34; Lic. Ex. 6; Lic. Exs. 22-23.[2/]

On September 27, 1979, the NRC Staff reached the preliminary conclusion that a surface displacement of 2-1/2 meters could occur beneath the GETR. Since this was in excess of the 1 meter surface displacement to which the modified GETR facility had been analyzed by GE, and since the Staff indicated that they were not aware of

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[2/] Citations to oral testimony in the transcript give the transcript page or pages. Citations to prepared written testimony give the last name of the witness or witnesses, the page of the transcript immediately preceding the prepared testimony, and the page or pages of the prepared testimony to which reference is made. Examples are: Jones, ff. Tr. 1500 at 5; and Jones and Adams, ff. Tr. 1600 at 10-12. Citations to exhibits designate the party who introduced the exhibit, the number of the exhibit, and the page or pages to which reference is made. Example: Lic. Ex. 2 at 10-12. Citations to the Stipulation, dated May 7, 1981, indicate the number and lettered statements of fact included in section "B" of that Stipulation. An example is: Stip. para. 2.a. Citations to the Stipulation of Facts set forth in this Initial Decision (Part III, infra) indicate the paragraph number only. An example is: Stip. para. 5. Finally, citations to proposed findings are as follows: to "Licensee's Proposed Findings of Fact and Conclusions of Law," dated July 6, 1981, indicated as Lic. Find., followed by the referenced finding number; "Intervenor's Proposed Findings of Fact and Conclusions of Law," dated July 23, 1981, are indicated as Int. Find., followed by the numbered finding being referenced; "Staff's Proposed Findings of Fact and Conclusions of Law," dated July 31, 1981 are indicated as Stf. Find., followed by numbered finding being referenced.

any structure which had been analyzed or built for this type of seismic loading, the Staff advised GE that it did not intend to continue its review of the GETR. Stf. Ex. 1-A.

Even though it was not required by statute or regulation, [3/] the NRC Staff referred the matter of restart of the GETR to the Commission's Advisory Committee on Reactor Safeguards (ACRS) for its review. An ACRS subcommittee meeting was held with GE and the NRC Staff on November 14, 1979, after which the Staff considered additional elements of information upon which its review had not previously concentrated. Stf. Ex. 2; Tr. 1883-86.

On May 23, 1980, after review of this additional information the Staff issued its final Safety Evaluation regarding the proper geologic and seismic design bases for the General Electric Test Reactor. The Staff modified its preliminary position to specify a surface displacement of 1.0 meter beneath the GETR as the appropriate design basis. The Staff further indicated its willingness to complete its review concerning the adequacy of the modified GETR seismic design. Stf. Ex. 1-B. Following additional

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3/ Section 182(b) of the Atomic Energy Act requires ACRS review for construction permit (CP) and operating license (OL) applications, and amendments thereto "specifically referred to [the ACRS] by the Commission." 42 U.S.C. § 2232(b). 10 C.F.R. § 50.58(a) imposes mandatory referral for CPs and OLs, but provides that applications for CP and OL amendments may be referred to the ACRS. The rulemaking notice accompanying the 1973 amendment to 10 C.F.R. § 50.58(a) clearly indicates that the Commission Staff has discretion to determine whether a particular CP or OL amendment application should be referred to the ACRS. 38 Fed. Reg. 22796 (August 24, 1973).

ACRS subcommittee meeting on June 16 and 17, 1980, on October 27, 1980, the Staff issued its Safety Evaluation Report (SER) for the GETR with regard to landslide hazard and seismic design of structures, systems, and components important to safety. Although the Staff had not finalized its position regarding effects of soil properties on the seismic analysis, the Staff tentatively concluded that upon completion of the proposed modifications, the GETR could be operated safely considering the geologic and seismic design bases determined by the Staff. Stf. Ex. 1-C.

The NRC Staff's SER was submitted to the ACRS. The ACRS met on November 6-8, 1980 to review the issue of GETR restart. The Committee concluded that the NRC Staff's geologic and seismic design bases were sufficiently conservative, and that the plant, as modified, should be able to to withstand the postulated seismic events with no significant release of radioactive material. Subject to resolution of the effects of soil properties on the seismic analysis, the ACRS concluded that the GETR, after modification, could be restarted and operated at its rated power level of 50 MW (thermal) without undue risk to the public health and safety. Stf. Ex. 2.

On January 15, 1981, the NRC Staff issued a supplement to its SER in which it concluded that the soil properties issue had been satisfactorily resolved and that the Staff's evaluation regarding Issues (1) and (2) of the Show Cause Order was complete. Stf. Ex. 1-D.

A "Notice of Hearing" was published on May 7, 1981. The hearing commenced in Livermore, California on May 27, 1981, at which time limited appearance statements from the public were received. Tr. 187-224. Evidentiary sessions commenced on May 27, 1981 and continued through May 29, 1981 in Livermore. The hearing reconvened in San Francisco on June 1, 1981 beginning with additional limited appearance statements. Tr. 731-67. The evidentiary sessions concluded on June 10, 1981. The record was kept open until June 26, 1981 for corrections and other concluding matters.[4/] The evidentiary record, consisting of 2306 transcript pages, includes the prefiled written and oral testimony of witnesses for the Staff, the Licensee, and Joint Intervenors together with documentary exhibits offered and received into evidence as indicated in Appendix A hereto.

4/ The Staff and the Licensee made timely submittals of their transcript corrections. Intervenors also made a timely submittal, indicating that they had no corrections to the transcript. By Board Order dated June 29, 1981, those transcript corrections were approved and the record in the proceeding was closed.

II. OPINION

The issues in controversy among the Parties in this proceeding involve the geologic and seismic characteristics of the GETR site. The Staff has recommended the following as the proper seismic and geologic design bases:

1. The Regulatory Guide 1.60 spectra anchored to 0.75g as the maximum effective vibratory ground motion at the site. This is set by motion on the Calaveras fault.
2. A surface displacement of one meter of reverse-oblique net slip along a fault plane which could vary in dip from 10 to 45 degrees and which could occur on a Verona fault zone strand (splay) beneath the GETR during a single earthquake event.
3. An effective vibratory ground motion of 0.6g, anchoring the Regulatory Guide 1.60 spectra, together with a fault displacement of one meter as described in 2. above.

Intervening parties have contended that the seismic design basis for the GETR should include a surface rupture of 2.4 meters and a vibratory ground motion above 1.0g.

The following are the major elements the Board finds persuasive in support of the seismic and geologic design bases recommended by the Staff.

The Verona fault was assumed to rupture along a fault length of 12 km. Field mapping and trenching demonstrated that the Verona fault length is substantially less than 12 km. Further, worldwide data indicate that actual rupture length would be substantially less than the total fault length.

Earthquake magnitudes of 6-6.5 and 7-7.5 may occur on the Verona and Calaveras faults respectively. The subsequent analyses used to develop design bases for vibratory ground motion assumed these earthquake magnitudes even though the available evidence shows that these are upper bound values.

The Verona fault was assumed to have been active during Holocene times (within the last 10,000 years) although trench data indicate that the last movement may have been pre-Holocene, and the seismological evidence characterizes the fault as "possibly" active.

An earthquake of magnitude 6.5 on the Verona fault was assumed to occur during the operating life (about 20 years) of the reactor in spite of the fact that a magnitude 6.5 event could be tens of centuries away.

In deriving the basis for 1-meter surface offset, it was assumed that the cumulative offset, measured on the several splays of the Verona fault zone, would aggregate in the future along a single splay beneath the reactor, in spite of the fact that this has not occurred for at least 128,000 years.

Minimum soil age estimates have been combined with maximum measured offsets to derive the slip rate from which the amount of future surface displacement can be predicted. It was assumed that all of the surface displacement in the trenches occurred co-seismically with maximum vibratory ground motion even though aftershocks and creep may well have contributed to the amount of surface displacements observed in the trenches. Moreover, the location of the trenches was such as to bias the measured surface displacements toward greater offsets.

The design basis for surface displacement assumes that the fault will occur directly beneath the reactor even though movement has occurred on the existing shears away from the reactor foundation during the last 128,000 years without formation of new splays between the existing shears or under the reactor. No reliable positive evidence has been found to show that a fault exists under the reactor.

The design basis of one (1) meter of surface displacement on a single splay of the Verona fault exceeds the mean plus one standard deviation of the surface displacements observed during the 1971 San Fernando earthquake. The San Fernando fault is a substantially more active fault and capable of greater displacements. Further, when compared with worldwide data regarding displacements for earthquakes of magnitude 6 to 6.5, the one (1) meter design basis is conservative.

A surface displacement of one (1) meter beneath the reactor foundation was specified as the design basis even though probability analyses showed an expected annual occurrence to be 10^{-6} or less. This probability is less than the probability for which the NRC staff will require consideration of natural phenomena in the design basis. Moreover, the absolute upper bound probability for the initiating event of a surface displacement of one (1) meter under the reactor foundation (10^{-4}) is comparable to the probability of core melt in a large nuclear power plant.

A one (1) meter surface displacement was assumed to intersect the reactor foundation even though geotechnical engineering considerations indicate that any fault originating beneath the foundation will deflect around the foundation.

Loads caused by surface displacements and vibratory ground motion were assumed to act simultaneously, even though this combination is considered to be a worst case.

Design basis values for response spectra were developed based upon Regulatory Guide 1.60, which envelopes the mean plus one standard deviation of the historic earthquake ground motion records (including the most severe horizontal motion measured at Pacoima Dam during the 1971 San Fernando thrust fault event.

The Regulatory Guide 1.60 response spectra are at least eight times more stringent than the uniform building code requirements for critical facilities (schools, hospitals, etc.). These spectra were anchored to effective accelerations of .75g and .6g for earthquakes on the Calaveras and Verona faults, respectively, even though the evidence would support more realistic values of .6g and .4g, respectively.

Regulatory Guide 1.60, anchored to 0.8g, would be a reasonably conservative design basis for a site proximate to the largest fault in the western United States, the San Andreas fault.

As a final point of perspective, the NRC and USGS geology and seismology witnesses were asked the question as to when, discounting all other evidence (including probability analysis) and based upon geological evidence alone, one would expect a design basis event at the GETR site. In response, all witnesses were of the view that the most limiting design basis event (magnitude 6.5 earthquake, coupled with a one (1) meter surface offset), was unlikely to occur within the operating lifetime of the GETR. In this regard, the earliest estimate for time to this occurrence, if it occurred at all, was probably 5,000 years in the future.

It is the opinion of the Board that the record developed supports the conclusion that the geologic and seismic design bases recommended by the Staff and enumerated above, are conservative and are those which are proper for the GETR facility (ISSUE ONE).

There was no dispute among the parties as to whether required modifications can be made so that GETR structures, systems and components important to safety can remain functional during, or after, a seismic design event.[5/] The analysis of the structures, systems and components, together with the required modifications, are contained in FINDINGS 107 to 181.

Therefore, the Board finds that the design of GETR structures, systems and components important to safety do require modification and these modifications can be made so that the GETR structures, systems and components important to safety can remain functional in light of the seismic bases determined in ISSUE ONE.

5/ Intervenor's witness I. W. Rutherford stated that some structural damage could be expected in the event of a surface rupture beneath the reactor although he could not quantify such damage (Tr. 2182).

III. STIPULATION OF FACTS

The parties entered into a stipulation under which it was agreed that certain matters of fact were not in issue, could be accepted by the Board as given in its decision, and need not be litigated in the hearings.[6/]

These matters of fact are as follows:

1. An average slip rate of 0.0004 ft/yr (0.012 cm/yr) fits a curve of cumulative apparent dip slip separation versus age of displacement on the Verona fault.
2. The Verona fault is tectonic in orgin.
3. Geologic data indicate that the GETR site is located within a zone of faulting (the Verona fault) which is at least 2200 feet wide.
4. Assuming that alluvial deposits in B-1 extended beneath GETR, the reactor rests on beds older than 70,000-130,000 years and younger than 300,000 years.
5. The assumption that the San Fernando and Verona fault zones are comparable is a conservative assumption.
6. The Verona fault, including its northwesterly projection along possible splays of the Pleasanton fault, has an estimated maximum surface length of 12 kilometers.

6/ The first Stipulation of the parties was transmitted to the Board by letter from NRC Staff counsel dated May 11, 1981, and approved and adopted by the Board in its May 14, 1981, Final Prehearing Conference Order.

7. The length of observed surface rupture during the San Fernando event was about 12-15 kilometers; movement was predominantly in a thrust sense with a substantial horizontal component.

8. Calculated slip vectors along an assumed fault plane in the Orange Grove Avenue and Eighth Street areas of the San Fernando fault that surface ruptured during the 1971 San Fernando event indicate that 2.4 meters of net slip displacement took place.7/

9. Concerning the 1971 San Fernando earthquake (based upon data by Barrows, et al., 1973):

   a. Regarding the 179 observations of vertical surface offsets occurring during the 1971 San Fernando earthquake, the mean of the observed vertical throw on a given fault break is about 34 centimeters (.34 meters).

   b. Of the 179 observations, 97% were less than 1 meter and 5 observations equaled or exceeded 1 meter.

   c. The maximum vertical offset noted which exceeds 1 meter is 160 centimeters (1.6 meter).

   d. One meter of vertical offset exceeds the mean plus two standard deviations for the San Fernando data.

7/ During the hearings the Staff modified its position concerning the width of the zone across which breakage was observed on the San Fernando fault (Tr. 1311-16). The result of this would nullify the last two sentences of the original Stipulation. Accordingly, those two sentences have been deleted in this version of the stipulated facts.

10. All of the shears exposed in trenches at Vallecitos Center have dips less than 45 degrees; seventy percent of dips measured are thirty degrees or less; two main shears closest to GETR have dips ranging from 0 to 25 degrees.
11. The potential earthquake sources that are important in assessing the vibratory ground motion hazard at the GETR site are the Calaveras fault and the Verona fault. Earthquakes occurring on these faults could have magnitudes of 7 to 7.5 and 6 to 6.5, respectively.
12. Strike-slip faults subsidiary to and connected to the San Andreas fault have generated maximum earthquakes of magnitude about 7 to 7 1/2 based on the data of Coffman and Von Hake (1973).
13. The base of the GETR foundation mat, which is located about 20 feet below grade, is underlain by very dense clayey sand and gravel with occasional layers of very dense sandy and/or gravelly clay to a depth of 70 feet.
14. There is a hard, cemented stratum known as the middle conglomerate unit of the Livermore Gravels, which crops out in hills on the west and south of the site, and which at the GETR site, is more than 70 feet below the surface.
15. Standard Penetration Tests performed for GE on the materials underlaying the GETR Foundation mat show blow counts of from 50 to 100 blows/foot penetration, affirming the very dense nature of these soils.

16. Groundwater levels at GETR were shown to vary from 20 feet to 28 feet below plant grade.

17. All of safety-related structures, systems and components necessary to shut down the facility and maintain the reactor in a safe shutdown condition during and following the design basis seismic events are identified in Table I, Section A of the SER (this is not an admission as to the proper seismic and geologic design bases of the GETR).

18. The horizontal vibratory ground motion at the GETR site resulting from an earthquake of magnitude 6 to 6.5 centered on the Verona fault could contain acceleration peaks as high as 1g. However, the overall level and duration of shaking at the GETR site would be less than for a magnitude 7 to 7.5 earthquake centered on the Calaveras fault.

19. The procedure used to assess the stability of hillside deposits as a result of an earthquake as described in Section 2.3, page 3 is appropriate for the purpose of this proceeding.[8/]

20. The investigations and reports provided by General Electric regarding landslides satisfy the requirements of 10 C.F.R. Part 100, Appendix A, Section V Seismic and Geologic Design Bases ((d) Determination of Other Design Conditions; (2) Slope Stability). In addition these investigations and

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8/ Stf. Ex. 1-C Part I, Section 2.3 at 3-4.

reports are in agreement with Standard Review Plan Section 2.5.5, Stability of Slopes.

21. An earthquake-induced slope displacement (landslide) of 1m is conservative.

22. Ground surface displacements resulting from these slope movements would be expected to occur near the toe of the slope, in the vicinity of the observed shear zone, and at some distance (approximately 300 feet) from the GETR plant. Therefore, ground surface displacements due to the postulated landslide must be considered in the design of safety related equipment located near the toe of the slope (e.g., fuel flooding system piping) but need not be considered in the design of the GETR reactor structure.

IV. FINDINGS OF FACT

Our findings of fact parallel the first two issues set forth by the Commission in its Memorandum and Order of February 13, 1978. The third issue in the Memorandum and Order, whether activities under the GETR operating license should continue to be suspended pending resolution of the first two issues, was not litigated in the hearing, as the Licensee stipulated that it did not presently intend to seek authority for interim operation pursuant to the third issue. Stip. para. 1. The first portion of our findings deals with the proper geologic and seismic design bases for the GETR. This issue in turn breaks down into subissues concerning geology, seismology, and earthquake engineering. The second issue involves the adequacy of the design of the GETR structures, systems, and components important to safety in light of the design bases determined in connection with issue one. These findings are set forth below.

ISSUE ONE: Determination of the Proper Seismic and Geologic Design Bases for the GETR Facilities.

A. Controlling Geologic Features

1. Regional Setting

1. The GETR is located in the Livermore Valley near Pleasanton, California about 35 miles east-southeast of San Francisco in a highly active tectonic environment. The predominant geologic and seismic feature of northern California and the San Francisco Bay area is the San Andreas fault (Lic. Ex. 1 at 35; and Tr. 227-29) which forms the boundary between the North American Continental plate and the Pacific plate.

Movement of this fault is apparently occurring at about 6 cm/yr with the Pacific plate moving northward relative to the North American plate. This movement results from a regional orientation of the maximum principal stress that is approximately north-south. Lic. Ex. 1 at 35, 36, 50; Tr. 227-29; Stf. Ex. 1-A at 10, 11).

2. In the vicinity of the San Francisco Bay, the San Andreas fault system consists of the main San Andreas fault itself and several other branching and subparallel faults. One of these is the Calaveras fault zone which passes about 2 to 3 kilometers west of the GETR site. Lic. Ex. 21 at 20; Tr. 285-86; Lic. Ex. 1 at 10. The Calaveras fault is a northwest trending strike slip fault which lies at the western reach of the Livermore Valley. (Lic. Ex. 1 at 36-37).

3. At the eastern reach of the Livermore Valley, another northwest trending right lateral strike slip fault, known as the Greenville fault, has been mapped northward to Mt. Diablo. Lic. Ex. 1 at 36-41. Although the Greenville fault is secondary in importance to Calaveras fault, the tectonic regime created between the Calaveras and Greenville faults establishes the geologic setting in which the lesser order Livermore, Verona, Las Positas, and Williams faults are located. Lic. Ex. 1 at 37-42; Tr. 227-29.

4. The following discussion addresses the tectonic regime which governs the lesser order faults in the Livermore Valley. The Livermore fault is a right lateral strike slip fault, located to the west of the Greenville fault and trending roughly parallel to it. The Williams fault, another northwest trending structure, lies to the west of the Livermore fault and to the southeast of the GETR site, and is similarly a

right lateral strike slip fault. Its northern mapped extension is located some three to four miles south and east of the GETR site. If its mapped trace were extended northward, it would pass several kilometers or more east of the GETR site. The Las Positas fault is one of the few structural features that trends northeastward across the predominant northwest trend of the major faults. Lic. Ex. 1 at 41-45. It has been mapped and observed between the Greenville and Livermore faults, and it has been hypothesized to extend beyond the Livermore fault on a line which passes several kilometers to the south of the GETR site. Stf. Ex. 1-B, App. B at 64-67.

5. Because the Verona fault is the geological fault in closest proximity to the reactor, it is of greater importance than the others in the Livermore Valley. In order to characterize the nature and extent of the Verona fault, an extensive geological investigation involving more than 2-1/2 miles of trenches was completed. Lic. Ex. 1 at 12-28; Lic. Ex. 2; Lic. Ex. 6. The fault is a zone of shears recognized in trenches and boreholes in the vicinity of the GETR. Analyses of regional geological evidence, led to the hypothesis that the Verona fault is related to the compressional stress regime created in the region bounded by the Calaveras and Greenville faults and the Las Positas fault. Stf. Ex. 1-B, App. B at 64-67. GE experts, however, believe the geologic evidence for either a landslide or tectonic origin is permissive. Tr. 431-32. Both GE consultants and the California Division of Mines and Geology concluded that features are landslide in origin. Stf. Ex. 1-A, App. D. USGS geologists, as advisors to the NRC Staff, undertook a comprehensive review of arguments and data provided by G.E. relating to

the presence or absence of the Verona fault. Stf. Ex. 1-B at 7. Their detailed review was reported in "Faults at the General Electric Test Reactor Site. Vallecitos Nuclear Center, Pleasanton, California, A Summary Review of Their Geometry, Age of Last Movement, Recurrence, Origin, and Tectonic Setting and the Age of the Livermore Gravel" (Stf. Ex. 1-B, App. B). The report supports the conclusion that the Verona fault should be considered to be a tectonic (earthquake) fault. This conclusion has been stipulated to for the purpose of this hearing. Stip. para. 2.b.

6. In terms of seismic risk to the GETR site, there is agreement among all of the experts and all parties that the controlling geological features are the Calaveras fault and the Verona fault. Stip. para. 11. Because of its known activity and relative proximity to the GETR site, the Calaveras fault is of obvious importance as a source of vibratory ground motion. Because the Verona fault is the feature in closest proximity to the reactor, it is likewise of importance, even though a measure of doubt may exist as to its real potential for seismic activity. Lic. Ex. 21 at 7-11; Tr. 1039; Ellsworth, ff. Tr. 996 at 3; Stf. Ex. 1-B, App. C at 14.

2. Characteristics of the Calaveras Fault

7. The Calaveras fault is well-defined geomorphically. Lic. Ex. 1 at 37-40. Earthquakes, ranging up to magnitudes estimated at 6.5, have been observed on the Calaveras fault within the past 120 years. Tr. 304-306. Its style of movement is predominantly strike slip, and as with all strike slip faults, the zone of movement associated with the

Calaveras fault is narrow and well-defined (about 1/8 mile). Tr. 286-92.

8. While characterized as a branch of and subsidiary to the San Andreas fault, the Calaveras fault does not embody the earthquake potential which one can associate with the San Andreas fault. Tr. 228, 695; Stip. para. 12.

9. Although deformation along the San Andreas fault is apparently distributed at depth between it and other branching faults, including the Calaveras fault, there is no corresponding relationship of earthquake movements between the San Andreas fault and the Calaveras fault. Tr. 1078, 1229-30. Instrumentation has been in place since the turn of the century which might have demonstrated any sympathetic earthquake movement on the Calaveras due to events on the San Andreas, and conversely, on the San Andreas due to earthquake events on the Calaveras. Tr. 1218. There is no credible evidence to suggest sympathetic earthquake movement, as between the San Andreas and the Calaveras faults. Tr. 641-47, 688-90, 1228-31.

10. None of the experts that testified supported the hypothesis that the Calaveras and Verona faults are connected in a direct structural relationship. Tr. 263-65, 292, 313, 1015-16, 1082-84, 1893. Both GE and USGS have conducted extensive field mapping and investigations to the south and west of the GETR between the Verona and Calaveras faults, and have found no evidence to support a connection between the Calaveras and Verona faults. Ibid. The field between these faults, to the south and west of the GETR site, contains a distinct, well-defined, and exposed middle conglomerate unit of the Livermore gravels. This field is

unbroken by any fault features of the age and sense of movement of the Calaveras or Verona faults. Tr. 296-98, 1083-86. Since this middle conglomerate unit is exposed, it provides evidence equivalent to trenching which precludes any connection between the Calaveras fault and Verona or Las Positas faults. Tr. 277-79, 296-98, 389-90.

11. To the north of the GETR site, a trench (denominated as "Trench E") was excavated across the mapped trace of the Verona fault. Lic. Ex. 1 at 23-25, Tr. 274-77. The exposure of Trench E showed that the Verona fault did not extend as far as Trench E and thus a northward connection of the Calaveras and Verona faults was precluded. Ibid. There is no geological evidence to support a postulated connection between the Verona fault and the Pleasanton fault to the north. Ibid. Tr. 1087. This would foreclose the possibility of a connection between the Verona and Pleasanton faults, and an extension of the Pleasanton fault beyond its mapped trace to, in turn, connect with the Calaveras fault.

12. Perhaps the most persuasive evidence negating a connection between the Calaveras and Verona faults can be found from the extensive trenching in the immediate vicinity of the GETR. Tr. 274-77. The trenches at the GETR site indicated that the most recent possible movement along the Verona fault was at least 2,000 years ago. Stf. Ex. 1-B, App. B at 16-21. It is well known that repeated movement has occurred along the Calaveras fault in recent times. Tr. 304-06. Given this observed, recurrent movement on the Calaveras fault, and none on Verona for at least 2,000 years, a connection between these faults is not credible. Tr. 292, 312.

13. The Intervenors also have argued that the Calaveras fault could extend onto the site by development of new breaks along the Calaveras fault away from its well-defined mapped trace. However, the consensus of the expert testimony is that although one cannot preclude any possibility in dealing with geologic features, a new splay to the east of the Calaveras fault is extremely improbable. Tr. 644-47, 656-58, 698, 1017-19, 1021-22, 1789-91, 1794-96. The available worldwide data, which reflect observations measured over geologic time (millions of year), indicate that it is unlikely that well-developed fault systems with patterns of recurrent movement will develop new rupture traces. Tr. 1017, 1340-41. More significantly, the field mapping of the unbroken middle conglomerate unit to the southeast, south and west of the GETR site, and the on-site trenches permitted observations of the geological record for hundreds of thousands of years to millions of years, during which no faulting which is characteristic of the Calaveras fault (i.e., northwest trending right lateral strike slip) has occurred on the site or immediately to the east of the Calaveras fault away from its mapped trace. Tr. 263-65, 1015-16. In the absence of any evidence to support the future occurrence of an extension of the Calaveras fault to the site, it must be discounted as speculation.

14. The Calaveras fault is of greatest significance in terms of its potential for generating strong vibratory ground motion at the GETR site. The first step in defining that vibratory ground motion for design

purposes consisted of estimating the magnitude of earthquake events which one could associate with the Calaveras fault. The parties have stipulated that a magnitude 7 - 7.5 event could be associated with this fault system (Stip. para. 11) and all qualified experts agree with this assessment. Tr. 695, 681-82, 1026-27; Stf. Ex. 1B, App. A at 1-5. It is well established that faults which are branches of and subsidiary to the San Andreas fault have the potential for generating earthquakes ranging up to a maximum of magnitude 7.5. Stip. para. 12. The length of the Calaveras fault (approximately 100 miles) correlates with available worldwide data for events ranging from 7 to a maximum 7.5 magnitude. Tr. 681-82. The Staff's recommended value of 7 - 7.5 magnitude for the Calaveras fault is well supported by the evidence in the record.[9/]

3. Characteristics of the Verona Fault

15. The Verona fault is characterized by dips angled (to the horizontal) between 10 and 45 degrees. Stip. Para. 10. The Verona fault zone has an estimated width of 2200.[10/] Stip. para. 3.

9/ The Intervenors have advanced arguments based upon the hypothesis that the Calaveras fault is in the state of "seismic gap". That is, since the last event on Calaveras of magnitude 6 or greater occurred more than 60 years ago, the absence of recent activity suggests that a major earthquake (7 - 7.5) could occur at any time. Although qualified experts have disagreed with the manner in which the Intervenors have construed the theory of seismic gap (Tr. 1615-18, 588-93, 2011-12, 2018-25), there is no disagreement that a 7 - 7.5 event on the Calaveras fault is possible. By the same token, the seismic gap argument makes little difference in the context of the Show Cause proceedings, since the NRC Staff's design bases assume this possibility, and have assigned a probability of 1 to the event. Tr. 1622-23, 2011-12.

10/ The width of the zone is the "outcrop width", or the distance between the surface expression or splays observed in trenches at the site. Tr. 1260.

16. The maximum surface length of the Verona fault, including its northwesterly projection along possible splays of the Pleasanton fault, is 12 km. Stip. para. 6. A possible connection to splays of the Pleasanton fault on the north is extremely unlikely. Tr. 274; Lic. Ex. 1 at 23-25. During the geological investigation, a trench (Trench E) was dug directly across the mapped trace of the Verona fault north of the site near Pleasanton. Lic. Ex. 1 at 24. That trench showed no evidence of faults or shears which could be associated in age or style of movement with the Verona fault. Tr. 247, 274-77; Lic. Ex. 1 at 23-25.

17. Dr. Herd of the USGS testified that based upon his extensive mapping of the region, there is no geological evidence to support a connection between the Verona fault and the Pleasanton fault. Tr. 1087. Dr. Brabb of the USGS considered such a connection theoretically possible, if the Verona fault turned southwesterly, and thus "avoided" the trench (Trench E) excavated on the northern trace of the Verona fault. Tr. 1200-03. In fact, to foreclose this possibility, GE performed seismic reflection and refraction profiles across the zone of Trench E and further to the southwest. Lic. Ex. 6, Apps. C and D. These studies preclude a bend around Trench E of any northern extension of the Verona fault to a possible connection with splays of the Pleasanton

fault. Tr. 390; Lic. Ex. 6 at Apps. C and D. Since it includes the length associated with the possible splays of the Pleasanton fault, the stipulated 12 km length for the Verona fault is conservative.

18. Evidence was presented concerning possible connection between the Verona and Las Positas faults. Dr. Herd from the USGS indicated his opinion was that the Verona fault and the Las Positas fault were interconnected. Tr. 1976-77. Dr. Slemmons, staff witness, testified that he would assign little weight to an interpretation that would connect these faults because of differences in mechanisms and difficulties in the dip of the two fault planes. The Licensee, on the basis of it's investigations and analyses developed two major lines of evidence to support this view. It was pointed out that there is an exposed middle conglomerate unit of Livermore gravels, which extends to the southeast of the GETR (Lic. Ex. 1 at 25-26; Tr. 298-301). In tracing this middle conglomerate unit in a continuous arc to the southeast of the GETR, exposure of the unit was found not broken by any faults which could be associated in age and style of movement with the Verona fault. Secondly, Licensee pointed out that if there were a connection to the Las Positas fault, the trace of the Verona fault must take two abrupt bends around the middle conglomerate unit to the southeast of the site to find a path for connection. Lic. Ex. 1 at 25-26. To check this possibility, GE, with the concurrence of NRC and USGS, dug a trench across the area where the Verona fault trace would complete its circuitous path to connect. Id. at 26-28. This trench, which is known as the A trench, did reveal a fault-like structure. However, the style of faulting in the trench was unlike that associated with the Verona fault or the Las

Positas fault and indicated that the fault in the Trench A is the Williams fault. Id. at 26. As previously indicated, the Verona fault is a low-angle thrust fault with the northeastern block of ground overthrusting the southwestern block of ground. The fault in Trench A had a nearly vertical orientation in contrast to the low-angle thrusting associated with the Verona fault. Ibid. Even if the Verona fault did pass through the middle conglomerate unit, and underwent a transformation from a low-angle thrust fault to a high-angle fault, the style of movement observed in Trench A is still inconsistent. Lic. Ex. 1 at 27; Tr. 298-99. After completing its bend and transforming to a high angle fault, the Verona fault would have the northeast side thrusting over the southwest side, consistent with its style of movement at the GETR site. Lic. Ex. 1 at 26-27. Then, as a matter of simple physical continuity, the fault in Trench A must necessarily show the northeast side thrust above the southwest side. Ibid. In fact, the opposite was observed in Trench A, and therefore, the fault in Trench A cannot be the Verona fault. The logical explanation for the observations in Trench A is that the fault observed is the Williams fault.[11/] Id. at 27-28.

19. There appears to be no reliable evidence to establish a connection between the Verona and Las Positas fault. This, in turn, buttresses the conclusion that the 8 km distance, between Trench E on the

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11/ The Williams fault would, if extended, pass to the north and east of the site on a parallel course with the Calaveras and Greenville faults. See Lic. Ex. 1 at 41.

north and Trench A on the south, defines the maximum length of the Verona fault, and that the 12 km length stipulated by the parties is conservative. Ibid. at 28.

20. The available seismic evidence concerning the Verona fault was extensively reviewed during the course of the GETR proceedings. The USGS completed a study of the Livermore Valley region seismicity. This study, entitled "Seismicity of the Livermore Valley, California Region 1969-79, Open-File Report 80-515," was prepared by S.W. Ellsworth and S.M. Marks, Stf. Ex. 1-B, App. C. With respect to the Verona fault, this study indicated that the Las Positas, Pleasanton and Verona faults are identified as probably seismically active faults. This conclusion was later modified with respect to the Verona fault so as to label it possibly active. Ellsworth, ff. Tr. 996 at 3. Ellsworth and Marks did conclude that earthquake focal mechanism solutions[12/] for events near Vallecitos Valley demonstrate that this region is a zone of active thrust faulting and that some of these thrust events are in possible association with the Verona fault. Stf. Ex. 1-B, Section A at 9.

21. GE interpreted the soil stratigraphy in the trenches to indicate the last movement on the shears, whether caused by landslide or tectonism, occurred between 8,000 to 15,000 years ago. Lic. Ex. 1 at 51. After careful review, the USGS indicated that the most recent fault

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12/ The USGS derived focal plane solutions for a series of recorded earthquake events in the Livermore Valley. Stf. Ex. 1-B, App. C. These focal plane solutions enable some to define the possible style of movement (i.e., strike slip or thrust fault) associated with those events. Lic. Ex. 21 at 8-9.

movement is believed to have occurred 2,000-4,000 years ago. Stf. Ex. 1-B at App. B. Dr. Slemmons indicated he would place an error band for fault displacement in the soil between approximately 1,500-2,000 years to 4,000 years before present for trench B-1, indicating the Verona to be a tectonic structure. Stf. Ex. 1-B at App. E. With the concurrence of the NRC Staff, GE performed its analyses on the assumption that the Verona fault is an active feature in Holocene times (less than 10,000 years ago). Stf. Ex. 1-B at A-5; Tr. 1216, 1220.

22. Estimates were made of the magnitude of the earthquake event which one could associate with the Verona fault. Dr. Kovach presented a correlation of fault area versus magnitude for worldwide data in order to estimate the expected magnitude for the Verona fault.[13/] Lic. Ex. 21 at 14-16. This correlation yielded magnitudes ranging from 5.8 up to 6.3, with a most likely value of 6.1. For the stipulated fault length of 12 km, Dr. Kovach's table would yield a magnitude of 6.0 or slightly less. Lic. Ex. 21 at 16.[14/] The NRC Staff's consultant, Dr. Slemmons, presented independently derived correlations of fault length, surface offset, and magnitude for a range of conditions which one might associate with the Verona fault. These analyses showed that for a

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13/ The fault area is that area along the fault plane for the surface to its maximum depth. Lic. Ex. 21 at 15.

14/ For an 8 km length, 8 km width, the rupture length of 1/2 of the total length, the magnitude would fall between 5.8 and 6.0. See Lic. Ex. 21 at 16.

12 km length, one can expect a magnitude ranging between 6 - 6.5, with a maximum value of 6.5, and a mean value of about 6.1. Tr. 1183-87, 1231-35. Stf. Ex. 1-B at App. E.

23. It is significant to note that the magnitude which one might associate with the Verona fault is not strongly dependent upon variations in length. Tr. 1574-75, 1585. Dr. Kovach's correlations show that for an increase in length of a factor of 2, one might expect an increase in magnitude of 3/10th. See Lic. Ex. 21 at 16. Dr. Slemmons' correlations showed a similar insensitivity to fault length. Tr. 1585. Even if, for example, the Verona fault were connected to the Las Positas fault, the total length of the Verona fault would not exceed 23 km, and the estimated magnitude would not exceed 6.5. Tr. 1585; Lic. Ex. 21 at 16. Therefore, a magnitude 6.5 event on the Verona fault can be considered a conservative upper bound. Tr. 1231-35.[15/]

B. Surface Displacement Along the Verona Fault

24. As indicated above, the controlling geological features for the GETR design are the Calaveras and Verona faults. For reasons set forth above in the discussion of the Calaveras fault characteristics there is no evidence to support projection of the Calaveras fault onto the site Hence there is no reason for encompassing movement associated with the

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15/ It should be noted that a hypothesized connection to the Calaveras fault would not impose a Calaveras magnitude 7 - 7.5 event upon an event on the Verona fault. Even with the connection, the Verona fault has insufficient length, depth, and potential for release of energy to generate an earthquake having the characteristics associated with the Calaveras fault. Tr. 269-70, 1580-82.

Calaveras fault on the design basis for surface displacement at the GETR.

25. Surface displacement design basis considerations were the subject of intense questioning at the hearings. The NRC Staff final recommendation is a value of 1.0 meter of net reverse oblique slip, occurring on a single splay of the Verona fault, as the design basis for surface displacement. Stf. Ex. 1-B at A-5.

26. Based upon its analyses and advice of consultants, the Staff initially concluded in its September 6, 1979 report that 2-1/2 meters of reverse-oblique net slip along a fault plane which could vary in dip from 10 to 60 degrees provides a conservative description of surface slip on the Verona fault zone during a single event. This judgment was based in part on observations and comparisons with the maximum calculated net slip displacement observed during the 1971 San Fernando, California earthquake. The position was based also on comparisons with the available worldwide fault offset information for reverse and reverse-oblique slip faults and the recommendations of the USGS and Dr. Slemmons. In addition, because of an inability to quantify the likelihood of new rupture between the existing shears, the Staff concluded that this offset could occur beneath the reactor. Stf. Ex. 1-B at 11.

27. Subsequently, both GE and the Staff presented their conclusions to a subcommittee of the ACRS. As a result of that meeting and the questions raised by the Subcommittee and its consultants, further review of the seismological parameters and a probabilistic assessment of the surface fault potential were undertaken. On April 12, 1979 GE submitted

a probability study done by Jack R. Benjamin and Associates but the Staff refused to accept the study and GE undertook a new probability study. In addition, the Staff received a number of reports from GE relating to the probability study, supporting bases for geologic assumptions in the study, a fault evaluation of GETR excavation photographs, dip of faults, discussions of the Livermore Valley regional seismicity, and the significance of observations of the 1979 Imperial Valley earthquake. Stf. Ex. 1-B at 1, 2.

28. The Staff and its consultants reviewed the newer information, and subsequently the Staff modified its conclusion regarding the proper design value for surface offset, assigning a final design value of one meter of offset for the GETR site. The bases for the selection of the final geologic design basis are set forth in the Staff's Safety Evaluation Reports (Stf. Exs. 1-B and 1-C).

29. The USGS geologists concluded that one meter of surface offset is not a conservative estimate of the total amount of offset that could occur along the Verona fault. Tr. ff. 996 at 5. Inherent in this opinion is that the total amount of offset will not necessarily occur on any one fault plane or strand of the Verona fault. The USGS indicated, however, it was not its responsibility to develop a design value for surface offset beneath the GETR and this conclusion was not a design basis recommendation. Ibid. The Staff concurred that the possibility exists that offsets larger than one meter could occur at some time in the future in the Verona fault zone, but that it is unlikely that an offset greater than one meter would occur on a single splay of the Verona fault directly beneath the reactor. No such splay of the Verona fault is known

to go beneath the plant, but for purposes of design of the facility, the consideration of one meter of offset on a splay of the fault beneath the reactor is required. Tr. 1394-95.

30. The USGS concluded that there were no direct measurements of Holocene (less than 10,000 years old) displacement in the GETR trenches on a single splay of the Verona which exceeded three feet in length. Stf. Ex. 1-B, App. B at 7, 22; Tr. 1484-85. Dr. Slemmons testified that the areas of trenching, i.e., where the 2 to 3 feet offsets were measured, are where the likely maximum displacements to be expected near the GETR. Tr. 1189-90.

31. The USGS interpreted 5.7 feet of offset from the log made of trench T-1. Counsel for the Licensee and the Board members questioned the USGS in detail regarding this interpretation. Tr. 135-79, 1430-1523. Dr. Herd and Dr. Brabb testified that this interpretation was not based on a direct measurement as was done in subsequent trenches. Rather, the 5.7 feet of inferred offset in T-1 is based on an interpretation of data from a log which was made several years after the USGS trench visit. Tr. 1165-66, 1477. T-1 was excavated for the purpose of determining whether there was or was not an active fault in close proximity to the plant and not for measuring the amount of displacement. Tr. 1134, 1159. Drs. Brabb and Herd indicated other difficulties in interpreting the offsets in trench T-1 without more information and verification of the soils in the trench and the unavailability of logs until well after the trench was closed. Tr. 1468, 1472-4. Dr. Herd's interpretation of the displacements, which was based in part upon photographs taken of the trench excavation (Stf. Exs. 5-A and 5-B), requires that the surfa soil

is offset. However, no offset of the surface soil is reported in the log of T-1. Tr. 1507-10. Dr. Herd concluded that the likely explanation is that the offset A-2 soil horizon was simply not identified by the persons logging the trench. Tr. 1509-10. Unlike the USGS, the Licensee's consultant interpreted T-1 to exhibit at most 2 feet displacement. Lic. Ex. 1, App. A at A-1.

32. Testimony by Dr. Jackson and Dr. Slemmons suggests additional reasons why a definitive conclusion is not possible from the evidence produced at the hearing from the extensive examinations on trench T-1. T-1 was located in a swale, with a rise on either side of it, whereas subsequent trenches were located on slopes inclined to the west. Consequently, there could have been some erosional aspect parallel to the fault at trench T-1. Tr. 1513. Dr. Slemmons indicated that T-1 may be a unique location where the two faults recognized in the B trenches come together (merge). Tr. 1295.

33. Thus, the interpreted 5 feet of offset in T-1 may be a cumulative displacement of multiple events, each occurring on the splays of the Verona, and none of which would necessarily exceed 3 feet of displacement individually. Ibid. The inconsistency between the possible offset of 5 feet in T-1 and 2-3 feet offsets measured in the other trenches further led Dr. Slemmons to suggest that trench T-1 probably exhibited a cumulative affect of two events, rather than a single event. Tr. 1585.

34. In light of the 22 direct measurement of displacements in the trenches closer to the GETR, all of which exhibited displacements of 3 feet or less (Stf. Ex. 1-B, App. B at 22; Lic. Ex. 1 at 50-51) and the

above discussion indicating uncertainty surrounding trench T-1 as a model for indicating geologic activity beneath the GETR, it does not appear reasonable that 5 feet of offset in trench T-1 to be controlling factors in the selection of a design value offset for the GETR. In this regard, even if the 5 feet interpretation at trench T-1 were included with the 22 direct measurements in the computation of slip rate, the stipulated 0.0004 feet per year value will not change in any significant way. Stf. Ex. 1-B, App. B at 22, 33-34; Tr. 571-73. Thus, the T-1 trench interpretation does not detract from the conclusion that 1.0 meter of surface displacement is a suitably conservative design basis. Further trenching could be undertaken, but results of a "fault deflection analysis" performed by the Licensee makes this additional investigation of little value.

C. <u>Supporting Evidence for 1-meter Offset Recommendation</u>

35. Several lines of evidence were presented to demonstrate the appropriateness and conservatism of the Staff's 1.0-meter criterion, i.e., 1) the data derived from the trenches at the GETR site and the calculations of slip rate based upon those data; 2) a comparison of the Verona fault with other faults in California, including the San Fernando fault; 3) a comparison of the Verona fault with worldwide data for maximum surface displacements during faulting; 4) two major independent probability analyses which demonstrate that the likelihood of a design basis surface displacement beneath the reactor is extremely low (10^{-6} per year or less); and 5) analyses of soil structure interaction for the GETR facility and site which shows that if a fault were located under the reactor, such that its upward projection would

intersect the foundation, movement along that fault would deflect around the foundation and not intersect the foundation. Each of the primary lines of evidence assessed for evaluation of the appropriateness and conservatism for the Staff's recommended design basis are presented below.

1. <u>The Observations of Displacements in the GETR Trenches - Slip Rate</u>

36. The parties have stipulated that an average slip rate of 0.0004 feet per year (0.012 cm/yr) fits a curve of cumulative apparent dip slip separation versus age of displacement on the Verona fault. Stip. para 1. This value was derived on the basis of some 22 direct measurements of surface displacement in the GETR trenches. Lic. Ex. 1 at 50-51. These measurements were verified by GE's consultants and the USGS. Tr. 1168. Experts considered these direct measurements are the primary and most reliable bases for assessing surface displacement in the trenches Tr. 1156-57, 1165. The trench data are the most reliable and applicable evidence for setting a design basis for surface displacement. Lic. Ex. 1 at 49-50; Tr. 1187-88.

37. The slip rate is significant inasmuch as it establishes a basis for prediction of future surface displacement on the Verona fault. Future movement would result from a build-up of strain along the Verona fault, and a subsequent, sudden release of energy from slip. Lic. Ex. 1 at 53; Tr. 229-32. Based upon the average slip rate, one would expect a build-up of 1 meter of strain every 8,000 to 10,000 years. Lic. Ex. 1 at 54; Tr. 229-32, 1659. If this built-up strain were released in a single event, one would then predict a surface displacement of 1 meter at the end of a 8,000 to 10,000 year period. <u>Ibid</u>. If more frequent surface

displacements occurred, these would be characterized by lesser amounts of surface displacement. For example, if strain built up over a 4,000 to 5,000 year period and were suddenly released in one event, a surface displacement on the order of 0.5 meter would be expected.

38. The slip rate determined from the observations and measurements in the trenches was based on conservative interpretations of the available data. That is, future surface displacements predicted from the stipulated slip rate value will overpredict the amount of surface displacement along a single splay of the Verona fault. There are at least two reasons for this: a) the average slip rate was based upon the total cumulative displacement measured across the entire Verona fault zone, and b) the average slip rate was based upon conservative interpretation of the age of soils and sediments in the trenches. The slip rate was based upon the cumulative displacement across the entire Verona fault zone. Stip. para. 1; Lic. Ex. 1 at 53-54; Stf. Ex. 1-B, App. B at 22, 33-34; Tr. 1027-29. There were three primary splays of the Verona fault observed at the site. Lic. Ex. 1 at 50-51; Stf. Ex. 1-B, App. B at 22. None of these splays intersect the reactor foundation. Lic. Ex. 1 at 55-56. The slip rate calculation treats the Verona fault as a total zone in which surface displacement has been observed to occur to each of the three known splays. Lic. Ex. 1 at 54; Stf. Ex. 1-B, App. B at 22, 33-34, Tr. 1027-29. The actual surface displacement measured for each individual splay was added or accumulated to obtain the total displacement on the entire fault zone, along with the corresponding age of each such total displacement. Ibid. The slip rate was then calculated as the average cumulative or total displacement on

the entire zone as a function of time. The trench observations indicate that the total displacement will in fact be shared among each of the three splays. Lic. Ex. 1 at 50-51; Stf. Ex. 1-B, App. B at 22. That is, as much as 1 meter of total offset will occur across the entire zone every 8,000 to 10,000 years, with each splay carrying a share of the one meter total. In order for one meter of offset to occur on a single splay, one must assume that no offset occurs on two of the splays, and that all of the offset along the fault zone occurs on a single new splay under the reactor. Tr. 1029-30, 1244-45.

39. This is a conservative approach since movement has occurred along the existing shears for a period of 128,000 to 195,000 years without formation of new splays between the existing shears, or under the reactor. Tr. 1030-32, 1245; Lic. Ex. 1 at 55; Jackson and Justus, ff. Tr. 996 at 11. Moreover, there were no direct measurements of recent displacements in the GETR trenches on a single splay which exceeded 3 feet. Lic. Ex. 1 at 50-51; Stf. Ex. 1-B, App. B at 22; Tr. 1484-85. In fact, the maximum 3 foot measurement of recent displacement was located at the base of the hillfront, where the stress regime would tend to exaggerate the amount of displacement measured. Tr. 1032-33, 1189-91. In addition, not all of the offset measured on a single splay in the trenches should be attributable to a single movement during a single event. Some of that movement could be attributable to multiple events, aftershock, creep, or gravity effects. Jackson and Justus, ff. Tr. 996 at 10-11, 1013, 1032-33, 1048-50. Thus, there is a high degree of confidence that the slip rate calculated from the trench data will

substantially overpredict the amount of future displacement on a single Verona fault splay during a single earthquake event.16/

40. The stipulated slip rate was also based upon conservative interpretations of the available data concerning the ages of soils and

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16/ The design basis also assumes that a new splay will develop under the reactor foundation and that all of the displacement along the Verona fault zone will occur on that particular splay. It is important to note that at the time the Staff issued its May 23, 1980 Safety evaluation, the entire analysis was colored by the belief then held by the Staff that a fault under the foundation was probable. Stf. Ex. 1-B at A-14, A-16-17; Stf. Ex. 1-B, App. B at 1. Indeed, this was one of the two major lines of evidence relied upon by USGS for their reservations as to the conservatism of the 1 meter surface displacement design basis. Stf. Ex. 1-B, App. B at 1. There is no reliable positive evidence that a fault which might intersect the reactor foundation actually exists under the foundation. Tr. 1039. GE, the NRC, and the USGS helped to plan, and agreed with, the location of the GETR trenches. Lic. Ex. 1; Tr. 473-77, 1345-46. The trenches near the reactor were located to intersect three lineaments shown on aerial photographs which were suggestive of the Verona fault. Tr. 1345-46. Upon excavation of these trenches, shears were discovered at locations corresponding to two of three lineaments predicted from the aerial photographs, while the third lineament proved to be an erosional nonconformity. Ibid. If any fault were under the foundation, there is no independent evidence from aerial photographs or otherwise, of its existence. A detailed review of high quality photographs of the original GETR foundation excavation was undertaken by GE, consultants for the ACRS, and USGS. No positive evidence of faulting in the foundation excavation was disclosed. Tr. 387-88, 451-52, 1035-37, 2013-15. This review caused USGS to downgrade its April 1979 position from "probable" faulting to "possible" faulting. Tr. 1035-38. It is agreed that this "possibility" implies a very low likelihood event. Tr. 1053-59. GE also interviewed personnel involved in the construction process who observed the excavation first hand, including one individual with a degree in mineral science and experience in geology. Tr. 2013-18. These interviews yielded no observations or recollections of any faults within the foundation excavation. Ibid.

sediments in the trenches.[17] The slip rate was calculated by dividing the total measured offset on the trench shears by the period of time in which the offset took place. There is agreement that the lower paleosol (B-2) horizon was formed during the period from 70,000 to 130,000 years ago. Stip. para. 4; Tr. 1120-30. The last offset of the lower paleosol was thus assumed to have occurred 70,000 years ago. The most recent offset was determined by GE's consultants to have occurred 8,000 years ago. Lic. Ex. 1 at 50-53.

41. USGS concluded that the last offset occurred 2,000 to 4,000 years ago. Stf. Ex. 1-B at 19-20. USGS did not accept the correction proposed by GE for radiocarbon dates on the modern soils. Lic. Ex. 6; App. A at A-18-36. GE based its calculation of slip rate on the minimum possible period of time during which the offsets could have occurred, 70,000 years for the oldest offset, less 8,000 years for the most recent offset. Lic. Ex. 1 at 53. Factoring in the USGS age of soils for the last offset would increase the period of time during which the offset occurred and yield a slightly lower slip rate. Thus, the 0.0004 ft/yr slip rate calculated by GE and stipulated by the parties is based upon a minimum time period and maximum amount of movement, with the result that it would overestimate future surface displacements at the site.

17/ There is no significant disagreement as to the validity of the direct measurements of the amount of displacement observed in the trenches. These measurement were, in fact, independently verified by the USGS. Tr. 1168.

2. Comparison with Other Faults, Including the San Fernando Fault

42. In order to provide an additional perspective on the 1 meter surface displacement design basis, the slip rates derived for the GETR site were compared with those for other faults in California. The Verona fault slip rate was compared with slip rate data determined for 5 major fault zones in California which are known to be active. The Hayward and Calaveras faults reflect more than 100 times greater slip rates. Lic. Ex. 1 at 59. The White Wolf and Sierra Madre faults, which like Verona are thrust faults, have more than an order of magnitude greater slip rate. Lic. Ex. 1 at 60. The Lakeview fault, which is a major segment of the San Fernando thrust fault system, has a slip rate which is more than 6 times greater than the Verona fault. Lic. Ex. 1 at 61.

43. The February 1971 San Fernando earthquake was employed by the NRC Staff as an analog or model to test the design basis surface displacement values for Verona. The San Fernando fault system comprised of thrust faults like the Verona is more than 100 miles in length and rupture was observed on that fault for a distance of 12 to 15 km during the 1971 event. Lic. Ex. 1 at 60; Stip. para. 7. In contrast, the entire Verona fault system is, at most, 12 km in length, and it is highly unlikely that rupture would occur along the entire fault length. Stip. para. 6; Lic. Ex. 21 at 15; Justus, ff. Tr. 996 at 10-11. It should be noted that fault length is minimally related to the amount of displacement along a thrust fault. However, there are other significant differences between the San Fernando and Verona fault systems. Lic. Ex. 1 at 49. The San Fernando fault system is located near the "big bend" of the San Andreas fault where movement between the Pacific crustal plate and North American crustal plate is translated into enormous

compressive stresses across the fault. Lic. Ex. 1 at 61-62. This compressive stress has been manifested in the dramatic uplift of the hills adjacent to the San Fernando fault. These hills rise abruptly more than 3,000 feet immediately adjacent to the fault, whereas the Vallecitos Hills rise more gradually to a maximum of 600 feet above the GETR. Lic. Ex. 1 at 66-67. There are a number of activities and characteristics for the San Fernando event that indicate it has a greater capability of producing a larger earthquake than the Verona fault zone. Tr. 1186. Thus, the San Fernando fault system represents a rigorous test for comparison of surface displacement with the Verona fault. Lic. Ex. 1 at 58-68; Tr. 232-34, 280-85, 1291-95, 1403-5, 1871-73; Justus, ff. Tr. 996 at 10.

44. The NRC Staff reviewed measurements of surface displacement for the 1971 San Fernando earthquake. Stf. Ex. 1-B at A-18-19. Of 179 observations of vertical surface offsets, the mean of the data is about 0.34 meters; 97% were less than 0.1 meter; and 5 observations equalled or exceeded 1 meter. Stip. para. 9a. One meter of vertical offset exceeds the mean plus two standard deviations for the San Fernando data. Stip. para. 9d. In view of the fact that the San Fernando fault is a rigorous standard for comparison with Verona, it follows that these data support the conservatism of the Staff's 1 meter surface displacement design basis.

45. GE performed additional analyses in an effort to correlate all of the available data from the 1971 San Fernando earthquake. GE developed an analytical method whereby measurements of horizontal and vertical offsets in the San Fernando fault zone were statistically

combined to develop a net slip value which is statistically representative of the San Fernando data. Lic. Ex. 1 at App. B. GE's analysis was prompted by the suggestion that the data presented in a paper by Robert Sharp of USGS which was based upon direct measurements of net slip taken at a single location. Lic. Ex. 1, App. B at B-2. Examination of that report indicated that individual offset components, rather than net slip, were measured, and the individual components were analytically combined by Sharp to determine net slip. Although mere arithmetic averaging of Sharp's data would yield a mean value in excess of 1 meter, the data base consisted of only 20 data points. Ibid.

46. In view of this, GE developed the statistical analysis using ten reported data sets for San Fernando offsets, including the Sharp data. Lic. Ex. 1, App. B at B-3. The total data base analyzed by GE included 238 measurements of vertical offset and 81 measurements of horizontal offset. Lic. Ex. 1, App. B at B-3. The GE statistical analyses determined that the mean value for net slip on the San Fernando fault was 0.22 meters. The mean plus one standard deviation for net slip was 0.72 meters. Ibid. Thus, these analyses confirm the conservatism of the NRC Staff's 1-meter design basis.

47. After commencement of the hearings, the USGS issued an Open File Report which presented a statistical analysis of the 20-point data set developed by Sharp. That report indicated that the mean of the San Fernando surface displacements, based upon Sharp's data and analysis, ranged between 0.58 and 0.78 meters. Tr. 258. The Staff's position did not change as a result of this report since it merely confirmed its view that the design basis 1 meter surface displacement on Verona exceeded the

mean offsets observed for the more severe San Fernando fault system. Tr. 557-59.

48. At the Board's request, GE also reviewed this Open File Report and concluded that its analysis was not affected. The Sharp data set had already been included in GE's analysis, along with ten other data sets. Moreover, since San Fernando is a conservative model for comparison, a mean in the order of 0.78 would only confirm the conservatism of the 1 meter design basis. Tr. 551-56.

49. The comparison of expected surface displacements on the Verona fault with the San Fernando data provides confirmation for the conservatism of the NRC Staff's design basis. The mere fact that a 2-1/2 meter surface displacement was calculated at San Fernando does not require the conclusion that 2-1/2 meters is an appropriate design basis for GETR. The Staff rejected the absolute worst case as the appropriate standard for establishing a surface displacement design basis for GETR. Tr. 1406-8. The available San Fernando evidence demonstrates that surface displacement in excess of 1 meter is not representative of future offsets for the Verona fault, and that the 1 meter surface displacement design basis is conservative for the Verona fault.

3. Comparison with Worldwide Data

50. As an additional point of reference for the 1 meter design basis, correlations of worldwide data for surface displacement were examined. Dr. Slemmons presented the results of worldwide data correlations for surface displacement and magnitude. Stf. Ex. 1-B at App. E; Tr. 1187-88. These correlations showed that for

a magnitude 6 - 6.5 event one can expect an offset of 1 meter, with extreme values (such as San Fernando) of maximum displacement ranging up to 2.5 meters. Tr. 1187-88. These correlations are based upon the maximum displacements observed in each event correlated. Tr. 1189. To that extent they represent an extreme, worst case and do not substantially affect confidence in the 1 meter design basis.

51. Still another independent perspective on the worldwide surface displacement data was provided by Professor Kovach of Stanford University. Professor Kovach presented seismic moment correlations which related the magnitude of a given event to the fault area, displacement, and material properties of the subsurface rock in which a given earthquake event originates. Lic. Ex. 21 at 16-71. For conditions appropriate to the Verona fault, the seismic moment correlation yielded an average displacement ranging from .31 meters up to 0.58 meters. Ibid. at 17. Thus, for a magnitude 6 - 6.5 event on the Verona fault, the mean of the worldwide data shows a displacement on the order of 0.6 meters. Ibid. On this basis, as well as Dr. Slemmons' correlations, it follows that the 1 meter design basis is consistent with and well supported by the available worldwide data.

4. Probability Analyses

52. Two major and independent probability analyses were undertaken to assess the likelihood that a design basis surface displacement would intersect the GETR foundation. These analyses were undertaken by GE's consultants and by NRC's consultants, LLL and TERA. Although the

methodology and approach in the two analyses differed, and although each was, in its own right, methodologically sound, it is significant that the results did not substantially differ. Tr. 1802-3, 1806.

53. GE calculated a best estimate probability for a surface displacement of any size under the reactor of 10^{-6} per year, with an upper bound or worst case probability of 10^{-4} per year. Lic. Ex. 1 at 80-82. TERA arrived at a best estimate probability for a 1 meter surface displacement under the reactor foundation ranging from 10^{-6} to 10^{-8} per year, with a worst case probability of 10^{-4}. Tr. 1804-6. This would suggest that the probability of a design basis surface displacement is substantially conservative. Lic. Ex. 1 at 84; Bernreuter, ff. Tr. 1801 at 2.

54. The GE analysis analyzed the probability of surface displacement of any size under the reactor foundation. Lic. Ex. 1 at 69. The data from the on-site trenches showed that there were repeated movements, for a period of 128,000 to 195,000 years, along the two shears which bracketed the reactor building. No movement or shears occurred between the shears or under the reactor building foundation for at least 128,000 to 195,000 years. Lic. Ex. 1 at 72. Given these facts, GE developed a simple, straight-forward model which calculated the probability that a surface displacement of any size would occur between the shears and intersect the foundation of the reactor building. This model yielded an annual probability on the order of 10^{-5} - 10^{-7} per year for a surface displacement of any size beneath the reactor building. Lic. Ex. 1 at 72-79; Lic. Ex. 10.

55. In order to determine the effects of reasonable changes in the assumptions in the GE model, the NRC Staff requested additional analyses by GE. Tr. 1811-12. Because the initial model assumed that a new fault could occur at random at any location between the existing shears, and that the timing of the event would be random, the Staff requested that a new model be developed to test the validity of the random time assumption or "Poisson" model. Tr. 453-60, 1811-12; Lic. Ex. 14. GE developed a more complex model which used a "hazard-increasing function," under which the likelihood of a shear between the existing shears increased as a function of time. Tr. 462, 1811-12; Lic. Ex. 1 at 79-82; Lic. Ex. 14. In other words, as the time since the last earthquake increases, the likelihood of another earthquake occurring increases. Further, the NRC Staff requested substantial sensitivity analyses under which the geologic input parameters were varied and the results analyzed to determine the effect of variations in geologic parameters. Lic. Ex. 1 at 79-82; Tr. 1811-12; Lic. Ex. 16. The hazard-increasing function model increased the risks predicted by the Poisson model by less than ten times. Lic. Ex. 1 at 79-82; Lic. Ex. 10; Lic. Ex. 14. The best estimate probability was about 10^{-6} per year, with values ranging up to 7.2×10^{-6} per year. Lic. Ex. 1 at 81; Lic. Ex. 14. The sensitivity analyses indicated that in order to achieve a probability greater than 10^{-5} per year, it was necessary to select unrealistic values of geological input parameters (e.g., soil ages younger than any which the geological experts would support). Lic. Ex. 1 at 82-83. Thus, an absolute upper bound on the annual probability of a surface displacement of any size beneath the

reactor foundation would be 10^{-4} per year. Lic. Ex. 1 at 82-83; Lic. Ex. 16; Tr. 1812.

56. In order to provide an additional, independent assessment of the GE probability analysis, the NRC requested that the LLL and its consultant, the TERA Corp., develop a probability analysis using different methods. Tr. 1802-3.

57. TERA's analysis, concurred in by LLL, concluded that the probability of occurrence of a 1-meter offset on the main Verona fault zone is about 5×10^{-5} per year. Bernreuter, ff. Tr. 1801 at 2. This calculated probability was not determined by relying on historical seismicity data, which itself provides an indication of that occurrence relationship, but instead relied on a slip rate based on inferred occurrence of earthquakes on a fault. This earthquake occurrence model resulted in the first of four conditional probabilities which when multiplied together result in the probability surface rupture beneath the GETR. Rather than using the slip rate from trenches B-1, B-2, and B-3, TERA and LLL independently calculated the slip rate, using the topographic expression between the Vallecitos hills and the valley in which the test reactor sits. The actual measurements taken from the trenches were used as an independent qualitative check on the results of the LLL/TERA analysis. Tr. 1803-4. This strain rate, used in the modelling, was more conservative than the actual measured strain rate taken from offsets in the trenches. cf. Tr. 1822 with Stip. para. 2a.

58. A second conditional probability was then calculated to determine, given the occurrence of an earthquake, what the likelihood would be of that earthquake-fault rupturing the surface. A third

conditional probability was calculated to produce the likelihood, given an earthquake of a given size rupturing at the surface, of the fault at the surface rupturing by the GETR facility. The fourth conditional probability was calculated to determine, given the above conditions, what the likelihood was of a displacement being experienced at that point on the fault. LLL/TERA multiplied all of these conditional probabilities together, yielding the likelihood of various size displacements occurring on a postulated Verona fault. Tr. 1804-5.

59. At this point, LLL/TERA applied two steps to determine the likelihood of displacements beneath the reactor. The first one was to determine the conditional probability of a geometric argument, the distance between the shears in trenches B-1/B-3 and B-2 compared with the size of the foundation. Tr. 1805. This step would reduce the probability of 5 x 10^{-5} per year by a factor of 0.06 for the estimate that the offset will occur beneath the reactor. Ibid.; Bernreuter, ff. Tr. 1801 at 2. A final step was then taken which was Bayesian in approach. This step was to take account of the fact that no shears had been observed between the shears represented in trenches B-1/B-3 and B-2 for a given period of time. This last factor would reduce the probability of exceeding a 1 meter displacement beneath the reactor to the order of 10^{-6} to 10^{-8} per year. Tr. 1806. All calculations up to the final step would be classical statistical analysis, as opposed to Bayesian analysis. Tr. 1805. The conclusion of the LLL/TERA report is that the probability of faulting beneath the GETR is very low, and the use of a mean plus 1 standard deviation value of

1 meter for net offset beneath the facility can be considered conservative. Bernreuter, ff. Tr. 1801 at 2.

60. The Intervenors presented testimony by Professor Brillinger in regard to the GE probability analyses. Professor Brillinger's basic criticisms of the GE probability analyses were: a) a single value of probability was calculated without providing a range of values or estimate of the influence of parametric variations (Int. Ex. 5 at 5); b) GE's modelling assumptions using Bayesian techniques (Id. at 3); and c) the geometry of the problem was not expressed in three dimensions (Ibid.)18/

61. Professor Brillinger provided a list of documents that he had reviewed in connection with the GETR probability analyses. Although his criticism emphasized the fact that GE had attempted to calculate a single number without examining the effect of parametric variations, he conceded that he could not claim to have reviewed all of the relevant analyses. Int. Ex. 6; Tr. 783-85. In fact, he had not reviewed the extensive

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18/ Professor Brillinger did not perform any independent analyses nor was he able to estimate the significance or effect of any of his criticisms. Tr. 811-13.

Although Professor Brillinger questioned whether it was appropriate to employ conservative assumption at each juncture in the probability analyses, he nevertheless agreed that conservative assumptions, such as those used by GE, would tend to overestimate the probability of a surface displacement. Tr. 712-14. Moreover, when asked, Professor Brillinger could not provide any specific instances, applicable to the GETR analyses, where the use of conservative assumptions would produce a non-conservative result. Ibid. Professor Brillinger indicated that he had reviewed the reports in the manner which he would employ for review of an academic journal article. He was interested in raising questions, and did not seek to provide answers. Tr. 811-13. He could provide no specific information which would indicate that restart of the GETR would be unsafe. Tr. 833-35.

parametric sensitivity analyses, which were requested of GE by the NRC. Compare Int. Ex. 6 with Lic. Ex. 16; Tr. 1811-12; Lic. Ex. 1 at 81-83. These analyses showed that reasonable parametric variations will yield a maximum increase in probability of one order of magnitude. At the extremes of reasonable parametric variations, GE's analysis shows an annual probability of less than 10^{-5} per year. Lic. Ex. 1 at 81; Lic. Ex. 16.

62. Professor Brillinger was critical of the modelling techniques employed in GE's analysis. Professor Brillinger preferred "classical" statistical techniques to Bayesian techniques, inasmuch as Bayesian techniques require the application of judgment. Int. Ex. 5 at 5; Tr. 721-24. Bayesian techniques would require a smart analyst and correct judgment to yield meaningful results. Tr. 722-23. Professor Brillinger believed that the use of Bayesian techniques and judgment fight against the natural role of the statistician. Tr. 723-24, 804-6. However, in making difficult judgments inherent in nuclear safety one must employ the information at hand. Tr. 464-65. Bayesian techniques can be used and have been used in NRC regulatory practice for making probability assessments. Tr. 788-89, 1813-14. Bayesian techniques can provide meaningful results if, as in this case, they are accompanied by sensitivity analyses which quantify the judgmental factors. Tr. 1813-14.[19/] In any event, probability assessments are not the

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19/ Professor Brillinger was not aware of, and had not reviewed, the sensitivity analyses.

sole basis for decision-making, but serve as an additional tool with which one can supplement deterministic and judgmental decision-making. Tr. 1352-59, 1801, 1822.[20/]

63. Professor Brillinger expressed his view that the probability analysis should have used a three dimensional geometric model. Int. Ex. 5 at 3; Tr. 790-1. However, he did not know whether this would have significantly affected the results of the analysis. Tr. 819-20. In fact, the results of the analyses would differ by a factor of 2 or less if a multidimensional model were employed. Tr. 1863-65. In the context of probability analyses, which are qualified by accuracies of plus or minus a factor of 10 this effect would not seem significant. Tr. 1869.

64. The more significant perspective on the probability analyses is that that both the GE models and TERA models establish an absolute upper bound of 10^{-4} per year. Indeed, TERA's model calculates a probability of 10^{-4} per year for a 1-meter offset anywhere on the site. Tr. 1820-21, 1844-45. If one then assumes that a fault exists

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20/ Professor Brillinger conceded that the GETR decision must ultimately involve subjective risk judgment (Tr. 804-6) and that it is useful and reasonable to use probability studies to supplement a deterministic or empirical finding. Tr. 804-6, 842.

under the reactor,[21/] or simply assigns a probability of 1 to a 1-meter surface displacement under the reactor, then the probability of a future 1-meter offset under the foundation would be 10^{-4} per year. Tr. 1819-21. This quantifiable lower likelihood of fault rupture confirms the conservatism of the NRC's surface displacement design basis. The Staff normally requires that a given natural event be part of design bases if the probability of that event is 10^{-4} per year or greater. Tr. 1669. Significantly, there are events for nuclear power plants involving core melt with annual probabilities on the order of 10^{-4} per year. Tr. 1821. In the case of GETR, the upper bound probability of 10^{-4} per year applies to the initiating event only, and not the multiplicity of unlikely additional events which must occur to cause core melt. Therefore, the conclusion following from the probability analyses is that 1-meter surface displacement as a design basis is conservative.

5. Consideration of Subgrade Rupture Mechanism

65. A final conservatism in the Staff's proposed design basis is the consideration of surface offset even though geotechnical engineering considerations indicate that a fault will deflect around the reactor.

21/ It should be noted that at the time of NRC Staff's May 23, 1980 Safety Evaluation Report was written, it was believed by the Staff and USGS that a fault probably existed under the foundation. See Stf. Ex. 1b at A-16. This fact was perceived as critically affecting the probability analysis, as a reason for not excluding surface displacement as a design basis. Stf. Ex. 1b at A-14. Subsequent investigation reduced the fault under the foundation to a mere possibility or very low likelihood event.

66. The Licensee presented testimony to the effect that, based on its analysis, the postulated Verona fault would not surface beneath the GETR, but rather would deflect around it. Lic. Ex. 1 at 84-94; Lic. Ex. 20. The Staff had reviewed the Licensee's analysis and presented testimony which agreed with that analysis. Stf. Ex. 1-D; Pichumani, ff. Tr. 996.

67. The Intervenors offered no direct testimony on the issue of fault deflection.

68. The Licensee testified that, if a fault began beneath the reactor, the irregular loading condition in the soil beneath the reactor will cause deformation and flow of the soil in such a way that the dislocation will bypass the reactor. Lic. Ex. 1 at 92.

69. If the reactor were sitting on hard rock that was subjected to a thrust fault, the reactor would be lifted partially off the ground. Id. at 85. Part of the foundation would be suspended without support, a cantilever condition, and a relatively severe load imposed on the foundation. Id. at 86. If, however, the reactor was on soft mud or loose sand, the fault would not lift the reactor. Tr. 238. The soil would deform or flow in such a way that the fault would bypass the reactor. Lic. Ex. 1 at 86-87.

70. The soil beneath the GETR is neither hard rock or soft mud but something in between. Tr. 239. The base of the GETR foundation mat, which is located about 20 feet below grade, is underlain by very dense clayey sand and gravel with occasional layers of very dense sandy and/or gravelly clay to a depth of 70 feet. Groundwater levels were shown to vary from 20 to 28 feet below plant grade. Stip. para. m.

71. GE's stability analysis visualizes that the thrust fault forms a passive Rankine wedge of soil that is pushed by a major principal stress. Pichumani, ff. Tr. 996 at 5. The inputs to the calculations are the weight of the soil, the strength properties of the soil, the location of the groundwater table and the weight of the reactor. The principal special condition that exists at GETR is the weight of the reactor, which is 4,000 lbs. per square foot. Tr. 2289.

72. The structural mechanics of a thrust fault can be simulated by applying a force to a block of soil. This vise-like squeezing will eventually cause a failure along a thrust fault. Lic. Ex. 1 at 91. Using a computer, the force for hundreds of possible failure planes was calculated. The force required to cause a failure plane that breaks ground directly beneath the reactor is always higher than the force required to cause a failure outside the reactor. Id. at 92.

73. GE concluded that the results of its computer analyses show that given the GETR foundation loads and dimensions, and the soil conditions known to exist to depths of 70 feet or more beneath the structure, faults beneath the GETR will be deflected in such a way that ground movement would occur outside of the perimeter of the reactor. Lic. Ex. 20 at 9.

74. The Staff testified that GE's method of wedge analysis is based on sound soil mechanics principles that have been accepted and applied by foundation engineers in the design of earth retaining structures. Pichumani, ff. Tr. 996 at 5. He testified that he was aware of one instance where a fault deflected around a massive structure, the Banco Central in Nicaragua. Tr. 1610. None of the members of the Staff's

geology/seismology panel had observed a fault deflecting around a structure. Tr. 1612-14. However, Dr. Pichumani stated that all that fault movement means is a failure plane forms and the problem becomes the same as any other slope stability problem, types of which have been observed and analyzed many times before. Tr. 1637. The weight of the GETR structure, 8,000 tons, is the main consideration. Tr. 1641. The Licensee and the Staff noted that the conclusions reached by this analysis are specific to the conditions at the GETR. In the case of a lighter structure with the same soil conditions, the fault may not be deflected. Tr. 1640-1641; Lic. Ex. 1 at 92, 93.

75. The Staff checked a few of GE's parametric calculations and found them to be correct. Pichumani, ff. Tr. 996 at 6. The Staff performed additional calculations for an assumed wedge depth of 100 feet using similar soil conditions and got similar results for the 21 foot surcharge load. Staff Ex. 1-D at 4. The Staff would be concerned about the stability of the GETR structure if 6 or 7 feet of overburden were removed. Tr. 1668.

76. An independent check of GE's conclusion was made by the Staff by performing a similar static stability analysis using a three-dimensional wedge. The results of this analysis confirmed GE's conclusion that the postulated thrust fault plane will be deflected away from the base of the reactor slab. Pichumani, ff. Tr. 996 at 6, 7. Accordingly, the Board agrees that the assumption of surface offset occurring beneath the GETR is conservative in light of the above geotechnical engineering considerations.

D. Appropriate Geologic Design Bases

77. A surface offset design value of 1 meter beneath the GETR is appropriate when placed in context of the total information presented in this proceeding. All witnesses who testified believed it to be the appropriate design value for surface offset beneath the GETR. Justus and Jackson, ff. Tr. 996 at 8-11; Slemmons, ff. Tr. 996 at 3; Newmark and Hall, Staff Ex. 1-B, App. A at 5; Bernreuter, ff. Tr. 1801 at 2; Vesely, ff. Tr. 1801 at 3; and Harding, Jahns, and Reed, Lic. Ex. 1 at 2, 58, 68, and 84.

78. The following geologic design parameters required by the Staff and pertinent to Issue 1 are appropriate: the outcrop width of the Verona fault zone at GETR be taken as at least 2200 feet; the Verona fault splays existing or which may develop be assumed to vary in dip from 10-45 degrees, to have reverse-oblique net slip character, and to slip coseismically and simultaneously with strong ground motion. See Stf. Ex. 1-B, Section A at 5, 6.

79. Furthermore, to the extent that a seismic event could trigger a landslide near the GETR, the hazard from such an event has been adequately considered by the Staff and Licensee and was not in dispute in this proceeding. The parties have stipulated that: 1) the procedure used to assess landslide stability is appropriate; 2) the investigations regarding landslides meet 10 C.F.R. Part 100 and the applicable NRC standard review plan section; 3) a 1 meter slope displacement is conservative, and 4) such slope displacements need only be considered to occur near the toe of the slope, at some distance from the GETR, and therefore need be considered in the design of safety related equipment

located in that area such as the fuel flooding system piping, but need not be considered in the design of the GETR reactor structure. Stip. paras. 1-4, contained in Staff counsel letter to the Board dated May 22, 1981. These conclusions are adequately supported by the record (Stf. Ex. 1-C, Part I). A 1 meter slope displacement near the toe of the slope is an appropriate and conservative geologic design basis for this proceeding.

E. Vibratory Ground Motion

1. Determination of Seismic Design Bases

80. The development of a seismic design value for a facility such as the GETR involves two basic steps. The first, involving the seismologist, requires the development of a controlling earthquake for the site in terms of its expected maximum magnitude and peak instrumental acceleration. The second step, involving earthquake engineer, involves the conversion of the peak instrumental acceleration values into effective accelerations, or ground motions which the structure is actually expected to experience.

2. Design Basis Earthquake

81. As indicated previously, the GETR site is located in a complex fault environment 2 to 3 km east of the Calaveras fault within the Verona fault zone and within 3 km of the Las Positas fault. The regional seismicity was studied by Ellsworth and Marks, whose report was received into evidence as App. C to Stf. Ex. 1-B.

82. The potential earthquake sources that are important in assessing the vibratory ground motion hazard at the GETR site are the

Calaveras fault and the Verona fault. Stf. Ex. 1-A at 30; Stip. para. 2k. Of the two, the Calaveras fault has the greater potential for generating strong vibratory ground motion at the GETR site. The parties have stipulated that a magnitude 7 to 7.5 event could be associated with this fault system. Stip. paras. 2k, r; Tr. 695. This value is supported by the testimony of Staff and Licensee seismologists. Devine, ff. Tr. 996 at 3; Tr. 681-82. It is well established that faults which are branches of and subsidiary to the San Andreas fault have the potential for generating earthquakes ranging up to a maximum of magnitude 7.5 Stip. para. 2.1. A larger earthquake (magnitude 8 to 8.5) could occur on the main San Andreas fault, but due to its distance from the GETR site, approximately 50 km, such an event would result in less vibratory ground motion at the site than would be caused by the potential events from the Calaveras or Verona fault. Stf. Ex. 1-A at 30.

83. The parties have also stipulated to the expected maximum magnitude event associated with the Verona fault, a value of M6 to 6.5. Stip. para. 2k. This value is also adequately supported by the record. Licensee witness Dr. Kovach presented a correlation of fault area (area along the fault plane at depth) with magnitude for worldwide data in order to estimate the expected magnitude for the Verona fault. Lic. Ex. 21 at 14-16. This correlation yielded magnitudes ranging from 5.8 up to 6.3, with a most likely value of 6.1. For the stipulated fault length of 12 km, Dr. Kovach's estimate would be a magnitude of 6.0 or slightly less. Lic. Ex. 21 at 16.

84. Dr. Slemmons presented independently derived correlations of fault length, surface offset, and magnitude for a range of conditions

which one might associate with the Verona fault. These analyses showed that for a 12 km length, one can expect a magnitude ranging between 6 to 6.5. Tr. 1187; Slemmons, ff. Tr. 996 at 3; Stf. Ex. 1-B, App. E. Mr. Devine, the Assistant Director of Engineering Geology for the USGS, also agreed with the use of 6 to 6.5 magnitude for the Verona fault. Devine, ff. Tr. 996 at 3.

85. As noted previously, there was speculation on the part of Drs. Brabb and Herd that the Verona fault could be connected with the Las Positas fault. However, if the Verona fault were connected with the Las Positas fault, the additional 15 km length added by the strike-slip Las Positas fault would still not produce an estimated magnitude which would exceed 6.5 by more than one tenth of an order of magnitude. Tr. 1584-86. This is because the fault length is not a very sensitive parameter when estimating magnitude based on the area of a fault. For example, a change of fault area of 50% or so would have only a minor impact on the estimate of magnitude for the fault. Tr. 1574. Dr. Kovach's correlations show that for an increase in length of a factor of 2, one might expect an increase in magnitude of 0.3. Lic. Ex. 21 at 16.

3. Peak Free Field Acceleration

86. The maximum vibratory ground motion that could be associated with events on the Calaveras and Verona faults were described for the Staff by Mr. Devine, as follows: Devine, ff. Tr. 996 at 3.

> Maximum vibratory ground motion at the GETR site would result from a magnitude 7 to 7.5 earthquake centered on the sector of the Calaveras fault nearest the site, with acceleration peaks at the free-field surface (i.e., without incorporating factors dependent on soil-structure interaction or behavior of the structure) which could

> be slightly in excess of 1 g. The horizontal vibratory ground motion at the GETR site resulting from an earthquake of magnitude 6 to 6.5 centered on the Verona fault could contain acceleration peaks as high as 1 g, but the overall level and duration of shaking would be less than that expected from the Calaveras fault. Devine, ff. Tr. 996 at 3.

87. GE presented testimony in which the peak instrumental values for relevant earthquake records were discussed and analyzed. Dr. Kovach developed a correlation of peak instrumental acceleration with distance data from the 1979 Imperial Valley and 1979 Coyote Lake earthquake records. He then tested this correlation against maximum peak instrumental acceleration data for seven earthquakes ranging in magnitude from 7 through 7.7. Based upon this corelation, he determined that for the GETR site, expected values of peak instrumental accelerations would range from 0.58 g to 0.74 g for a magnitude 7 to 7.5 event on the Calaveras fault. He concluded that expected accelerations would range up to about 0.4 g for a 6 to 6.5 event on the Verona fault. Lic. Ex. 17-22; Tr. 593-96.

88. In response to Intervenors' questioning, Licensee and Staff witnesses indicated that they had not used all peak acceleration values instrumentally recorded during the 1971 San Fernando event at the Pacoima Dam, or the 1979 Imperial Valley earthquake. See Tr. 675-79, 1020-21, 1671-74. However, the site conditions at the Pacoima Dam were unique. The accelerometer which recorded the high peak acceleration value at Pacoima Dam was located on a steep ridge which runs up to the abutment of the dam, which had the effect of concentrating energy and amplifying the recorded acceleration. Lic. Ex. 21 at 22; Tr. 2003-5. No such ridge

exists at the GETR site, nor is there any geological analog at the site. The GETR site is underlain by dense, stable Livermore gravel which would not exhibit any tendency to amplify vibratory ground motion in any manner resembling the Pacoima Dam conditions. Lic. Ex. 21 at 22; Tr. 1596, 2003-5.

89. Dr. William Hall presented a comparison of the Regulatory Guide 1.60 response spectrum to the earthquake record for the Pacoima Dam site. His comparison shows that the Regulatory Guide 1.60 spectrum, when anchored to 0.75 g effective, exceeds the Pacoima Dam record in all cases except for several short duration, high frequency peaks, which would not affect the structure of a nuclear power plant. Significantly, in spite of peak accelerations in excess of 1.2 g, there was no significant damage observed at the Pacoima Dam site. Tr. 1713-15.

90. The Intervenors argued that the 1.74 g vertical acceleration recorded at Station 6 during the Imperial Valley 1979 event was relevant. This data point was the product of peculiar site conditions which do not exist at the GETR site. The Imperial Valley Station 6 was located in a wedge of ground in close proximity to the intersection of two fault rupture locations. This tended to amplify the vertical throw and the corresponding vertical accelerations. Lic. Ex. 21 at 22-23; Tr. 1020, 1588-911, 2001-2. In addition, the soil/sediment conditions in the Imperial Valley bear directy on the observed accelerations. The Imperial Valley site is underlain by thick alluvium. This produced steep velocity gradients at the approach to the surface, which tended to amplify the vertical motion. Tr. 526-7; Lic. Ex. 42; Tr. 2001-3. Neither of these

conditions found at Imperial Valley is found at the GETR site. The GETR is not located on a wedgelike portion of ground situated in close proximity to the junction of two fault ruptures. Tr. 2003. Moreover, the GETR site is not characterized by the presence of deep alluvial sediments. The GETR site is underlain at depth by dense Livermore gravels, and the high velocity gradients which contributed to the high vertical accelerations at Imperial Valley Station 6 cannot be expected at GETR. Stip. paras. 2m, n; Tr. 1596, 1997-98.

91. Finally, the high vertical acceleration recorded at Station 6 occurred at frequencies in excess of 10 hertz and was the result of a single peak of acceleration, rather than sustained ground motion. Tr. 1020,2003. This latter point is important, since such high frequency, single-peak accelerations do not result in damage to a structure such as the GETR. Ibid; see also, Tr. 2007-8.

92. Similarly, a 1.3 g vertical acceleration observed at the Gazli, USSR earthquake was caused by unusual site conditions leading to high velocity gradients and the GETR site geology would not lead to comparable amplification. Tr. 690-95, 1997-98, 2005-6.

93. Intervenors questioned the Licensee witnesses about USGS Report 81-365 and its effect on correlating acceleration values with earthquake magnitude. Tr. 621, 634; see also, Int. Find. 3, 6. However, Mr. Devine of the USGS testified that this report was supportive of his conclusion that the appropriate peak accelerations at the GETR associated with magnitude 7.5 and 6.5 events on the Calaveras and Verona faults,

respectively, would be slightly in excess of 1 g and as high as 1 g, respectively. Devine, ff. Tr. 996 at 3.

94. The Intervenors also questioned, on the basis of the Imperial Valley earthquake record data points, whether it is conservative to specify vertical accelerations as 2/3 of the horizontal accelerations, pointing to a few data points where vertical accelerations exceeded this ratio. The Licensee and Staff witnesses agreed that the relevant data show that, after anomalous readings are eliminated, it is appropriate to treat vertical accelerations as 2/3 the amount for the horizontals. Tr. 524-26, 1647-49, 1718-19, 2007-8, 2030-32. Significantly, the few instances where verticals do exceed horizontals are generally characterized as involving frequencies of oscillations in the upper end of the scale, which are not of concern to structures. Ibid; see also Tr. 1725.

95. An additional significant factor is that buildings in general are inherently strong in the vertical direction, and the rigid massive structures involved in nuclear power plants are relatively insensitive to vertical loadings. Tr. 699-70, 2082-89. Vertical loadings account for an insignificant fraction of the total loads placed on a nuclear power plant structure under design basis seismic conditions. Tr. 2082-89, 1727. It seems clear that the Staff's use of vertical accelerations 2/3 of the size of the horizontal accelerations is well supported by the evidence.

96. Finally, the Intervenors questioned whether seismic focusing or directivity could result in amplification of accelerations at the GETR

site, apparently referring to a paper published by Dr. Bolt concerning the Livermore/Greenville earthquake sequence. Tr. 575-78 (Questioning by Barlow). At the Intervenors' urging, GE produced Dr. Bolt as a witness. See Tr. 1991-2076. Dr. Bolt testified that the phenomenon of seismic focusing is part of every earthquake, and therefore is part of the data base and cannot be separated from it but that its significance in terms of effects may be quite small. Ibid; Tr. 2001. Dr. Kovach and Mr. Devine agreed that the effects of focusing are included in the existing earthquake data base from which the criteria for vibratory ground motion for the GETR are derived. Tr. 697, 1021. Further, although focusing could have had a role in causing the results which occurred at Livermore, it is unlikely that the observations of the Livermore earthquakes of 1980 would apply to the GETR site. The Livermore site was characterized by deep layers of soft aluvium, while the GETR site is characterized at depth by dense Livermore gravels, which would not enhance the intensity of the ground motion as would conditions at Livermore. Tr. 1993-98.

97. In conclusion, on the basis of the record as a whole, and giving due consideration to the Intervenors' concerns raised during cross-examination, that it is reasonably conservative to factor into the seismic design basis for the GETR the following maximum effects from earthquakes: peak horizontal accelerations at the free-field surface slightly in excess of 1 g from the Calaveras fault, and up to 1 g peaks from the Verona, with vertical accelerations 2/3 of those values.

4. Effective Acceleration

98. Since the peak instrumental accelerations analyzed by the seismologist may not be directly applicable to structural analysis, the earthquake engineer must analyze the data provided to them in order to develop a set of structural design parameters. Tr. 1698, 2158-60. The two principal design parameters are: a) a "response spectrum," and b) an "effective acceleration," to which the response spectrum was anchored. The "response spectrum" is a plot of the responses of a number of simple damped oscillators, having various frequencies in terms of the acceleration of the mass, the relative velocity, and the relative displacement. Tr. 1708-9; see Stf. Ex. 8. The response spectrum prescribed for the GETR was Regulatory Guide 1.60, which was derived from a statistical compilation of historic earthquake ground motion records, and envelopes the mean plus one standard deviation of the data from those records. Tr. 1677, 1711-13.

99. Drs. Newmark and Hall selected the Regulatory Guide 1.60 response spectrum to characterize, as a function of frequency, the response velocities, displacements, and accelerations for use in the structural analysis. Stf. Ex. 1-B, App. A at 2, 3. In recognition that structural response and damage potential is related to repeated motions of strong energy content, and considering the Staff recommendation of peak instrumental accelerations, they recommended acceleration values of 0.75 g effective and .6 g effective as conservative anchor points for locating the response spectrum for events correlated with the Calaveras

and Verona faults, respectively. Stf. Ex. 1-C, App. A, report of September 29, 1980 at 6-8; Hall, ff. Tr. 1680 at 5.

100. Effective acceleration was defined by Dr. Hall, quoting from Dr. Nathan Newmark, as:

> that acceleration which is most closely related to structural response and to damage potential of an earthquake. It differs from and is less than the peak free-field acceleration. It is a function of the size of the loaded area, the frequency content of the excitation, which in turn depends on the closeness to the source of the earthquake, and to the weight, embedment, and stiffness of the structure and its foundation. Hall, ff. Tr. 1680 at 40.

101. Their analysis indicated that 0.6 g and 0.4 g would represent acceptable values for effective acceleration associated with events on the Calaveras and Verona faults, respectively. Stf. Ex. 1-B, App. A at 5; Stf. Ex. 1-C, App. A at 8. They added an additional margin of conservatism to each of these values when they chose the values of 0.75 g effective and 0.6 g effective for the Calaveras and Verona faults, respectively. In order to account for greater uncertainty in the geological and seismological base of information for the Verona fault, and because of the use of magnitude 6.5 value for an earthquake on this fault, they added a greater margin of conservatism to their choice of an acceleration value for the Verona. Ibid. The Staff specified that these horizontal accelerations represented by the Regulatory Guide 1.60 response spectrum should be multiplied by a factor of two-thirds to obtain the appropriate values for vertical accelerations for design purposes. Tr. 2258-59.

102. In selecting the anchor point, the amplitude of peak instrumental accelerations is not the sole parameter of interest to the

earthquake engineer. Single high frequency, high amplitude peak instrumental acceleration values identified by the seismologist are not useful indicators of damage potential and structural response resulting from vibratory ground motion. The earthquake engineer will consider the frequency and duration of these peaks in light of the characteristics of the structure. High frequency, short duration instrumental peaks such as those observed during the 1971 San Fernando earthquake, will not significantly affect the characteristically massive structures associated with nuclear reactors. Tr. 1714-15, 1725, 1740-41.

103. In this sense, then, in accordance with the definition given by Dr. Newmark, the effective acceleration normally is not that value connected with the high spikes of instrumentally recorded high frequency accelerations commonly found to occur close to the source of seismic energy release, such as in the case with GETR with respect to the Verona and Calaveras faults. Rather, the effective acceleration would be expected to be very close to the peak instrumental acceleration for locations at significant distances from the source, zones where such high frequency acceleration peaks normally are not encountered. Accordingly, for design purposes, the effective acceleration value is used to anchor the design response spectrum. Hall, ff. Tr. 1680 at 5; see also Tr. 2158-63.

104. Two points of perspective on the severity of the design basis response spectra warrant particular emphasis. First, the accelerations prescribed by the Regulatory Guide 1.60 response spectra are more than eight times higher than those prescribed by the Uniform Building Code for

emergency facilities. Tr. 1716-18. Second, it is unrealistic to require a more stringent basis for design than the 0.75 g effective/Regulatory Guide 1.60 design basis prescribed by the Staff for the Calaveras fault. Even in the vicinity of the largest fault on the west coast, the San Andreas fault, the use of a 0.8 g/Regulatory Guide 1.60 spectrum would be a reasonably conservative design basis. Stf. Ex. 1-C, App. A at 8.

105. Moreover, the Staff recommended that the maximum vibratory ground motion associated with a 6 - 6.5 event on the Verona fault should be combined co-seismically with the 1-meter surface displacement design basis. Stf. Ex. 1-B at C-6. The latter design basis is a suitably conservative criterion.

106. Intervenors did not present any affirmative evidence on the matter of earthquake engineering, nor did they draw into serious question any of the Staff-recommended seismic design bases.

ISSUE TWO: Whether the Design of GETR Structures, Systems and Components Important to Safety Requires Modification Considering the Seismic Design Bases Determined in Issue One Above, and If So Whether Any Modification(s) Can Be Made So That GETR Structures, Systems and Components Important to Safety Can Remain Functional In Light of the Design Bases Determined In Issue One Above.

A. Facility Description

107. The GETR is a high-flux, pressurized water reactor which operates at a maximum power of 50 MW thermal. Pressure is maintained in the pressurizer by nitrogen gas. The reactor core is contained in a 2-foot diameter cylindrical pressure vessel positioned on the bottom of a 9-foot diameter pool. The pool is flooded with demineralized water to a level 11 feet above the top of the reactor vessel or 23 feet above the core. Demineralized water is pumped through the reactor vessel and out

to heat exchangers for cooling. Coolant enters the pressure vessel near the top of the reactor vessel via two 12-inch diameter inlet pipes, flows downward through the core and out near the bottom via two 12-inch diameter outlet pipes. The reactor coolant operates at a maximum temperature of 180 degrees F and maximum pressure of 150 psig. The coolant is subcooled at atmospheric pressure. Stf. Ex. 1-C at A-1; Lic. Ex. 22 at 2-6.

108. The reactor does not produce electricity, and dissipates the heat produced through coolant towers. It operates at a stable steady-state power level without any load demand changes. Lic. Ex. 22 at 3.

109. The reactor, primary coolant system, irradiated fuel storage facility, experimental facilities and miscellaneous reactor auxiliary systems are housed in a reinforced concrete structure located in a steel containment building. The structure is of heavy, massive construction. The foundation mat is 4'8" thick. The vertical walls that make up the sides of the concrete core structures are 6'6" thick. Tr. 1912.

110. The reactor core contains square cross-section fuel elements, filler pieces, and six bottom-mounted, top-entry control rods arranged in a close-packed square array. Experiment capsules may be positioned in the filler pieces to utilize the high core neutron flux. The number and position of fuel and filler pieces is adjusted as necessary to achieve the appropriate reactivity balance and flux distribution. Surrounding he square array, appropriately shaped beryllium and aluminum peripheral pieces round the core into a 2-foot diameter, 3-foot high cylinder. Lic. Ex 22 at 8.

111. The six individually actuated combination control rod and fuel follower assemblies are each separated from the other by at least one lattice unit. Shutdown or scram action permits the simultaneous drop of all cor.rol rods by gravity with primary coolant assist. The fuel follower section drops out of the core and the poison section enters the core. Any combination of five control rods provides a minimum shutdown margin of at least 1% Δk/k under all reactor loading or operating conditions. For the normal core, which contains an equilibrium xenon concentration and partly burned fuel, either center rod or any combination of three or more rods is sufficient to ensure lasting subcriticality. Lic. Ex. 22 at 9.

112. A storage facility (canal) for irradiated fuel is located adjacent to the pool and is also within the massive concrete shielding structure. The canal is filled with high purity demineralized water. Canal gates, which normally separate the pool and canal, are removed during shutdown to facilitate refueling. The irradiated fuel is stored in leaktight fuel storage tanks located in the bottom of the canal. The canal water is circulated through a separate heat exchanger system to remove residual heat from the stored fuel. Lic. Ex. 22 at 9.

113. A domed, cylindrical steel containment building encloses the reactor, pool, adjacent fuel storage canal, shielding, heat exchangers, primary pump, and reactor servicing and experiment areas. The containment building extends approximately 90 feet above ground and 20 feet below ground surface; the diameter is 66 feet. Containment building penetrations permit secondary coolant water to be pumped from the primary, pool and canal system heat exchangers to the cooling tower.

Control and instrument penetrations permit reactor control and experiment instrumentation to be monitored in the adjacent reactor control room. Lic. Ex 22 at 13.

B. Operation of Reactor Cooling System Following Scram/Shutdown

114. A natural convection cooling system provides backup cooling for the reactor under certain emergency conditions and also during normal shutdown periods. In the event of high reactor inlet temperature, low reactor differential pressure, low primary cooling flow or seismic switch trip, the reactor scrams and an emergency cooling trip signal causes four valves to open the primary system to the reactor pool. A pneumatically reset, solenoid-tripped, spring-to-open, emergency cooling valve is provided on each leg of the two primary inlet cooling lines. In each of the primary coolant outlet lines in the reactor pool, check valves (installed vertically) open due to gravity when the primary system is depressurized. If the primary pump continues to run, approximately 33% of the primary flow is bypassed to and from the pool with the cooler water from the pool mixing with the primary system. If the primary pump stops, the flow through the reactor reverses in a short interval and natural convection cooling circulates from the pool through the open check valves up through the core and back to the pool via the emergency cooling valves. The residual heat from the relatively small mass of the core and structure can easily be removed following shutdown or scram so long as makeup water is available (normally supplied from the pool via the vertical check valves into the bottom of the core). No electrical energy is required to maintain a safe shutdown status for an extended

period. Lic. Ex. 22 at 11, 13, 14. The decay heat load for the GETR is about 2% of a modern power reactor. Within 40 hours after shutdown, it is at a level of about 0.1 megawatt thermal. Tr. 1906. As long as the fuel is kept covered with water, the cladding temperature of the fuel will remain low enough to prevent damage by means of heat transfer due to pool boiling. Stf. Ex. 17-C at A-2.

C. Postulated Accident Following Design Basis Event

115. The Board has determined that 1 meter of offset coupled with 0.6 g effective acceleration for an event on the Verona fault, as well as a 0.75 g effective acceleration for an event on the Calaveras fault with no simultaneous offset, are conservative geologic and seismic design bases.

116. The Licensee considered three steps necessary for providing protection during and following the design basis seismic event:

1. Reactor scram at the onset of the seismic event to terminate the fission heat source.
2. Initial removal of decay heat by boiling/evaporation of the water inventory existing in the reactor pool and fuel storage canal at the onset of the seismic event.
3. Long-term cooling/decay heat removal by providing sufficient makeup water flow to the reactor vessel and fuel storage containers.

Stf. Ex. 1-C at A-1; Lic. Ex. 22 at 16.

117. Based on a review of possible failures resulting from the seismic event for determining reactor cooling requirements, the Staff and the Licensee concluded that the rupture of the primary coolant piping

is the most limiting postulated accident to follow from the design basis seismic event. Stf. Ex. 1-C at A-3.

118. The assumptions made for evaluating this postulated accident include:

1. The worst postulated earthquake occurs with reactor trip initiated by the seismic scram system;
2. Simultaneous non-mechanistic rupture of the primary system
3. Heat transfer and decay heat rates based on 25 day power run of the reactor operating 50 MW.

Stf. Ex. 1-C at A-2; Lic. Ex. 22 at 16, 17.

119. Results of the analysis of the primary pipe rupture show that water will drain from the reactor vessel and pool through the primary return lines until the water reaches the level of the return line outlet from the reactor vessel (5.5 feet above the fuel). Lic. Ex. 22 at 16, 17; Stf. Ex. 1-C at A-1, A-2. The water level drops to the top of the core at 45 hours after the event assuming no makeup flow. At that time, the boil-off from decay-heat requires makeup water to the core at a rate of 0.8 gpm. Stf. Ex. 1-C at A-2.

120. The Staff and the Licensee concluded that the cooling water makeup requirements for stored fuel are set by the case which considered a freshly discharged core. The assumptions made for evaluating this fuel storage situation include:

1. The seismic event occurs six hours after shutdown from a 25-day run at 50 MW;
2. The temperature of the canal water is assumed to be 130°F;

3. Heat transfer calculations for the stored fuel are based on decay heating equivalent to an infinite irradiation of a single core at 50 MW with a 6-hour decay prior to the seismic event; and

4. The primary pipe rupture discussed above is assumed to occur due to the seismic event.

Stf. Ex. 1-C at A-2; Lic. Ex. 22 at 19.

121. The results of the analysis show that following approximately 34 hours after shutdown with no makeup, water must be added to the fuel storage canal at a rate of 1.64 gpm to account for boil-off due to decay heat. This makeup flow rate requirement decreases with time. Stf. Ex. 1-C at A-2; Lic. Ex. 22 at 19.

122. Therefore, the total makeup flow requirement for both the core and the canal is 2.44 gpm. Tr. 2249.

D. Structures, Systems and Components Important to Safety

123. The Licensee has identified the systems necessary to shut down GETR, maintain the reactor in a safe shutdown condition and to cool stored fuel assuming the accident and fuel storage locations discussed above. These systems include new systems, existing systems and existing systems with modifications. The parties have stipulated that all of the safety-related structures, systems and components necessary to shut down the facility and maintain the reactor in a safe shutdown condition during and following the design basis seismic events are identified in Table 1, Section A of Stf. Ex. 1-C. Stip. para. 2q.

124. An amplification and further description of the structures, systems and components identified in Table I follows.

125. To assure emergency cooling by natural circulation of pool water or from the proposed Fuel Flooding System, the primary system must be shut down and depressurized. A seismic trip system will scram the reactor, open the emergency cooling valves and isolate the pressurizer at a low seismic activity level of approximately 0.01 g peak ground acceleration. The depressurization would be accomplished within one second of seismic scram actuation, prior to any significant seismic load being reached. In the event of a loss of power the emergency cooling valves fail open and the pressurizer isolation valves fail shut. Stf. Ex. 1-C at A-4.

126. The reactor concrete structure, reactor pressure vessel and the canal fuel storage tanks serve as the containers for fuel cooling water. Integrity of these structures must be maintained to assure that coolant leakage will not exceed that assumed in the analyses (60 gph from reactor pool; 400 gph from storage canal) and, in the case of the reactor concrete structure, that support for other safety related equipment is retained. Water contained within these structures at the time of the seismic event serves as the initial heat sink for fuel decay heat. Stf. Ex. 1-C at A-4.

127. The canal is separated from the pool by a 3-piece removable gate to allow underwater pool and canal transfers. All irradiated fuel not in the core is stored in racks designed to maintain a subcritical configuration. The racks are inserted in stainless steel tanks. To replace the water removed by boiling, the proposed Fuel Flooding System

will supply adequate water flow to the fuel stored in the canal in the event of a seismic event, without operator action. Modifications to the fuel storage tanks include redundant supply line and nozzles for each tank. The nozzles are installed to act as siphon tubes to maintain all tanks at the same level. The reactor pressure vessel supports the core and other internals which must maintain their integrity. Stf. Ex. 1-C at A-4.

128. Control rods must function properly to shut down the reactor and maintain the reactor in a shutdown condition. All systems penetrating the reactor vessel or storage canal whose failure would provide an unanalyzed coolant leak path, must maintain their integrity. These systems include the pool and vessel drain lines, poison injection lines, capsule coolant system, canal emergency recirculation system, control rod drives and isolation valves associated with these systems. Restraints will be added and valves seismically qualified to assure the necessary integrity. Stf. Ex. 1-C at A-5.

129. A pneumatically closed, spring opened, solenoid-tripped, emergency cooling valve is provided on each of the two primary inlet cooling lines. A check valve is provided on each of two primary outlet cooling lines. On receipt of the seismic trip signal or a loss of power to these valves the emergency cooling valves open the primary system to the reactor pool. System depressurization is assured by closing the primary system pressurizer isolation valves and pressurizer supply valve. Depressurization does not cause flashing and blowdown of the primary

system because the coolant is subcooled at atmospheric pressure. Stf. Ex. 1-C at A-5.

130. If a rupture occurs in the primary piping water will drain from the pool and reactor vessel until the level drops to the level of the anti-siphon valves. Standpipes will be added to the top of the check valves to insure that the water level in the reactor vessel remains above the core regardless of the water level in the pool. The standpipes serve as the injection points for makeup from the fuel flooding system. Stf. Ex. 1-C at A-5.

131. The fuel flooding system is initiated automatically by the seismic trip described above to provide water to the core and to the fuel storage tanks without operator action. The system will consist of two identical redundant legs each capable of delivering the required flow rate. The required flow rate of 2.44 gpm is the maximum evaporation rate from the irradiated fuel subsequent to postulated canal and pool drainage. Sufficient water is provided for seven days of operation at this flow rate. The reservoirs will be situated on a hill adjacent to the containment building at an elevation to provide adequate gravity feed flow. Each supply leg will approach and penetrate the containment building from a different angle and will be routed to the fuel storage baskets and to one of the stand pipes to be installed on the emergency cooling system. The flow control valves are air operated and fail open on loss of air. The solenoid air control valve will vent air pressure from the flow control valve operator on loss of power, making the system fail safe. Stf. Ex. 1-C at A-5.

132. Testimony was offered and received into the record of this proceeding concerning whether the failure of other equipment during the design seismic event would jeopardize the safety-related equipment.

133. The Licensee proposed additional modifications to insure that failure of non-safety-related equipment during the seismic event will not affect the capability to safely shut down the reactor. A description of these modifications follows.

1. Modifications to Provide Additional Assurance of Reactor Vessel Integrity

134. The reactor pressure vessel is centered in the pool five feet below the top of the vessel with three restraints. The restraints attach to the side of the pool. Evaluation showed that one of the pins was of inadequate strength, and it was replaced. Lic. Ex. 22 at 24.

135. There are four different kinds of restraints that are or will be installed on the primary piping system to eliminate stress on the reactor vessel, thus assuring its integrity. The first kind strengthens the gusset below the 20-inch elbow connected to the primary pump discharge. A second restraint is a saddle and U-bolt arrangement that provides a vertical restraint for the 14-inch reactor vessel discharge pipe. The third type provides vertical restraint of the right pump discharge pipe and the left heat exchanger inlet pipe where the two run in parallel. It is planned to mount the restraint on the floor of the equipment room. The fourth category of pipe restraints are collars that

attach the pipes to the walls. They consist of a clamp around the pipe with an interconnecting strut to a wall bracket. Lic. Ex. 22 at 24, 25.

136. In addition to the large pipe restraints described above, restraints were added to the small diameter piping that is connected to the bottom of the pool and the vessel. Lic. Ex. 22 at 25.

137. Restraints were also added to the primary heat exchanger. Collars were placed around the heat exchanger near its top and center. Struts were installed between the collar and attachment points on the walls. In addition, a restraint is attached to the bolt circle on the bottom of the heat exchanger with struts connecting the restraint with attachment points on the walls. Lic. Ex. 22 at 25.

138. Restraints were placed around the pool heat exchanger so it would not fall into the primary system piping. Standpipes were installed above the emergency cooling check valves so that in the unlikely event of water from the pool, water would stay over the core. Lic. Ex. 22 at 25.

2. <u>Modifications to Provide Additional Assurance of Canal Storage Tank Integrity</u>

139. The canal storage tanks are located in the storage canal on the bottom at the end farthest from the pool. A new canal storage tank has been constructed that consists of three leak-tight inner tanks placed in a leak-tight outer tank. There are, thus, two leak-tight containers to assure water will remain over the stored fuel elements in the unlikely event that water is drained from the canal. The inner tanks are constructed of one-quarter-inch 304 stainless steel, and the outer tanks

are of one-half-inch 304 stainless steel. The thick-walled outer container also provides physical protection for the inner tanks. Lic. Ex. 22 at 26.

140. Modifications have also been made to prevent equipment on the third floor from dropping on the canal storage tank or reactor pressure vessel. This missile impact system consists of a series of structural frames that are strategically located on the third floor of the reactor building, and are designed to prevent the overhead crane assembly from impacting either the reactor vessel itself or the fuel storage tanks. The frames are covered with approximately 14 inches of aluminum honeycomb. The function of the honeycomb is to mitigate the postulated impact of the polar crane assembly, and in this way minimize the loads both on the frames and on the floor of the reactor building. Tr. 1919.

3. Accident Analysis of Structures, Systems and Components Important to Safety

a. Seismic Scram System

141. The scram circuitry is activated by two kinemetrics triaxial seismic triggers. The three component triggers (two horizontal and one vertical) will replace the existing two component (two horizontal) triggers. The sensitivity of these seismic triggers is such that they will initiate trip signals at ground accelerations of 0.01 g and are seismically qualified to ground accelerations up to 0.5 g. Stf. Ex. 1-C at B-1.

142. The GETR scram system operates when (among other events) the seismic switches close. The reactor control rods are disengaged from the

the drive mechanism 180 milliseconds after either of these two seismic switches make electrical contact. That is, all the electrical and electronic scram circuitry have operated and the control rod magnetic latch circuit has been interrupted and the control rod begun its drop by the end of 180 millisecond period. The control rod then drops by the forces of gravity and primary coolant flow so as to be fully inserted from a 36-inch withdrawn position within 500 milliseconds from the time the control rod is disengaged from the drive. Based on available rod drop data, it is conservatively estimated that within 300 milliseconds from the time the control rod is disengaged from the 36-inch withdrawal starting position, or 480 milliseconds from seismic switch trip, the control rods will be at, or below, the 12.2-inch withdrawn position whereupon the reactor is considered to be shut down. Stf. Ex. 1-C at B-8, B-9.

143. The emergency cooling power-operated valves, pressurizer valves and fuel flooding system admission valves begin to open and the pressurizer valves to close within 190 milliseconds after triggering of the scram system. The remainder of the valve operation is complete within a total of one second from scram seismic trip. Stf. Ex. 1-C at B-9.

144. In order to determine the adequacy of the seismic scram system, with regard to the trigger level (0.01 g) and time required to complete the scram action (1 second), the Licensee submitted a study of near field time histories to the Staff. The main objective of this study was to determine whether consequential horizontal or vertical

accelerations would be reached before completion of the scram action. Stf. Ex. 1-C at C-12.

145. The earthquake threat at the GETR site comes from two main sources, strike slip events (up to magnitude 7.5) on the Calaveras fault-2 km away and thrust events (up to magnitude 6.5) in the immediate vicinity of the plant. Thirty-six sets of records from well recorded events up to surface wave magnitude 6.9 for strike slip and surface wave magnitude 7.0 for thrust faulting were analyzed. Several sets of accelerograms were recoroed at distances less than 1 km from the fault. The data set can be considered a representative sample of all available data in the magnitude and distance range of interest. Envelopes of all horizontal and all vertical accelerations during the first second after recording 0.01 (the seismic trigger level) were computed and plotted. The highest peaks were associated with the Pacoima Dam record from the 1971 San Fernando earthquake. These were 0.13 g for the horizontal component recorded 0.66 seconds after reading 0.01 g and 0.24 g for the vertical component recorded 0.52 seconds after reaching 0.01 g. It is the Staff's position that in determining the adequacy of the seismic scram system that high frequency (10 Hz) peaks of this amplitude (approximately 0.25 g) could occur anytime during the first second after 0.01 g on either, or all, components of motion. Stf. Ex. 1-C at C-12.

146. The Staff testified that, based on the reliability assessment of the scram system, tests performed on the control rods and internal components, and evaluations performed, reasonable assurance is provided

that the circuits required to perform automatic actions will function satisfactorily, considering the minor loadings postulated during the first second of the design seismic events. Stf. Ex. 1-C at B-4 to B-9, C-12.

4. Structural Analysis

147. The Staff and Licensee testified that, given the seismic design parameters, only the following structural and mechanical requirements must be satisfied:

1. The structural integrity of the massive concrete structure which suppports other systems and components important to safety must be maintained.
2. The structural integrity of the reactor vessel and canal fuel storage tanks must be assured.
3. A source of water, including the associated piping system, must be available after the seismic event to provide water to the spent fuel canal storage tanks and the reactor pressure vessel to replenish that lost through boil off and evaporation in the process of cooling the fuel.

Stf. Ex. 1-C at C-2; Martore, ff. Tr. 2200 at 4; Lic. Ex. 22 at 23-24.

148. Upon questioning by the Board, Staff witness Nelson testified that containment integrity was not required for the design bases seismic event. Containment integrity is required to mitigate the consequences of GETR design bases accidents which involve a core melt. However, the worst accident caused by the seismic event was determined to be a loss-of-coolant accident by the quickest means, the rupture of the

primary piping. This loss-of-coolant accident does not involve a core melt. The Staff did not take into account the possibility that there might be first a design-basis accident in which there was a need to rely upon the containment, and subsequently a seismic event which might breach the containment. The Staff testified that there is no need to require that it be postulated that those two very low likelihood events be considered simultaneously for design purposes. Tr. 2212, 2214, 2215, 2230.

149. The Board notes that 10 C.F.R. Part 50, Appendix A, Criterion 2 required the design bases for nuclear power plants to reflect combinations of accident conditions with the effects of natural phenomena, such as earthquakes. The Staff responded that this regulation's applicability is limited to power plants and the GETR is not a power plant. Therefore, this requirement is not applicable to the GETR. See, "NRC Staff's Brief in Support of Certain Conclusions of Law" dated July 31, 1981.

150. The Staff testified that Appendix A should not be used as a guideline in that the GETR differs from nuclear power plants in power level, fission product inventory, seismic scram system, lack of need for complex systems to mitigate accidents and the fact that at operating temperature the GETR is subcooled at atmospheric pressure. Tr. 2229.

151. In addition, the Staff has evaluated the offsite radiological impact associated with the design seismic events. The seismic event is assumed to result in breach of the containment above and below grade. Although the Staff's analysis shows the structural integrity of the pool

and canal would be maintained, a release of the radioactive containments of the pool water was assumed in order to provide a bound of the radiological consequences of this event. No fuel failure, and hence no fission product release from the fuel was postulated. It was postulated that all five test capsules would fail, thereby releasing the fission products which could have accumulated with the capsules. Stf. Ex. 1-C at D-1.

152. The offsite radiological consequences resulting from this postulated release are only fractions of the 10 C.F.R. Part 100 guidelines. The 0-2 hour thyroid dose at the exclusion area boundary is 20 rem, less than 10% of the 10 C.F.R. Part 100 guidelines values. The maximum 50-year organ dose from ingestion of water at the well nearest the site boundary is less than 10 m rem to the GE tract - lower large intestine, from non-absorbed ^{106}Ru. Stf. Ex. 1-C at D-2.

153. The Staff concluded that no offsite radiological impact detrimental to the public health and safety will result from the postulated seismic event, assuming loss of containment. Stf. Ex. 1-C at D-2.

154. The GETR facility, with proposed modifications, has been reanalyzed by GE, and reviewed by the NRC Staff and its consultants, to

determine whether assurance is provided that the GETR can safely withstand the effects of the seismic design events. Detailed reviews have been carried out on safety related structures, systems and components required to withstand the loadings representing the hazard defined by the seismic design criteria, including possible effects of shaking and faulting. Martore, ff. Tr. 2200 at 4.

155. The Licensee performed analyses to determine the ability of the concrete core structure to withstand the effects of a vibratory motion of 0.8g at the GETR site. Concrete cracking capacities have been determined using maximum allowable compressive stress values of 5400 psi, 3400 psi and 5000 psi for ordinary concrete, magnetic concrete and ferrophosphorus concrete, respectively, which are appropriate species of concrete in the reactor building walls. Lic. Ex. 25 at 1-2. Linear elastic, time-history dynamic analyses were performed using a lumped-mass cantilever model with foundation springs. Torsional effects were considered by including the eccentricity between the center-of-mass and shear center at each floor level of GETR. Shear forces and overturning moments were computed for all members and response spectra were generated for each elevation. Parametric studies were performed to investigate the influence on the response of the structure to variation in soil shear modulus and average area of contact between the base slab and the underlying soil. The effects of torsion and foundation embedment on the structural response were also investigated. Additional parametric studies were performed to investigate the influence of the variation in model damping effects on the structural response.

156. The potential nonlinear effects were investigated by performing nonlinear analyses using appropriate analytical models. The objectives of the nonlinear analyses were to confirm the conservatism of the results of the linear elastic analyses.

157. Stress analyses were performed using a detailed finite element model consisting of three-dimensional elements. The analyses were based on a 0.8g effective peak horizontal ground acceleration and 2/3 of this value for acceleration in the vertical direction. The ground response spectra was anchored to Regulatory Guide 1.60. The result of the analyses showed that the induced stresses in the portion of the concrete core structure which surrounds the pool and storage canal, and which also supports and protects the safety-related equipment and components necessary for safe shutdown, were much smaller than the cracking stresses. These stresses were determined from the forces obtained from the linear elastic dynamic analyses. The forces obtained from the nonlinear analyses were smaller than those obtained from the linear analyses. Furthermore, these analyses showed that, although some cracking of slabs may occur exterior to the safety-related portion of the structure, the ductility demand for these slabs will be low resulting in minor cracking. Lic. Ex. 25 at 2-1.

158. An analysis of the reactor building for effects of a hypothetical surface rupture offset was performed using a finite element model of that portion of the reactor building which supports and protects the safety-related equipment and components necessary for safe shutdown. A one (1) meter surface rupture was assumed as the basis for the

analysis. The surface rupture plane was considered to be at an angle of 15 degrees with the horizontal, however, the angle of rupture does not affect the results of the analysis.

159. Three principal cases were analyzed:

Case 1. The surface rupture was considered to intersect the reactor building on the near side.

160. For this case, the near side basement walls would be heavily loaded and would crack. The horizontal thrusts associated with the wall pressures would be resisted by shear forces due to friction under the basement mat. The soil pressures on the far side of the basement walls would not be significant and cracking of these walls would not occur.

Case 2. The surface rupture occurs on the far side of the reactor building.

161. In this instance, the horizontal soil pressures would be large and might cause the basement wall to deform on the far side. The horizontal force caused by the soil pressures on the exterior basement wall would be resisted by the shear forces mobilized by friction between supporting soil and the bottom of the foundation mat.

Case 3. The offset was assumed to occur near the center-of-gravity of the reactor building.

162. This case may create a cantilever effect since the far portion of the reactor building might be unsupported between the edge and the area where the soil makes contact with the foundation slab. The maximum stresses in the concrete core structure are produced for the cantilevered configuration. The length of the cantilever is dependent upon the soil

bearing capacity beneath the reactor building. If the hypothetical surface rupture offset intersected the foundation mat between the far side of the reactor building and its center of gravity, the result may be an uplift of the building. To verify that the concrete surrounding the pool and canal could resist a cantilever situation, an analysis of the core and radial wall concrete was conducted to verify that the weight of the cantilevered portion of the building could be resisted. All computed stresses for the cantilever case are well below cracking threshold capacity valves.

163. If the offset intersects the foundation mat closer to the near side, the reactor building would tilt and be supported in a simple beam configuration. It has been shown that if the foundation mat were to span as a simple beam, the foundation mat and reactor building floor slabs would yield until the concrete core structure settles down to the supporting soil. Soil pressures on both sides of the basement wall would be large and cracking would probably occur.

164. The Licensee performed a detailed analysis of concrete cracking patterns which are expected to occur in the event of the postulated surface rupture offset. It was found that the reinforcement in the base slab would yield first at a loading equal to, or less than, one-tenth of the weight of the reactor building. A soil bearing capacity of 20 ksf was assumed in the analysis. Even if the ultimate capacity of the soil were increased, a higher value of soil bearing capacity would not change the results since the base slab has already yielded. The concrete cracking patterns were shown to occur in such a manner as not to affect

the interior portion of the structure surrounding the pool and canal. Excessive deformation of the basement walls would not adversely affect the concrete core structure since these exterior walls are not essential to the integrity of the structural system which supports the pool and storage canal. Lic. Ex. 25 at 3-1.

165. The Licensee performed an analysis of loadings on the reactor building which result from the combined effects of vibratory ground motion together with a surface rupture of one (1) meter occurring beneath the building. The analysis assumed that a vibratory ground motion of 0.8g occurred subsequent to the surface rupture. Furthermore, it was assumed that the damage caused by the offset had occurred prior to the ground shaking and that only the undamaged structure would resist the vibratory ground motion. The effective peak ground acceleration value of 0.8g was anchored to Regulatory Guide 1.60 spectra. It was found that the safety-related portion of the structure would be stable and that the forces and corresponding stresses induced by the post offset motions would be below the threshold of concrete cracking. Lic. Ex. 25 at 4-1.

166. Additional studies were performed by the Licensee to determine the effects on the core structure when surface offset and vibratory motion were considered to occur coseismically. If the offset intersects the foundation slab near the center-of-gravity of the reactor building, the building may exist in a cantilever configuration. A soil pressure analysis was performed to determine the physical limits on the combined load case comprised of a ground acceleration and a surface rupture offset, the latter being represented analytically as the cantilever

length. Results were obtained for several cases of cantilever length and horizontal earthquake accelerations at which incipient, as well as complete, yielding of the soil occurs. Lic. Ex. 38.

167. The Staff questioned the soil bearing capacity analysis performed by the Licensee. It determined that the analysis had been based upon a lower soil bearing capacity (20 ksf) than was justified and that higher bearing capacities may result in greater unsupported cantilever lengths than had been analyzed by the Licensee. Stf. Ex. 1-D at 2-3 and C-8.

168. The Licensee performed an additional analysis of the subgrade rupture mechanism resulting from the postulated Verona fault event. This analysis consisted of a comparison of the static stability of two-dimensional soil wedges formed by thrust fault planes meeting the reactor foundation at different locations (Rankine Fault Model). It was found that rupture planes would be deflected away from the base of the reactor slab because of the weight of the GETR and the surcharge. Lic. Ex. 20.

169. To support the fault deflection analysis, an event was described when such an effect is believed to have occurred, namely in 1976 beneath the Banco Central in Nicaragua. Lic. Ex. 1 at 93-94. This event was considered appropriate for analogy because of the similar massive compact structural characteristics of the Banco Central and the GETR.

170. The Staff reviewed the Licensee's fault deflection analysis and concurred with the finding that the previously hypothesized cantilever

condition should not occur. The Staff concluded that use of results of the soil pressure analysis are acceptable for use in comparison with the inputs to the structural evaluations since they postulate a greater loading on the foundation mat than that predicted by the fault plane analysis. (Stf. Ex. 1-C, Appendix B at 6).

171. Notwithstanding the possibility that the extreme weight of the GETR structure will cause fault deflection which would prevent the postulated cantilever, the Licensee's geotechnical expert testified that analyses had been performed using higher values (up to 30 ksf) of soil bearing capacities even though these values are believed to exceed those characteristic of the soils beneath GETR. (Tr. 2295)

172. The Licensee and the Staff testified that the detailed analyses performed for the vibratory ground motions and surface rupture offset demonstrate that the concrete core structure which surrounds the pool and storage canal will maintain its integrity in the event that major earthquake motions and/or surface rupture occur at the GETR site. Lic. Ex. 22 at 127; Stf. Ex. 1-C at C-13. Thus, independent of the fault deflection analysis, this is additional assurance that GETR will withstand the full range of cantilever loading cases which might be postulated.

173. The integrity of the reactor vessel and the canal fuel stroage tanks was evaluated by assuring the integrity of the supporting concrete core structure as discussed above, and by assuring the capability of all essential components and equipment meet the seismic criteria.

Evaluations of the reactor vessel lower head penetrations indicate that maximum stresses do not increase significantly during the design events and remain less than 10% of allowable. Therefore, failure due to seismic effects is not expected. In addition, it was assured that the failure of any non-safety related components or equipment would not comprise the integrity of essential items. Stf. Ex. 1-C at C-9.

174. GE has evaluated the reactor vessel and internals, including the fuel and experiment capsules, for the loads resulting from the design seismic criteria. The fuel assemblies used in the core are flat-plate, uranium-aluminum alloy assemblies, consisting of 19 fuel plates each 0.050-inch thick (nominal), 2.80-inch wide and 37.25-inch long. The fuel plates are roll-swaged into 6061-T6 aluminum slide pieces, which act as protective skin containing the fuel. The allowable stress for this aluminum skin has been appropriately determined to be 200 PSI. This allowable stress does not take credit for the increased yield strength of the aluminum due to irradiation. The results of the seismic analyses indicate displacements at the core region to be minimal, and stresses on the aluminum fuel covering, about 70 PSI, to be significantly below allowable. Stf. Ex. 1-C at C-9.

175. Supports for the piping system and the other safety related components have been analyzed in accordance with the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Subsection NF. The piping systems have been evaluated against the loading combinations and acceptance criteria based upon the ASME Boiler and Pressure Vessel Code, Section III, Subsection NC for Class 2 piping. Stf. Ex. 1-C at C-4.

176. The allowable stress limits for structures, piping systems and components are determined on the basis of material properties at temperatures corresponding to the specific load combinations. Stf. Ex. 1-C at C-5. When appropriate, the procedures in the following concrete and structural codes have been utilized to evaluated the structures and components:

1. ACI 318-1971, "Building Code Requirements for Reinforced Concrete," American Concrete Institute, 1971.
2. AISC, "Specifications for Design Fabrication, and Erection of Structural Steel for Buildings," American Institute of Steel Construction, 1969.

Stf. Ex. 1-C at C-5.

177. In addition, to assure the integrity of the reactor pressure vessel and canal fuel storage tanks, to keep all fuel covered with water, a source of make-up water to replenish that lost through boil off and evaporation is required. To achieve this goal, GE has proposed to install a Fuel Flooding System with redundant gravity flow (no power required) supply capability. Stf. Ex. 1-C at C-10.

178. The system consists of two redundant legs each capable of delivering the design flow rate. Each reservoir site consists of two 50,000 gallon polyurethene flexible "pillow" or "bladder" tanks situated on a hill adjacent to the containment building at an elevation which provides adequate gravity feed flow. Each supply leg is constructed from 1-1/2" I.D., reinforced synthetic rubber. The line is "snaked" in a shallow trench providing line slack and permitting the line to

accommodate postulated surface faulting. The Licensee performed a test to demonstrate that the postulated surface offset would not cause the line to fail. Lic. Ex. 22 at 117. Through the yard area, the line is buried in the event of postulated surface faulting due to either a seismic event or seismic initiated landslide. Each supply leg approaches and penetrates the containment building from a different angle, and is routed to the irradiated fuel storage tanks in the canal and to the reactor pressure vessel. Each supply line inside the containment building is allowed to move within a protective cover. This arrangement protects the line and prevents unacceptably high seismic stresses. The lines inside the containment building are a combination of: (a) high pressure, high vacuum rated reinforced rubber, (b) stainless steel flexible hose, and (c) rigid stainless steel pipe. Reactor pressure vessel water addition (from the Fuel Flooding System) is to the reactor vessel standpipes previously discussed, and therefore, to the bottom of the pressure vessel. Stf. Ex. 1-C at C-10, C-11.

179. An in-service surveillance and inspection program has been developed for the Fuel Flooding System from the source tanks to the points of connection at the reactor pressure vessel and the spent fuel storage system, including the interface with the containment structure. The design and analysis of the Fuel Flooding System together with the implementation of the in-service surveillance and inspection program, provide reasonable assurance that required makeup coolant fluid to the reactor and the fuel storage system is available following the design basis seismic events. Stf. Ex. 1-C at C-11.

180. The Licensee testified that the structural and mechanical analyses described in the testimony demonstrated that the GETR safety-related structures and equipment as modified meet the following requirements:

1. The integrity of the reactor building concrete core structure which supports other systems and components important to safety is assured;
2. The integrity of the reactor pressure vessel is assured;
3. The integrity of the canal fuel storage tanks is assured; and
4. The capability of providing makeup water to the spent fuel storage tanks and reactor pressure vessel is assured.

Lic. Ex. 22 at 131.

181. The Staff agreed with the Licensee and will impose technical specifications requiring completion of the modifications on the GETR before it resumes operation. Compliance with the technical specifications and periodic test and maintenance procedures will be verified by the NRC Office of Inspection and Enforcement. Tr. 2243.

V. CONCLUSIONS OF LAW

The Licensing Board has thoroughly reviewed and evaluated the evidence submitted by all parties with respect to the issues set forth in the Commission's February 13, 1978 Memorandum and Order. The Licensing Board has also considered all the proposed findings of fact and conclusions of law submitted by the parties. Those proposed findings not adopted by the Board are herewith rejected. Based upon its evaluation of the Staff's and Licensee's safety evaluations, the admitted written testimony of all of the witnesses, as well as the answers elicited from these witnesses in response to questions of the Board and the parties, the Board makes the following conclusions of law:

1. The proper geologic and seismic design bases for the GETR should be as follows:
   a) A surface offset design value of one meter of reverse-oblique net slip beneath the GETR should be utilized, along a fault plane of 2200 foot-wide Verona fault zone, which could vary in dip from about 10 to 45 degrees, occurring during a single event.
   b) The Regulatory Guide 1.60 Response Spectra, anchored to .75 g effective acceleration for an event on the Calaveras fault, and .6 g effective acceleration on the Verona fault.

c) Combined loads caused by fault offset at the surface and vibratory ground motion from the Verona fault must be considered to act simultaneously, and that the entire one meter of surface offset is considered to occur coseismically.

d) A seismic event could trigger a landslide, causing a 1.0 meter slope displacement occurring near the toe of the slope, at some distance from the GETR; accordingly, the one meter offset caused by the landslide must be considered in the design of safety-related equipment located in the area of the toe, such as the fuel flooding system piping, but need not be considered in the design of the GETR reactor structure.

2. The General Design Criteria of Appendix A to 10 C.F.R. Part 50 apply only to power reactors and do not apply to the GETR.

3. Appendix A to 10 C.F.R. Part 100 apply to power reactors and not to facilities such as the GETR which does not produce electric or heat energy.

4. The design of GETR structures, systems and components important to safety do require modifications, and these modifications can be made so that the GETR structures, systems and components important to safety can remain

functional in light of the seismic design bases determined in Issue One above.

5. The proffered testimony of James Glenn Barlow was properly excluded from the record in this proceeding.

ORDER

WHEREFORE, IT IS ORDERED, in accordance with 10 C.F.R. Sections 2.760(a) and 2.762, that this Initial Decision shall constitute the final action of the Commission thirty (30) days after the date of issuance hereof, unless exceptions are taken in accordance with Section 2.762 or the Commission directs that the record be certified to it for final decision. Any exceptions to this Initial Decision or designated portions thereof must be filed within ten (10) days after service of the decision. A brief in support of the exceptions must be filed within thirty (30) days thereafter (forty (40) days in the case of the NRC Staff). Within thirty (30) days of the filing and service of the brief of the appellant (forty (40) days in the case of the NRC Staff), any other party may file a brief in support of, or in opposition to, the exceptions.

IT IS SO ORDERED

FOR THE ATOMIC SAFETY AND
LICENSING BOARD

Dr. George A. Ferguson
ADMINISTRATVE JUDGE

Dr. Harry Foreman
ADMINISTRATIVE JUDGE

Dated at Bethesda, Maryland
this 16thday of August 1982

VII. SEPARATE OPINION

Herbert Grossman, Chairman,
Dissenting in Part and Concurring in Part

The Commission has requested the Board to determine the proper seismic and geologic design bases for the GETR facility and whether any modifications can be made so that the GETR structures, systems and components important to safety can remain functional in light of these bases. Commission Memorandum and Order, February 13, 1978. My fellow Board members have adopted the design bases recommended by NRC Staff and have determined that the modifications recommended by GE and Staff will maintain the functional integrity of the GETR's safety systems.

The principal geologic design basis adopted for the GETR consists of a surface offset design value of 1 meter of reverse-oblique net slip beneath the GETR resulting from an earthquake occurring on the Verona fault. The principal seismic design bases consist of the Regulatory Guide 1.60 response spectra anchored to a .75 g effective acceleration for an event on the Calaveras fault, and a .6 g effective acceleration on the Verona fault. The combined loads caused by the fault offset and the vibratory ground motion from the Verona fault are to be considered as acting simultaneously on the GETR.

I dissent from my colleagues only on the surface displacement design parameter of 1 meter, which I consider not sufficiently conservative.[22/] I would adopt, instead, a 2-meter offset. This is slightly less than the Staff's original choice of a 2-1/2 meter offset as a conservative design parameter, which led to its original conclusion that the GETR should not be restarted. Staff has changed its recommended geologic design parameters to a one-meter surface displacement, and has concluded on that basis that the GETR, modified as proposed by GE, can safely withstand the postulated design basis events.

Notwithstanding the Staff's original recommendation of non-resumption of operations because of the 2-1/2-meter design parameter and Staff's current unwillingness to endorse a resumption of operations within a design parameter greater than 1

22/ Because of the Commission's charge to us to determine the geologic design bases, the portion of my opinion that disagrees with the Board majority's 1-meter design parameter must be considered a dissent, even though I agree (conditionally) that the GETR, as modified, can be restarted.

meter.[23/] I would permit a resumption of operations under my recommended 2-meter design parameter. I would do so on the basis of GE's fault deflection analysis (which the Staff and I accept, albeit with some reservations on my part) that makes the size of the prospective surface displacement irrelevant with regard to the loading cases analyzed by GE. The fault deflection analysis concludes that an offset occurring beneath the GETR would be deflected to the perimeter of the reactor building. Except for certain flexible piping, used for the fuel flooding system and located outside of the reactor building, there does not appear to be any structure or equipment related to the seismic safety of the GETR that would be adversely affected by an offset that deflects around the reactor building. I expect that the flexible water piping could easily be modified to accommodate a displacement of 2 meters,

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23/ If Staff has some reservations with regard to the ability of the GETR's safety systems to withstand a surface displacement greater than 1 meter, it has failed to sustain its burden of proving that such an offset would cause unacceptable damage. Under Section 556(d) of the Administrative Procedure Act (APA), 5 U.S.C. § 556(d), which applies to this proceeding by virtue of APA Section 554(a), Section 181 of the Atomic Energy Act, as amended, 42 U.S.C. § 2231, and 10 CFR § 2.732, the proponent of a show cause order has the burden of proof. In Consumers Power Co. (Midland Plant, Units 1 and 2), ALAB-315, 3 NRC 101 (1976), the Appeal Board recognized that general rule of placing the burden of proof on the proponent of a show cause order, but applied an exception to the general rule by determining that the Atomic Energy Act and the Commission rules placed the burden on the applicant prior to the issuance of an operating license. Because we are considering a show cause order in this proceeding that involves an operating license granted on January 7, 1959 under which GETR had operated for almost 20 years, the exception recognized in Midland would not apply and the burden would remain with those attempting to establish that the GETR must remain shut down.

rather than the 1-meter displacement for which it has been analyzed, and would require that modification as a condition for restarting the GETR.

I. GEOLOGIC AND SEISMIC DESIGN BASIS

A. Geologic Design Basis

I would reject Staff's recommended design parameter of a 1-meter surface displacement from an event on the Verona fault, and would adopt a 2-meter displacement in its stead.

To place my major disagreement in sharper focus, it is important to recognize that, from the issuance of the show cause order in October of 1977, through September of 1979, Staff had adopted a surface displacement design parameter of 2-1/2 meters, which led it to conclude that the GETR should not resume operations. It had rejected as a basis for its analysis GE's probabilistic study from which GE concluded that an offset underneath GETR could be disregarded as being improbable. Upon the urging of a member of the Advisory Committee on Reactor Safeguards, to which Staff had referred its recommendation, Staff reversed its position of not accepting probabilistic studies as a significant element in formulating its conclusions. Staff reevaluated its conclusions based on the GE probabilistic study and an independent probabilistic study by TERA Corp., which Staff had commissioned, and determined that a 1-meter offset was a conservative design parameter. On that basis, Staff reversed its prior recommendation prohibiting the resumption of operations, and concluded that GETR could be restarted if GE performed its recommended structural modifications.

For reasons explained below, I give little weight to the GE and TERA probabilistic studies, which were the most significant factors in the Staff's change of design parameter from 2-1/2 meters to 1 meter, and conclude that a 1-meter offset is not sufficiently conservative.

1. <u>NRC Staff's Change in Position</u>

In September of 1979, the NRC Geosciences Branch issued a Safety Evaluation Report that supported its October 1977 decision to shut down the GETR. Stf. Ex. 1-A; Int. Ex. 8.[24/] Based upon the underlying report, Staff concluded that a surface offset of 2-1/2 meters could occur beneath the GETR and that no analytical argument could be formulated which could conclusively support the ability of a structure such as GETR to withstand such a surface offset. Stf. Ex. 1-A, cover letter.

Staff's judgment was based, in part, on its understanding and evaluation of surface faulting that occurred during the 1971 San Fernando, California, earthquake. Staff believed that the comparison was reasonable because of general similiarities between the San Fernando fault and the Verona fault. Staff also relied

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24/ At the hearing, Staff offered as its Exhibit 1-A, an expurgated version of the September 1979 Geosciences Branch Safety Evaluation Report. See discussion at Tr. 986-88. Significant portions of the SER consisting of observations and conclusions that tended to support Staff's original recommendation of a 2-1/2 meter surface displacement were deleted. The Board later received Int. Ex. 8, which was a complete copy of the original SER, <u>sans</u> the September 27, 1979, cover letter to GE under which the SER was issued. For convenience, I will cite only to Int. Ex. 8, the complete SER, unless I specifically refer to the cover letter that is included only in Stf. Ex. 1-A.

upon observations and calculations of its expert consultant Dr. David B. Slemmons that a 2-1/2 meter net slip value is reasonable for a fault with a length between 8.2 and 12 kilometers, and on observations during site visits that there had been recurrent movements on the order of 1 meter on the three known shears in the Verona fault zone which could have occurred simultaneously during a single earthquake event. Since these shears were splays of the same fault at depth, even though the movements had occurred separately on the three shears, Staff considered that the total displacements for those shears might occur in a future event on any single splay or between them. Ibid.

Subsequently, although not required by statute or regulation, NRC Staff referred its recommendation to the Commission's Advisory Committee on Reactor Safeguards for its review. At an ACRS subcommittee meeting held on November 14, 1979, GE presented its probabilistic analysis which Staff had previously rejected. Staff presented its comparison of the San Fernando data with the postulated 2-1/2 meter offset from the Verona fault. Staff left that subcommittee meeting with the feeling that it was being a little too extreme in its use of the San Fernando data and that it should consider GE's probabilistic study in its further review of the geologic parameters. Tr. 1883-86. The Staff had received such a strong endorsement from the ACRS of the need for a probabilistic approach that it considered the meeting as "almost a mandate" that the Staff utilize a probabilistic analysis in establishing the design basis offset. Tr. 1887.

On May 23, 1980, Staff issued a Safety Evaluation Report (Stf. Ex. 1-B), which modified the conclusions regarding the proper geologic and seismic design bases expressed in its September 27, 1979 Report. The main change in design basis, which led to the Staff's recommendation that the GETR could be restarted, was the determination to include in the design basis a surface displacement of only one meter of reverse-oblique net slip on a postulated Verona fault zone strand beneath the GETR, as opposed to the prior determination to include a 2-1/2 meter displacement.

Of some significance is the position of the US Geological Survey. On December 9, 1977, NRC Staff had requested the USGS to assist in the review of the potential for surface faulting within the immediate vicinity of the GETR. Geological Survey personnel subsequently participated with Staff in the examination of the geology of the GETR site and the review of the geologic documents submitted to the NRC by GE. On September 5, 1979, the USGS submitted its review of the geologic data. After GE's presentation to the ACRS subcommittee on November 14, 1979, the USGS reviewed the material and submitted a further report to the NRC (under cover of letters dated April 22, 1980 and May 8, 1980). In both reports, the USGS insisted that the surface displacement of one meter proposed by GE did not appear to be conservative. Int. Ex. 8, App. A at Conclusion 8; Stf. Ex. 1-B, App. B at

May 8, 1980 cover letter. The Geological Survey continued to maintain that position throughout the hearing. Tr. 1243, 1378-81, 1384-85. The USGS explained its characterization of the postulated 1-meter offset's not being conservative as meaning that the Geologic Survey considered the likelihood of one meter being exceeded as "reasonably high." Tr. 1410.

2. The Probabilistic Analyses

Despite the steadfast refusal of its principal geologic and seismic advisor, the USGS, to characterize the postulated 1-meter offset as a conservative design basis, the NRC Staff adopted the 1-meter offset as a design basis in its May 1980 SER. The main instigation for this change from 2-1/2 meters to one meter was Staff's new-found reliance upon probabilistic analyses that it felt had been almost mandated by the ACRS. Based upon a conclusion that the probability was small that an offset from the postulated Verona event would surface beneath the reactor, Staff determined that it was unnecessary to consider the maximum offset that might occur from an event on the Verona. In its September 1979 Report, in which it had established a 2-1/2 meter offset as a design basis, Staff had relied upon the maximum determined offset from the 1971 San Fernando event of 2.4 meters; the maximum displacements observed on a worldwide basis for magnitude 6 to 6.5 earthquakes; the possible maximum offset that had previously occurred on the Verona fault; and the assumption that the Verona fault could rupture to an extent greater than its entire mapped length of 8 kilometers, to its projected 12 to 15 kilometers of total length.

Based upon the probabilistic analyses, Staff now (in its May 1980 SER) decided that it could use the means, rather than maximums, of relevant geologic analogies to establish the design basis. In particular, Staff relied upon the means of the surface displacements from the 1971 San Fernando event; the characteristic offsets of from 2 to 3 feet observed in the trenches at the GETR site; the probability that in a future event the surface displacements would be distributed between different splays in the Verona fault zone rather than on a single splay beneath the reactor; and the probability that the Verona fault would not rupture over its entire length. Justus and Jackson, ff. Tr. 996 at 8-11; Tr. 1389-95, 1888-92. Staff, however, recognized that any future displacements on the Verona fault could have offsets of from 2 to 2.5 meters and that less than a 2-1/2 meter offset would not be a conservative projection for the Verona fault zone but only for an offset occurring directly underneath the plant. Tr. 1394-95, 1402, 1404-05.

a. GE's Probabilistic Analysis

My review of the probabilistic analyses suggests that they should be given little weight. GE's probabilistic study was based upon geologic data derived from the trenching operations around the GETR. GE had discovered three separate shears, identified by the principal trenches in which they were unearthed: the H shear; the B-1/B-3 shear (also disclosed by trench T-1); and the B-2 shear. For its model, GE utilized the B-1/B-3 shear and the B-2 shear which were 1,320 feet apart, on two opposite sides of the

72-foot wide reactor building. By dating the soils from these trenches, GE determined a time period, t, by which it could reference its observations within that 1,320-foot wide zone with regard to the discovered shears and the area between them in which no shears were discovered.

GE presented a detailed probabilistic calculation. Lic. Ex. 1 at 79-83; Lic. Ex. 10, 12, 14, and 16. Recognizing that the complexity of the study would tend to obscure the important features, GE simplified it so as to permit an analysis by the Board. Lic. Ex. 1 at 76-79. The probabilistic model considered three cases: Case 1, based upon offset observations on shear B-1/B-3 resulting in annual probability P_1; Case 2, involving offset observations on shear B-2, resulting in annual probability P_2; and Case 3, involving offsets on unknown and undiscovered shears in the region, resulting in annual probability P_3. GE added P_1, P_2, and P_3 to arrive at its overall probability estimate of P.

The simplified equation for probability P_1 was given, as follows (Id. at 77):

$P_1 =$	$\frac{N}{t}$	x	$\frac{1}{N}$	x	$\frac{72 \text{ ft}}{1320 \text{ ft}}$
Event:	A		B		C
	offset occurs on existing shear B-1/B-3		offset occurs between existing shears given offset on existing shear B-1/B-3		offset occurs beneath reactor building given offset between existing shears

As GE describes the formula, for Event A the mean rate of occurrence of offsets on the existing shear is equal to the number of past offset events, N, divided by the amount of time, t, during which the events have been occurring. The time period, t, is equal to the age in years of the soil at the bottom of the trenches (which GE assumes to be 128,000 to 195,000 years). In this time period, N represents the number of events that have occurred on existing shear B-1/B-3 (similarly, another number of events have occurred on the B-2 shear). For the same time period, as determined by the age of the soil at the bottom of the trench, GE assumes that the soil between the existing shears is unbroken; thus, that no events have occurred between the existing shears for the last 128,000 to 195,000 years. For small mean rates (i.e., a small number of offsets occurring over a long period of time), GE assumes that the probability of one event in a year is essentially equal to the mean rate. In other words, the probability is just equal to the number of offsets divided by the time period in which they occurred.

GE further states that, since during the same time period, t, none of the N events have occurred between the existing shears, it is possible to use zero divided by N as the probability for a future offset's occurring between the shears given an offset on the existing B-1/B-3 shear. However, since GE concedes that this estimate would not be conservative for Event B, it assumes 1/N as a conservative probability of an offset's occurring between the shears instead of on shear B-1/B-3.

Finally, GE determines the probability of a new shear coming up beneath the reactor foundation instead of merely within the zone between the offsets, Event C, as being the width of the reactor building (72 feet) over the width of the zone between shears B-1/B-3 and B-2 (1,320 feet).

My major difficulty with GE's probabilistic model relates to the middle term 1/N, representing the probability of an offset's occurring between existing shears. GE's use of this term as a multiplier, with N in the denominator, permits it to cancel N from the equation so as to eliminate it from the numerator of the first term (N/t). Consequently, GE can claim that the "probability is independent of the number of offsets, N." Id. at 79.

However, the relationship assumed by GE of 1/N to N/t, a simple inverse relationship, is based upon an assumption that the offsets on the shears were not accompanied by offsets between the known shears (i.e.,within the 1,320 foot zone between shears B-1/B-3 and B-2), although G.E. used 1/N,[25/] rather than 0/N, for conservatism." While such an assumption may reasonably be made with regard to the topsoils where no surface shears can now be observed between the existing shears, the credibility of that inverse relationship between the number of offsets observed on the known shears and the probability of offsets occurring between the shears, expressed as 1/N, becomes strained as the age of the soils

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25/ There is no basis in the record for assuming that one (or only one) offset has occurred between the discovered shears.

(t) becomes greater. With regard to subsurface soils, comparatively little is known about the existence or non-existence of shears in between the known shears, except for the small areas that were actually trenched.

Furthermore, it is difficult to ignore the evidence that there may be existing shears, disclosed by photographs taken at the excavation of GETR, that surface directly beneath the reactor. USGS expert Dr. Brabb had examined the original excavation photographs and concluded that there was evidence of faulting. On receiving better quality photographs he downgraded the likelihood of the shears from being "probable" to "possible" because some of the features he had associated with faulting in the original photographs were shown to be material that was smeared on the side of the reactor excavation by the construction. However, he also indicated that not all of the features that he saw in these later photographs could be explained in that manner. Tr. 1036, 1059. Even if the possibility is slight but credible that the excavation photographs disclose existing faults, the basis for GE's probabilistic analysis (i.e., that prior offsets have occurred on shears B-2 and B-1/B-3, but not in between) has been undermined.

The probability, P_2, of a shear developing off of existing shear B-2 was calculated in an identical manner. Similarly, probability P_3, was stated to represent a new shear forming due to unknown-undiscovered shears in the region. The same formula was utilized. Lic. Ex. 1 at 78-79. In each case (with regard to shear B-1/B-3, shear B-2, and undiscovered shears) the formula was reduced to 1/t x 72/1320, as the middle term 1/N cancelled out N from the numerator of the first term, N/t. In order to calculate the total probability, P, GE added probabilities P_1, P_2, and P_3, to arrive at P = 3/t x 72/1320. As GE indicates, this combined probability is independent of the number of offsets, N. Id. at 79.

Even if I were to accept the proposition that the probabilistic model is appropriate for shears developing from existing shears B-1/B-3 and B-2 (which I do not because I cannot accept the middle term 1/N as valid, as discussed above), I fail to see how P_3 can represent any more than a probability relating to only a single undiscovered shear existing between the two known shears. For any additional undiscovered shears, P_4, P_5, P_6 . . . P_y would have to be calculated, where y = total of undiscovered shears in between shears B-1/B-3 and B-2. Consequently, the probability that a shear will intersect the foundation becomes P = (2 + y)/t x 72/1320, rather than P = 3/t x 72/1320. Since y has not been determined, we cannot calculate the probability.

In its September 1979 Report recommending the 2-1/2 meter offset, Staff said the following about the use of probabilistic methods to predict ground displacement in the Verona fault zone (Int. Ex. 8 at 24):

> Although probabilistic methods generally can be utilized for assessing the likelihood of occurrence of specific events, we conclude that such methods cannot be used with any level of confidence to specifically predict the location and likelihood of fault offsets within this active fault zone which is poorly understood.

At the time, GE's trenching operations to determine the geology of the Verona fault zone had already been completed. Id. at 13-18.

Even after receiving its "mandate" from the ACRS to utilize probabilistic methods, Staff made this comment in its May 1980 report in which it recommended the 1-meter offset (Stf. Ex. 1-B at 15):

> Deciding the proper surface offset design basis for a facility within a fault zone by using the proposed proababilistic methods is not favored by any of the geological personnel involved in the review of this site. Several specific areas of concern were outlined above. Far more important, however, is the judgment that such methods are highly dependent on very uncertain input parameters and the critical effects of localized site specific conditions, that such methods have yet to be critically tested against sensitivity to a variety of parameters, and finally, that such methods suffer from a lack of testing against observations of fault behavior in well-known geological areas. The probabilistic calculations do, however, provide a frame of reference for making a judgment on geological offset parameters that are not at the upper bound for the dispersion of the available data. Furthermore, they help provide a perspective of the type of data which is needed and which is most critical to making a conservative estimate of the surface offset displacement.

How, in light of the judgment that the probabilistic methods were highly dependent on very uncertain input parameters, they were able to "provide a frame of reference for making a judgment on geological offset parameters," is not explained. The uncertain input parameters were stated by the USGS to include the "number, location, length, width, geometry, and age of [the] thrust faults" in the Verona fault zone which the USGS concluded had not been adequately determined. Id., App. B at i. Furthermore, the USGS believed that GE's consultants had provided incorrect information on fault potential. Ibid.

Moreover, the USGS experts continued to express at the hearing the same reservations regarding the sufficiency of geologic information on which to base a probabilistic analysis as they had in their written reports: they questioned whether a sufficient number of ages had been developed in the dating of the soil deposits to give any degree of confidence in interpretation (Tr. 1468); they questioned whether enough investigation had been made of existing shears in the zone to permit a probabilistic determination (Tr. 1538-39); they indicated a reservation with regard to the amount of cumulative offset that was determined and also the amount that was determined on any one splay (Tr. 1552-53); they did not believe that the observations along the three observed shears were sufficient to allow them to assume any consistency with regard to the amount of offset that might have occurred at any particular event (Tr. 1555); and, to sum it up, they felt uneasy about critical information needed to predict the future behavior of the Verona fault in the sense of time, in the sense of the amount of displacement, and in the sense of where this displacement will occur. Tr. 1543. Furthermore, because the Verona fault zone had been observed to be not just a single fault plane, but one of complexity, it suggested a great deal of additional complexity that had not yet been observed, such as the existence of a number of small, intermittent, and short-length faults. Tr. 1536-37.

b. TERA's Probabilistic Analysis

In view of the uncertain assumptions in GE's probabilistic analysis, it is not surprising that Staff requested Lawrence Livermore Laboratories (LLL) to develop a probabilistic analysis using an alternative methodology. LLL in turn subcontracted this analysis to TERA Corp. Bernreuter, ff. Tr. 1801 at 2.

TERA Corp's model did not rely upon the data derived from the trenching operations in the Verona fault zone. Instead, it calculated a slip rate, using the topographic expression between the Vallecitos hills and the valley below within which the test reactor sits. Based upon this slip rate, it then determined the likelihood of having one meter of slip occur in a tectonic event directly underneath the reactor building. Tr. 1803-06.

To calculate a slip rate using the topographic expression between the Vallecitos hills and the valley below, TERA must have made certain assumptions with regard to the time period over which the hills were formed, the nature of the fault movement at each offset, the distribution of movement between all possible shears in the area, the consistency of movement within the large time frame (1 million years) covered in the calculation and the effects of erosion upon topographic expression, to mention only a few possible assumptions. How TERA could make these assumptions with a high degree of confidence was not explained in the record.

Even assuming that one could arrive at a slip rate based upon topographic expression with any degree of confidence, translating the slip rate into a predictive tool for earthquake recurrence would appear to require considerable speculation. While the gradual buildup of strain and its sudden release in a tectonic offset is a generally accepted theory regarding the cause of earthquakes, use of this theory based upon topographic relief as a quantitative predictor of earthquakes in any particular region would be novel. I would have considerable difficulty in rationalizing the possibility of the occurrence of the 6.5 magnitude Imperial Valley earthquake of 1979, containing ground displacement of up to .8 meters so soon after the occurrence of the 1940 7.0 magnitude event in which the maximum displacement on the same shear was 6 meters (see Tr. 562-3), if the strain release theory were used as a predictive, rather than merely an analytical, tool.

The unreliability of the use of a TERA-type analysis to predict the rate of occurrence of earthquakes is underscored by the testimony of certain of the expert witnesses. Staff's witness Wight from TERA discussed the model used to translate slip rate into a prediction of earthquake recurrence, in which the equation involves an estimate of fault area, slip rate, and rigidity of materials around the fault. Because there was no basis in the literature for using different values for the rigidity of the earth at different locations, TERA merely used commonly accepted values for the western United States. Tr. 1823-24.

Staff witness Slemmons testified that he would not make a decision on establishing the risk at major vital structures on the basis of the TERA probabilistic analysis, and couldn't even assess its reliability. Tr. 1822, 1824. The most he could offer for the analysis was that it had a sound basis and seemed to fit empirically reasonably well with field observations. Tr. 1824-25. He did not believe that future earthquake activity could reliably be predicted for a zone such as the Verona fault zone which is tectonically related to activity on the Calaveras, Las Positas and Greenville faults, with the entire region undergoing strain that might vary with time and which might result in various sequences of activity from one fault to another. All of these interrelated fault zones suggested to him patterns of stress build-up that change with time. In addition, he saw very little data for reverse slip type faults, such as the Verona fault, on which to base a prediction. Tr. 1830-31. Dr. Slemmons also noted that a slip rate based on recent soils would usually be the most credible type of information but, because such a sampling would approach the length of an average recurrence interval, TERA had to base its study on a longer-term average rate (over approximately 1 million years), which might not be representative of the current seismicity. Tr. 1831-32.

GE's witnesses Drs. Jahns and Bolt had recently co-authored a report evaluating the seismic hazard in California. They had estimated the seismic hazards on the basis of three different kinds of evidence. Tr. 2009-10. They did not take into account evidence with regard to strain and rate of slip, because the actual implications and extent of fault creep are not very well known at the present time. Tr. 2024. Had the rate of slip been a reliable indicator of earthquake recurrence, Drs. Bolt and Jahns would have relied upon it in their paper. Tr. 2026-27. Even taking into account the possibility that strain might be released by gradual creep or by large displacements in a tectonic event and making an assumption about the percentage of each that would release the strain, Dr. Bolt would not give very much weight to any analysis based upon the uplift of hills. Tr. 2040-41. Moreover, any assumptions made about the percentage of strain that might be relieved in slow creep as opposed to tectonic displacement would not be reliable. There is no general figure that would apply: slow creep could account for 80 percent of the movement in one place and 20 percent in another. No generalization could be made with regard to the Verona fault. Tr. 2040, 2065-66.

I do not question the value of probabilistic determinations to give numerical perspective on the risks being considered. Nor would I attempt to substitute my scientific judgment for that of the eminent scientists on the ACRS who recommended relying on probabilistic analyses. However, from the evidence adduced at this hearing it does not appear to me that the views of the Staff geologists and their geological advisers from the USGS with regard to the uncertainties in the assumptions underlying the probabilistic calculation were given sufficient weight in Staff's final conclusions. Although the Staff geologists appear willing to defer their judgment to the probabilistics experts, notwithstanding the geologists' apparent reservations with regard to the adequacy of geologic data on which to base a probablistic estimate (see discussion at Tr. 1330-36), the Board cannot so easily delegate its responsibility. While the numbers may work out to a low probability of offset beneath the reactor, the decision on whether the geologic data are sufficient for a probabilistic determination is a geological decision, not a statistical one. The Board must rely upon the geologic evidence and an evaluation of the geologic opinions to make that decision.

In my opinion, based upon the evidence discussed above, neither the GE nor TERA probabilistic analyses (nor the combination of the two) is based upon data sufficient to establish that the maximum offset that might occur in the Verona fault zone has only an insignificant chance of occurring beneath the reactor. In determining the design basis parameter for an offset occurring beneath the reactor, I would take into account the maximum offset that might likely occur in the Verona fault zone based upon what has been observed in the trenches, upon the geological history of the area, and upon appropriate comparisons with other faults.

3. Observations at the GETR Site

There were three primary splays of the Verona fault observed at the site, identified by the trenches in which they were observed: (1) the B-1/B-3 (and T-1) splay; (2) the B-2 splay; and (3) the H splay. According to GE's experts, cumulative displacements going back from 1 to 4 million years measured in trenches in B-1, B-2, and H amounted to over 40 feet, over 80 feet, and over 20 feet, respectively. Lic. Ex. 1 at 50-51. GE makes much of the fact that there were no direct measurements of recent displacements on a single splay which exceeded 3 feet. Ibid., Lic. Req. Find. 48. By "recent displacements" GE apparently refers to the last displacement shown in each of those three trenches in which the maximum measurements were 2 feet, 3 feet, and 1.5 feet, respectively.[26/] The USGS experts, however, dispute GE's determination that none of the latest offsets were greater than 3 feet. According to them, the shear that was exposed by trenches T-1, B-1 and B-3, disclosed an offset in trench T-1 of from 5 to 7 feet in the most recent soil in which the full displacement could be observed. Stf. Ex. 1-B, App. B at 22; Tr. 1133-36, 1155, 1157, 1164, 1176-77.

Viewing Staff's Exhibit 7, which is an annotated version of a portion of the T-1 trench log containing all of the line projections and points discussed with regard to trench T-1, and reviewing the voluminous testimony regarding that trench, it appears more likely to me that the amount of displacement that occurred in the more recent soils would be measured from points 2 or 3 to point 9, a distance of from 5 to 7 feet (as interpreted by

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26/ Since the prior cumulative displacements in the Paleosol and the Livermore gravels totalled more than 3 feet in each of the trenches, it is impossible to determine whether the maximum displacement in any one prior event was as little as 3 feet. Lic. Ex. 1 at 50-51.

the USGS) than from points 2 or 3 to point 1, a distance of 2 or 3 feet (as interpreted by GE). See Tr. 324-59, 1133-78, 1436-1523. The USGS experts believed that the evidence in trench T-1 showed a displacement of about 5 feet on each of 2 breaks and they had a high degree of confidence in that conclusion, which was contrary to the conclusion of 2 feet of displacement testified to by GE's witnesses. Tr. 1155, 1157, 1176-77. When discussing a 5-foot displacement, the Geological Survey experts actually intended to encompass a 5 to 7 foot displacement. Tr. 1163-65.

Although GE raised many significant questions regarding the testimony of the USGS experts (See Lic. Prop. Finds. 51-57), the result is more to underscore the difficulty in arriving at a definitive interpretation of prior displacements on the observed shears, than to undermine the USGS's conclusions. With regard to whether certain of the conditions necessary to support the USGS's interpretation were absent from the soils, the USGS experts disputed the accuracy of the trench logs with regard to soil conditions and possibly some of the faulting, which were prepared by GE. Tr. 1111-12. In particular, the Geological Survey experts recalled an offset in the surface soils that would support their conclusion. They had reported the offset in their 1979 report to the NRC. They believed that GE's consultants had agreed to its existence but when they received the trench log of T-1 those soils were not shown as being offset. Tr. 1499-1500, 1510-11. Furthermore, according to the USGS experts, the soil units were not mapped on the log and therefore did not preclude the existence of a soil wedge that might be necessary to support their interpretation. Tr. 1511. The USGS witnesses also believed that GE's theory was flawed because it depended upon a surface's being rotated before the displacement of a fault--a theory that was implausible according to the geometry of the trench log. Tr. 1521-22.

Although GE downplays the significance of a belief that the recent soils were offset more than 5 feet in the T-1 trench, the USGS experts and Staff's consultant Slemmons disagree with GE. The belief that 5 or more feet of offset of the recent soils had been observed in trench T-1 apparently did have some influence on the USGS contention throughout the proceeding that a 1-meter offset would not be a conservative estimate for a future offset on the Verona fault. Stf. Ex. 1-B, App. B at May 8, 1980 Cover Letter; Tr. 1243, 1378-81, 1384-85, 1410. Dr. Slemmons indicated that if it could be verified that there had been a displacement of 5, 6 or 7 feet in trench T-1, he would change his opinion that a 1-meter offset would be a conservative projection. Tr. 1295, 1569.

In my opinion, we cannot determine with any confidence the maximum amount of offset that had occurred in any one event on the Verona fault. Although I would assign the highest credibility and competence to the USGS experts, Drs. Brabb and Herd, their analyses and observations could be mistaken. However, I would not give much weight to GE's argument that the number of direct measurements of displacements (22) indicating displacements of less than 3 feet should establish the maximum to be expected. See Lic. Prop.

Find. 57. These measurements were made in trenches B-1 and B-3 and, like the measurements made in trenches B-2 and H of displacements in the most recent soils, probably relate to only a single episode of faulting. Moreover, because the soils in those trenches could not be correlated with the soils in trench T-1 (which may have exhibited a younger soil), they may have reflected a different faulting episode than observed at T-1. Tr. 1462-68. While it is possible that a 5 to 7 foot displacement in trench T-1 could have reflected the cumulative offset of 2 faulting episodes, one on shear B-1/B-3 and the other on shear B-2 as suggested by Dr. Slemmons (Tr. 1295), it is also possible, as Dr. Slemmons further testified (Tr. 1569), that this total offset of from 5 to 7 feet could have occurred in one event on the splay in T-1 and branched off into lesser offsets on shears B-1/B-3 and B-2. More importantly, even if that latter suggested movement had not actually occurred so as to be responsible for the observations in the trenches, the Board should not ignore the possibility that the cumulative offsets shown in the observed shears from any one faulting episode might occur as a single displacement on a single shear in a <u>future</u> event.

As stated by Dr. Slemmons, "The possibility of simultaneous distributed displacements on two or more fault strands connecting at depth or a single cumulative displacement on one strand has not been evaluated . . .." Int. Ex. 8, App. C at 2. In view of the similarity in strike and dip between the shears observed in trenches B-1/B-3, B-2 and H, suggesting some connection at depth, I do not see how we can dismiss, with a high degree of confidence, the likelihood of the total movement in any one event occurring as a single displacement on a single splay in the future, so as to eliminate that possibility from the design basis. Considering the likelihood that the total displacement for the three shears in what appeared to be the latest faulting episode was estimated to be between 6.5 feet and 9.5 feet (Int. Ex. 8, App. B at ii, 22), I would not set the design basis at less than approximately 2 meters (approximately 6-1/2 feet) if I were basing the decision on what was observed in the GETR trenches. Even excluding the H shear and considering the B-1/B-3 (and T-1) shear and the B-2 shear, which were most similar, the cumulative offset in what may have been the last faulting episode was between 5 and 8[27/] feet. Ibid.

4. Comparison With Other Faults, Including the San Fernando Fault

In establishing the 2-1/2 meter displacement design basis in its September 1979 SER, Staff relied not only upon a conservative interpretation of the displacements that had been observed in the GETR trenches, but also upon comparisons with the 1971 San Fernando, California earthquake and other worldwide events. Int. Ex. 8 at 20-23. On the basis of worldwide data and given a rupture length of 12 to 15 kilometers as observed after the 1971 San

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[27/] Actually between 5 and 10 feet, if we take the maximum of the 5 to 7 foot offset suggested for the T-1 trench. Tr. 1163-65.

Fernando earthquake, the studies relied upon by Staff would have predicted a maximum net slip value of from 1.66 to 1.83 meters. Id. at 22. Those figures were not much less than the maximum net slip of 2.4 meters observed at San Fernando. Consequently, the Staff adopted 2-1/2 meters as a conservative value. Staff's consultant Dr. Slemmons agreed that a 2-1/2 meter net slip value was reasonable for a fault with a length of between 8.2 and 12 kilometers (as had been estimated for the Verona fault) and the observed 1-meter offsets in the GETR trenches, and that it was consistent with worldwide data. Id. at 23; Id., App. B at 3. GE, however, developed its own plot of surface displacement versus rupture length based on worldwide data and, using 1/2 of the total map length of 8.2 kilometers for the Verona fault, arrived at a maximum surface displacement of 1.02 meters. Id. at 20.

In revising the design basis to a 1-meter offset, Staff was motivated primarily by its acceptance of the probabilistic studies which suggested to the Staff that it need not consider only the maximum values of offsets in the trenches, in the San Fernando fault zone, and on a worldwide basis, but could consider the characteristic or mean values. Tr. 1890-92. As indicated, above, I do not give much weight to the probabilistic studies, and could not justify a change in parameters on that basis. With regard to the San Fernando event, Staff also relies upon the stipulation that the assumption that the San Fernando and Verona fault zones are comparable is a conservative assumption and upon testimony to the effect that the use of a conservative analog such as San Fernando permits a scaling down from the maximum values to mean values. Stip. B at para. 2e; Tr. 1293-94; Stf. Prop. Finds. 53, 54.

Staff's reliance on the conservatism of the San Fernando model to scale down the maximum offsets observed in that event is misplaced. Although it may be a conservative model because the rupture length in the 1971 event was estimated at from 12 to 15 kilometers as opposed to the estimated maximum surface length for the Verona fault of 12 kilometers, stipulated to by the parties and approved by the Board (Stip. B at paras. 2f and g), there is no basis for presupposing that every characteristic of the 1971 San Fernando event will necessarily bound every similar future event on the Verona fault. Even if we could determine with certainty the maximum displacement, the mean displacement, and the peak ground motions at various distances in the 6.4 magnitude, 1971 San Fernando event, we cannot be assured that none of these values is likely to be exceeded in any future 6 to 6-1/2 magnitude event on the Verona fault. To illustrate the point, we need only refer to the testimony (Tr. 562-64) regarding the Imperial Valley earthquakes of 1940 and 1979. In the 1940 7.0 magnitude event there was an average displacement of 1.7 meters and a maximum displacement of 6 meters; in the 1979 6.5 magnitude event there was an average displacement of 0.4 meters and maximum displacement of .8 meters. Had the events been reversed and the characteristics of the 1979 event been used to predict the 1940 event, it would have "seriously underestimated" the 1940 values, even on that identical fault. Tr. 563. Here we have a comparison of two <u>different</u> faults

(Verona with San Fernando) with only similar characteristics of faulting (i.e., reverse-oblique, with some strike-slip component) and similar lengths, in common.

Moreover, we are not at all certain how much more conservative we should consider the San Fernando analog to be to a future event on the Verona fault. It has been stipulated that an earthquake occurring on the Verona fault could have a magnitude of from 6 to 6.5 Stip. B at para. 2k. Staff's consultant Dr. Slemmons had previously indicated a potential magnitude of about 6.5 ± 0.5 for an earthquake generated by faulting that is limited to the Verona fault zone. Int. Ex. 8, App. B at 3; Stf. Ex. 1-B, App. E at 12-13. The San Fernando event had a 6.4 magnitude.

Although the Verona fault has been mapped at from 8.2 to 12 kilometers and stipulated to be a maximum of 12 kilometers, this compares very closely with the stipulated observed surface rupture during the San Fernando event of about 12-15 kilometers (Stip. B at para. 2g). We have no reason to believe that a future high magnitude event on the Verona fault would rupture any less than its observed trace, as suggested in GE's original calculation of a 1.02 meter offset based on only 4.2 kilometers rupturing of the assumed 8.2 kilometers of the total length of the Verona fault. Int. Ex. 8 at 20. No evidence has been offered that would support the conclusion that the 1971 earthquake ruptured only a portion of the known trace of the San Fernando fault. For all this record indicates, the 1971 San Fernando earthquake may have ruptured along a length of fault much greater than had been previously traced or had even been previously faulted.

Furthermore, even if we assume a slightly lesser length for the Verona than for the San Fernando fault, the difference should not be significant in evaluating surface displacement. The relationship of maximum surface displacement to length of surface rupture, as observed from world-wide data, appears to be logarithmic so that, unless the estimated length of surface rupture were to change dramatically, the difference in estimated maximum surface displacement would only be slight. Lic. Ex. 1 at 47-49. Also, as noted by GE, the plot of world-wide data for different types of earthquakes indicates that the best straight-line fit for reverse-oblique-slip faults, the characterization given to the Verona fault, has a negative slope that indicates decreasing surface displacement with increasing fault length. Ibid. (See also the testimony indicating that the relationship between rupture length and magnitude is considered logarithmic so that estimated magnitudes would be relatively insensitive to variations in postulated lengths of rupture. Tr. 1574-85.)

With regard to the comparisons of length of surface rupture between the Verona and San Fernando faults, we cannot be certain which lengths are most relevant for comparison. The San Fernando fault zone has been described as part of the Sierra Madre-Santa Suzanna system, which is perhaps 100 kilometers or more in length. However, that system is rather segmented and the San Fernando fault portion that broke in 1971 had a length of about 12 to 15 kilometers. Tr. 1872. Even the San Fernando portion that ruptured in 1971 had 4 discrete segments, each with its own characteristics: the Sylmar, Tujunga, Mission Wells and Lakeview segments. Two of those segments exhibited principally strike slip movements and the other two thrust fault movements. Tr. 1283-84.

Similarly, the Verona fault has been described as either truncated by or merging with the Calaveras fault to the northwest and joining with or being truncated by the Las Positas fault on the east, which in turn is connected to the Greenville fault. Tr. 1096, 1193-96, 1830; Int. Ex. 8 at 11, 21; Stf. Ex. 1-B, App. B at 66. The mapped length of the Calaveras is approximately 100 miles (Tr. 681), considerably longer than the 10C kilometers estimated length of the Sierra Madre-Santa Suzanna-San Fernando fault system. I see little in the record to demonstrate that the Verona fault is not as directly connected to either the Calaveras or Greenville fault systems as is the San Fernando to the Sierra Madre-Santa Suzanna fault system.

Although the estimated length of the Verona fault of 12 kilometers is less than the 12 to 15 kilometers of rupture length of the San Fernando fault, it is considerably greater than any of the four segments that ruptured during the 1971 earthquake. Moreover, by adding the length of the Verona fault to that of the Las Positas fault, which the Staff witnesses thought were connected and would have a combined length of from 23 to 29 kilometers (Tr. 1096, 1196, 1249-56, 1676), we would arrive at approximately twice the length of the 1971 San Fernando rupture. Since the same compressive forces have been theorized as creating the faulting movements on the Verona as on the Las Positas fault (Stf. Ex. 1-B, App. B at 64-67), it would not be unusual for future movement to be simultaneous on both faults, albeit predominantly thrust faulting on the Verona and strike slip faulting on the Las Positas. This would be similar to the simultaneous rupturing of the four discrete segments of the San Fernando fault in 1971, with a somewhat different character of movement on each segment. Consequently, while the comparison of the 12 kilometers of Verona fault to the 12 to 15 kilometers of the San Fernando fault may appear to support the conservatism of the analogy to the San Fernando 1971 event, I am not assured that the comparison of those two lengths is the most significant that can be made, and that the comparison is conservative.

There is some uncertainty with regard to the application of the San Fernando data to the Verona fault zone. Although the experts appear to agree that the maximum net slip observed in the 1971 San Fernando earthquake was 2.4 meters, when it comes to projecting an estimated offset to the Verona fault they are not unlike the six blind men and the elephant, with each examining a different characteristic of the event and projecting it to a variety of postulated events on the Verona fault. Although the Staff originally adopted the 2-1/2 meter maximum net slip observed at San Fernando, when it changed the design parameter to one meter it relied upon data compiled by Barrows and others in a 1973 paper based on 179 observations of vertical surface offsets that occurred during the San Fernando earthquake. The Barrows analysis determined the means of observed vertical throw on a given fault break to be about 0.34 meters. Staff then applied its projected 1-meter net slip offset to a postulated fault dipping at 45 degrees, and calculated a 0.7 meter vertical throw. The 0.7 meter throw not only exceeded the calculated .34 meter mean, but apparently exceeded the mean plus 1 standard deviation for the observed data for all segments of the fault. Stf. Ex. 1-B, Section A at 19.

Dr. Brabb of the USGS disagreed with the Staff's treatment of the San Fernando data from Barrows and preferred data based upon net slip determinations, rather than projections from calculations of vertical throw. He relied upon net slip determinations made by Sharp of the USGS which yielded a mean value slightly in excess of 1.0 meters, one meter being exceeded 52% of the time. Lic. Ex. 1 at B-2.

GE made its own calculation for San Fernando and arrived at a mean net slip of 0.22 meters, a standard deviation of 0.50 meters, with a total mean plus one standard deviation of 0.72 meters. Id. at B-3 to B-10. GE's approach was to assume a grid of squares, each 72 feet by 72 feet (i.e., the area of the GETR foundation) placed over the entire San Fernando fault zone. For each square, an offset was calculated in a fashion similar to Sharp's analysis by analytically combining measurements of vertical and horizontal offsets based upon data compiled by Sharp, Barrows and others. GE determined that, for the total of 7,383 72' by 72' squares in the

San Fernando fault zone, 1,888 contained offsets and 5,495 did not. It then determined that the mean offset for all squares, including those without offset, was .22 meters. Ibid.

At once, GE's analysis says too much and too little about the San Fernando event for a comparison with the Verona fault. It presumes not only that the magnitude of the surface displacements observed in the San Fernando fault zone will be comparable to that which could be expected in a future event on the Verona, but that the configurations of the fault zones are similar. No such foundation has been established and, from the testimony presented with regard to the four discrete segments of the San Fernando zone (Tr. 561-62, 1283-84), such similarity in the respective fault zones appears unlikely. GE's analysis is basically a probabilistic determination of the net slip that could be expected if a future event were to occur in the San Fernando fault zone similar to what occurred in 1971 and a structure such as GETR were placed at random in that zone, giving full weight to the possibility that the structure might be located on a square that would not experience an offset. Lic. Ex. 1 at B-3. That comparison goes too far. The comparison should only proceed to the point of projecting an expected net slip on the Verona shears from the San Fernando data and then, perhaps, evaluating the possibility of those shears intersecting the GETR facility based upon the configuration of the Verona fault zone (if sufficient geologic input is available).

GE's analysis says too little about the displacement that actually occurred on the San Fernando shears that might be projected to the Verona fault, when it concludes that a mean of 0.22 meters can be assumed for the squares with and without offsets. If, however, we eliminate the squares without offsets (5,495 in number) and distribute the displacements to the squares with offsets (1,888 in number), we arrive at a mean offset of .88 meters of surface displacement. This figure roughly coincides with, and appears to confirm the reasonableness of, the Sharp calculation of an average offset approximately equal to one meter, referred to above.28/

Viewing the evidence and statistical interpretations regarding the San Fernando event as a whole, it would seem reasonable to conclude that three quarters of a meter to one meter could be considered a "characteristic," "typical," or "mean" displacement along the shears of the San Fernando fault. It is also clear that net slip along the four discrete segments of the fault varied, as did even the displacements within the segments. In fact, Staff expert Dr. Justus agreed (Tr. 1283) that calculated net slip of from 2.0 to 2.5 meters was representative of at least 1.4

28/ It does, however, appear to conflict with the Staff's calculation that 1 meter of net slip would result in approximately 0.7 meters of vertical offset and that 0.7 meters offset would exceed the mean plus one standard deviation for the observed data for all segments of the San Fernando fault. In view of the method utilized by Staff of considering only observations of vertical throw on the San Fernando fault and calculating net slip on the basis of a postulated offset dipping at 45 degrees, one could have little confidence in the result. It is perhaps for this reason that Staff offered that its statistical interpretation must be viewed cautiously because of possible bias in the sampling and measurement of offsets in the field. Stf. Ex. 1-B at 19.

kilometers of the 2.9 kilometer length of the Sylmar segment. This 1.4 kilometer section represents approximately 10% of the total San Fernando rupture length.

The San Fernando data and interpretations appear to confirm the observations at the GETR site. The characteristic displacements of perhaps three-quarters of a meter to one meter in the San Fernando zone are almost exactly duplicated by the apparent consensus among the experts that, in the latest faulting episode on each of the three known Verona shears that were observed in the B-1 trench, B-2 trench and H trench, the observations of net slip were 2 feet, 3 feet, and 1-1/2 feet, respectively. The interpretations of the latest movement on the shear observed in the T-1 trench ranged from 2 feet to 7 feet, duplicating the range between the "characteristic" movement and the maximum movement on the San Fernando fault.

Even if we could analogize the configuration in the San Fernando fault zone to the Verona fault zone, I see little merit in reducing the movement on the San Fernando shears to a movement within a typical 72'-square zone and applying that zonal movement to the GETR site. If we could accept as valid the hypothesis that in a future event in the Verona fault zone only 1 out of 4 squares in the area of the GETR foundation will experience displacement, those that do will experience the full displacement, not merely one quarter of it. Whether we should also take into account the probability that a square will experience displacement is an entirely separate consideration, but taking into account a probability of 25% for the occurrence of an event is insufficient, in my opinion, to remove it from the design basis.

In sum, I can accept the proposition that one meter or slightly less than one meter can be considered a characteristic displacement for the Verona fault zone, as it was for the 1971 San Fernando event. However, even if one meter were a characteristic movement for the next event on the Verona fault, there is a strong possibility that it will be exceeded on some portions of the shear. Hence, I could not consider one meter to be conservative and, therefore, appropriate for the design basis. If anything, the San Fernando data demonstrates that a measurement at one location on the rupture is unlikely to reflect exactly the movement at any other location. Consequently, a movement of 5-7 feet on the T-1 location of the Verona fault is not necessarily inconsistent with movements of 2 or 3 feet in other locations for the same event. Based on the San Fernando observations, it would only be a matter of chance if the trenches at GETR managed to unearth the locations that experienced the greatest movements in the most recent events.

Similarly, on the basis of what had been observed on the Imperial Valley fault in the 1940 and 1979 events, where the average and maximum displacements between the two events differed by factors of from 4 to 7, respectively, we must take into account the possibility that the mean displacement on the next Verona event could greatly exceed what had been experienced in the recent past or in the San Fernando event. I can find no exact number to represent a conservative design parameter. For the reasons just discussed, one meter appears not to be conservative. The original

Staff design parameter of 2-1/2 meters, representing the single observed maximum in the San Fernando event and the maximum interpretation of the T-1 trench observations at GETR is, perhaps, too cautious. In the absence of any compelling reason to the contrary, I would select a 2-meter offset as an appropriately conservative figure, given that one meter is inadequate.

5. Lack of Conservatism in the 1-Meter Offset

The Staff has justified the 1-meter surface displacement design parameter as including a set of conservative assumptions. Stf. Prop. Finds. 40-42. It explored these alleged conservatisms in detail (Prop. Finds. 43-93), and concluded (Prop. Find. 94) that the use of the design value of 1 meter beneath the GETR is reasonably conservative when placed in the context of the total information presented in this proceeding. I do not agree.

a. Landslide vs. Tectonic Origin of the Verona

Although the parties have stipulated (Stip. Para. 2.b.) that the Verona fault is tectonic in origin, the Staff notes that GE's experts and the California Division of Mines and Geology had concluded that a landslide is the preferred interpretation of the cause of the Verona shears. Stf. Prop. Find. 43. In light of the

Board approved stipulation, which removed the issue from consideration, it would be improper for the Board to give any weight to that interpretation. Moreover, the evidence appears overwhelming that the shears had a tectonic origin. See Stf. Ex. 1-B at App. B; Tr. 1606-09. The testimony and evidence presented to the contrary reflect more upon the reliability of the experts presenting that evidence than upon the merits of that issue (or non-issue, as the stipulation requires). See Tr. 247-53, 474-78, 1602-09.

Even accepting the possibility of a landsliding origin for the observed shears does not justify attributing any conservatism to the quantitative design parameters established for vibratory motion or surface displacement. If the possibility is substantial that there was a tectonic origin to the shears, we must consider the full extent of a possible future tectonic event; we cannot adopt design parameters that represent a hypothetical compromise between a tectonic event and a landslide.

b. Probability of Occurrence of 6.5 Magnitude Event on Verona Fault

The Staff also uses as a conservatism for its 1-meter design parameter the testimony given at Tr. 1657-63 that it is unlikely that a 6 to 6.5 magnitude event would occur on the Verona fault for thousands of years. Stf. Prop. Find. 44. Staff's summary of the opinions offered, that it is unlikely that such an event would occur for "up to 10,000 years" (ibid.), covers a wide range. It covers only two numerical figures given of "in about another 5,000 years" (Tr. 1660) and of "perhaps 5,000 or 10,000 years down the road" (Tr. 1663), which were based upon a slip rate of one meter per 10,000 years for that magnitude event and an assumption (disputed by GE) that the last event of that magnitude had occurred only 1,500 to 4,000 years before.[29/] The testimony summarized by Staff also included an opinion that the likelihood of such an event is "high enough that it should be considered" in the design basis. Tr. 1658. Moreover, the top-of-the-head opinions were not intended as affirmative evidence, but appeared to be based upon accepting as hypotheses certain geologic approximations made by other Staff witnesses that must be independently assessed by the Board on the basis of the evidence.

c. Consideration of Fault Rupture Greater than the Mapped Length of Verona

The Staff claims that it assumed a rupture of 12-to-15 kilometers for the Verona, despite its entire mapped length of no more than 12 kilometers, which Staff indicates would "correlate with" a displacement of about one meter. Stf. Prop. Finds. 45, 46.

29/ If we accept GE's assumption that the last such event occurred 10,000 years ago (see Stf. Ex. 1-B, App. B at 16), a similar event would be imminent according to the testimony alluded to by Staff.

By "correlate with" Staff apparently means result in a likely, rather than maximum, displacement. See Tr. 1187-88. Its reference to Lic. Ex. 21 at 16, 17 for the proposition that a rupture length of up to 15 kilometers results in a "maximum surface offset of less than 1 meter," is inaccurate. That exhibit (the prefiled testimony of Licensee's witness Kovach) was based on calculating an "amount of expected average net offset." Id. at 17. GE had earlier estimated a maximum surface displacement of 1.02 meters using a total length of only 4.2 kilometers based upon data by Staff witness Slemmons in a 1977 study. Int. Ex. 8 at 20. In a later study done for the NRC in this proceeding, Dr. Slemmons used rupture lengths for the Verona of from 8.2 kilometers to 15 kilometers and arrived at "likely" surface offsets of from 2 to 3 feet, and "maximum" offsets of from 2 to 2.5 meters. Stf. Ex. 1-B, App. E at 12-14; Tr. 1187-88. As discussed in detail above, we have no way of knowing whether a future surface rupture would confine itself to only a portion of the known trace of the Verona, would cover the entire trace of the Verona, or would even extend beyond the presently known trace. Furthermore, we must recognize the possibility, however slight, that the Verona and Las Positas combined, of from 23 to 29 kilometers, might be the controlling length of fault for influencing the magnitude and, hence, the amount of surface displacement in a future event. Taking all of these factors into account, the Staff's 1-meter design parameter cannot be considered conservative. These factors reinforce my position that, while one meter could well be the characteristic displacement in a future event of the highest magnitude expected on the Verona fault, a greater displacement could likely occur that should be taken into account in the design parameters.

d. Consideration That Offset Will Occur Beneath the Reactor

Staff contends that its design basis is conservative because it assumes an offset will occur directly beneath the reactor even though future offsets are more likely to occur on existing faults and GE's experts had concluded, upon analysis of photographs of the excavation of the GETR foundation, that there were no faults under the GETR. Stf. Prop. Find. 55.

Staff errs in analyzing its own position as including an assumption that there is a capable fault beneath the reactor building. Staff, in fact, accepted GE's probabilistic conclusions which were based upon an assumption that there were no capable faults underneath the reactor. As discussed above, GE recognized that a future offset would most likely occur on an existing shear, rather than between shears. It treated the area underneath the GETR foundation as having a low probability (equal to any other area between the B-1/B-3 and B-2 shears) of experiencing an offset. Had GE assumed a capable fault beneath the GETR, it would have had to assume a higher probability for a future offset's occurring beneath GETR. The Staff cannot, on the one hand, accept GE's probabilistic conclusions, which are based on the assumption that there is no capable fault underneath GETR and, on the other hand, profess to have assumed in its design basis the existence there of a capable fault.

Similarly, the Staff is inaccurate in claiming that it was conservative in assuming that "an offset will occur directly beneath the reactor." Stf. Prop. Find. 56. As the section on structural analysis demonstrates, and as Staff's Proposed Finding 183 concedes, Staff did not find GE's bearing capacity analyses, that were based upon an offset occurring directly beneath the reactor, to be acceptable. In their stead, Staff accepted GE's fault deflection analysis that was based upon an assumption that the offset will not occur directly beneath the reactor because it would be deflected to the perimeter of the reactor foundation.

Finally, as discussed above, the testimony indicated a possibility that the excavation photographs disclosed pre-existing faults underneath the reactor. Since Staff, in fact, did not give any weight to that consideration in arriving at the 1-meter design parameter by accepting GE's probabilistic analysis and deflection analysis, both of which assumed that no capable fault existed beneath the GETR, Staff's design parameters are non-conservative in that respect.

e. Consideration of Co-Seismic Slip and Combined Loads

Staff contends that its consideration of an offset's occurring simultaneously with the ground motion in calculating the combined loads on the reactor is a conservative assumption in that "most of the time" they are separated in time. Staff attributes this conclusion to its Staff expert, Dr. Jackson, and to the USGS. Stf. Prop. Find. 57. Staff points out that co-seismicity is a "worst case assumption." Ibid.

Staff portrays the testimony somewhat inaccurately. The Staff's and USGS's experts modified their original testimony, given at Tr. 1048-50, which Staff accurately summarizes, to indicate that the ground motion and surface displacement were simultaneous at San Fernando; that co-seismicity is the rule for strike/slip and normal dip faults; and that there is very little data on which to form a general opinion with regard to reverse dip faults (as is hypothesized for the Verona fault). Tr. 1051-53. What they did reach a definitive conclusion on was that co-seismicity is an appropriate assumption. Tr. 1053.

Moreover, Staff's assertions (Stf. Prop. Find. 58) are misleading that it required as part of the design basis that the total surface offset and vibratory ground motion be considered to occur concurrently at the GETR. That assumption was not included in the design requirements of GETR for its structural analysis. As my discussion with regard to the structural analysis will indicate, GE made no calculation using more than a 0.3 g vibratory ground motion (and certainly not the postulated 0.6 g maximum vibratory ground motion from the Verona fault) in conjunction with any surface displacement. Nor did it consider the maximum loading that could be imposed on the reactor building from a surface displacement of one meter in conjunction with any ground vibratory motion, as will be discussed below. Furthermore, since the Staff did not accept GE's structural analyses on the combined loading, but rather accepted only the deflection analysis which concludes that a combined loading on the foundation of the reactor will not occur, it cannot properly claim to have made any assumption of co-seismicity, much less a worst case assumption in which the total surface offset and vibratory ground motion are considered concurrently.

f. Other Lack of Conservatisms in Staff's Proposed Design Basis

In addition to the conservatisms discussed above that were allegedly relied on but not actually taken into account in the Staff's proposed design basis (e.g., Verona fault combined with Las Positas, Greenville and/or Calaveras; possible existence of capable fault under GETR; concurrent total ground displacement and maximum vibratory ground motion), there are a number of other observations testified to by the experts that suggest a lack of conservatism in Staff's proposed design basis, even though they may not have been quantifiable.

i. In the structural analysis, Staff and GE did not take into account vertical accelerations greater than 2/3 of the horizontal accelerations, even though the peak vertical accelerations at the Imperial Valley 1979 earthquake, the Gazli earthquake of 1976, and the Coyote Lake earthquake of 1979 exceeded peak horizontal accelerations. Tr. 528, 618-19.

ii. Staff and GE did not take into account a hypothetical earthquake on the Calaveras fault a few kilometers north of GETR near Dublin, such as occurred in 1861, with a rupture propagating to the south, which could create greater than anticipated ground motions at GETR because of seismic focusing and which could rupture the surface at GETR. Tr. 590-91, 641-46, 689, 700-01.

iii. Staff and GE did not take into account the fact that, because GETR lies within a zone of faulting of such complexity, there are typically other breaks that would comprise that zone so that there would be a greater likelihood of faults in the zone other than those already discovered, including faults beneath the reactor itself. Tr. 1346-47, 1536-37.

iv. Most importantly, in accepting a design parameter of one meter of surface displacement, Staff and GE did not take into account the possible observed offset of 5-7 feet in trench T-1, the possibility that a future offset under GETR could experience a total displacement equal to what had been observed as separate displacements on the known shears in the most recent event, and the 2 to 2-1/2 meter offsets at San Fernando which were typical of the displacements on a significant segment of the fault as more fully discussed above.

B. Seismic Design Parameters

For its seismic design basis parameters, Staff has recommended that the Regulatory Guide 1.60 response spectra be anchored to .75 g effective acceleration for events on the Calaveras fault, and to .6 g effective acceleration for events on the Verona fault. For the Verona fault, the ground motion would be combined with whatever surface displacement is appropriate from an event on that fault. Staff does not distinguish between horizontal ground motion and vertical ground motion in its stated proposed design basis parameters. However, in conformance with current engineering practice, it requires that the structure be able to withstand vertical ground accelerations equal to two-thirds of the horizontal accelerations.

I concur with my fellow Board members in accepting the ground motion design parameters recommended by Staff. I do not, however, subscribe to their entire analysis in arriving at this joint conclusion. In certain respects, I believe their findings overstate the case made by Staff and GE.

1. Horizontal Ground Acceleration

I accept, as the starting point for determining effective acceleration, the stipulated peak horizontal acceleration at the GETR site resulting from an earthquake of magnitude 6 to 6.5 centered on the Veorna fault, of 1 g. Stip. 2.r. Consistent with that value resulting from an event on the Verona fault, would be a peak horizontal acceleration at the GETR site slightly in excess of 1 g, resulting from an earthquake centered on the point of the

Calaveras fault nearest the site. Devine, ff. Tr. 996 at 3. The testimony of GE's witness Dr. Kovach, alluded to in Staff Proposed Finding 104, suggesting lower values of peak instrumental accelerations, does not withstand careful scrutiny. Dr. Kovach reached expected values of peak instrumental accelerations of from .58 g to .74 g for an event on the Calaveras fault and up to about .4 g for an event on the Verona fault. Lic. Ex. 21 at 21-22; Tr. 593-96. However, he used the means of the horizontal peaks and their 90° components, rather than the peaks themselves (Tr. 616-17); he admitted that the USGS calculated values 20% higher than he, including a determination that peak accelerations for a 7.5 magnitude event at 3 kilometers (analogous to ground motion at the GETR site from an event on the Calaveras fault) of 1 g would be exceeded 50% of the time (Tr. 633-35); he admitted that seismic focusing might increase the values by up to 20% (Tr. 536, 700-01); and, he did not exclude the possibility that peak accelerations on the order of 1 g could occur at the GETR site (Tr. 539). Dr. Kovach's testimony, taken as a whole, lends support to the stipulated value for peak horizontal accelerations of approximately 1 g.

The design basis parameters, however, are not tied to peak instrumental accelerations, but to "effective" acceleration values of .75 g and .6 g for events on the Calaveras and Verona faults, respectively. The Regulatory Guide 1.60 response spectra are anchored to those values. It is Staff's testimony regarding "effective" acceleration that is critical to the design parameter since no other party offered evidence on effective acceleration.

Staff's testimony equated effective acceleration with values for peak instrumental accelerations recorded at locations at significant distances from the earthquake source. Hall, ff. Tr. 1680 at 5. The main justification for using less than the peak near-field instrumental acceleration to anchor the response spectra is that the peaks recorded in the near field are at too high frequencies and are insufficiently repetitive to cause structural damage. Tr. 1736-40. Staff offered extensive, uncontradicted, testimony to the effect that peak instrumental acceleration in the near field must be reduced in order to correlate the response spectra anchor points to observations of damage to structures. Tr. 1687-88, 1728, 1730-32, 1754; Hall, ff. Tr. 1680 at 2-4.

While I do not doubt that the peak instrumental acceleration figures must be reduced to correlate them to observed damage, I am not fully satisfied with how the Staff experts arrived at their .75 g value of effective acceleration from an event on the Calaveras fault. Apparently, the ACRS subcommittee (at a meeting in June, 1980) had also not been satisfied with the substantiation for Staff's effective acceleration anchor points, and requested further background material. Staff's experts, Drs. Hall and Newmark, submitted a further report which attempted to supply that background. Stf. Ex. 1-C at App. A. That report, entitled "Seismic Evaluation of Vallecitos Site--Basis of Earthquake Ground

Motion Design Criteria," still does not supply much hard data or objective criteria to support its conclusions. Ibid.

The bulk of the justification for reducing peak instrumental acceleration to effective acceleration is contained in the following portion of the report (at 2-3):

> Specifically, the near-field effects (as deduced from measurements and observations) as affected by the type and geometry of the structure, by soil-structure interaction and feedback, by the incoherent and complex seismic wave field, and by damping and energy dissipation mechanisms, on motions transmitted to the structure, typically have led to "design" or "effective" (acceleration) coefficients in the lower levels of buildings that are less than the peak near free-field instrumental values. Recent unpublished studies by the TERA Corporation suggest that at least a 20 percent reduction in motion is indicated when data on buildings and free-field data are both available. Because of the foundation conditions (structural mat and a relatively rigid structure) there is probably a more significant reduction for reactor structures; the relatively large and rigid foundation mat responds to some average acceleration value associated with the travel time of the seismic waves. An analogy of some help in visualizing this interaction effect is to consider the motions transmitted to a small boat and an ocean liner in rough seas.
>
> The situation in the case of the Vallecitos General Electric Test Reactor is somewhat, but not generally, different from that just described.

To what extent these factors were taken into account in arriving at the final figure for effective acceleration is undisclosed: Staff's experts used these factors only in an "implicit manner" and relied primarily upon their own "judgmental assessment" in arriving at their conclusions. Id. at 5; Tr. 1730, 1758. It would have been helpful to the Board to have heard a more detailed and quantitative exposition on the judgmental assessment.

It appears that the Hall-Newmark-Martore analyses for this proceeding relied heavily upon those experts' more detailed analyses for Pacific Gas & Electric Co. (Diablo Canyon Nuclear Power Plant, Units 1 and 2), ALAB-644, 13 NRC 903. In fact, the experts arrived at the same .75 g anchor point for an event on the Calaveras fault as had been used for the Hosgri fault in Diablo Canyon. Tr. 1708. It would also have been helpful to have heard a full explanation of why the same effective acceleration anchor point was appropriate for the GETR, considering that the Diablo Canyon facility is about 5.8 kilometers from the Hosgri fault (13 NRC at 926) as opposed to the 2 to 3 kilometer distance of GETR to the Calaveras fault. Furthermore, the Hosgri fault is associated with "smaller earthquake accelerations with definitely smaller magnitudes" and having greater return periods than the Calaveras fault. Stf. Ex. 1-B, App. A at 4. Apparently, these differences were not significant and the large margin of conservatism incorporated in the anchor point used in Diablo Canyon permitted use of the identical anchor point in this proceeding. However, a full presentation of these matters at hearing would have been appropriate.

2. Vertical Acceleration

Nor did I consider the Staff's and GE's testimony with regard to vertical accelerations entirely satisfactory. In its structural analyses, GE anchored the Regulatory Guide 1.60 response spectra to .75 g horizontal accelerations (not in combination with surface offset), and used two-thirds of the horizontal vibratory motion for vertical vibratory motion. Tr. 1969. Intervenors, however, urge using vertical ground accelerations in excess of the peak 1.74 g instrumental recording for the Imperial Valley earthquake of 1979. Int. Prop. Find. 85; Int. Prop. Concl. 19.

GE and the Staff discounted the high vertical ground motion recorded at Imperial Valley on the following alleged grounds: because it was attributable to a single, anamalous data point at Station 6, within the apex where the Imperial and Brawley faults meet (Tr. 600-614, 1595); because only two anomalous data points in the Imperial Valley set exceeded two-thirds of the peak horizontal acceleration (Tr. 1720); and because, in addition to being located between the Imperial and the Brawley faults, the high readings were attributable to the soil/sediment conditions in the Imperial Valley, which is overlain by alluvium at depth that produces high velocity gradients at the approach to the surface and tends to amplify the vertical motion (Tr. 526-27, 2003). Moreover, the high vertical readings were characterized as involving high frequencies (at 10 hertz or greater), which are not of concern to structures (Tr.1725, 2003), and as involving isolated peaks, rather than the sustained strong motion which causes damage to structures (Tr. 1725). In addition, the Board is urged to maintain the design basis vertical component of vibratory motion at two-thirds the horizontal because buildings in general are inherently strong in the vertical direction, and the rigid massive structures involved in nuclear power plants are relatively insensitive to vertical loadings. Vertical loadings are said to account for only an insignificant fraction of the total load placed on a nuclear power plant structure under design basis seismic conditions. Stf. Prop. Find. 112; Lic. Prop. Find. 36; Tr. 699-700, 1727, 2082-89.

A distinction should be made between whether the high vertical readings at Imperial Valley were attributable to anomalous data points, or whether the event itself was anomalous in that there were high vertical accelerations. I agree only with the latter interpretation. As to the data points being anomalous, the testimony was misleading. Referring to a standard reference tool not in evidence,30/ Seismic Engineering Program Report, September-December 1979, Geological Survey Circular 818-C, at 25-28, it is clear that vertical accelerations exceeded the mean peak horizontal accelerations at eight stations,31/ rather than at one or two. Peak vertical accelerations were also roughly equivalent to the mean peak horizontal accelerations at five other locations.32/ The vertical accelerations at five of these

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30/ The Board distributed copies of that document to the parties and requested their opinions on it by Order dated October 7, 1981.

31/ El Centro Imperial County Center, Array Station 5, Array Station 6, Array Station 7, Array Station 9, Differential Array, Holtville Post Office, and Parachute Test Site.

32/ Brawley Airport, Calexico Fire Station, Array Station 8, Meloland Overpass on Route I-8, and Westmorland and Fire Station.

stations[33/] exceeded the mean peak accelerations at Bonds Corner, the highest mean peak horizontal acceleration recorded. Furthermore, correlating the strong motion readings with the map on figure 4, page 6, of the document, containing the close-in motion stations, demonstrates a very consistent reduction in vertical readings as one moves further away in either direction from Array Station 6 (the only station within the apex of the Brawley and Imperial faults), which is the station closest to the Imperial Fault on the eastern side. Moreover, the durations of strong motion (defined in the document as peak accelerations greater than 0.1 g) for the vertical accelerations are shown not to be significantly less than the durations of horizontal motion. The maximum reading at each location, of course, would relate to the highest single peak, whether given for the vertical or horizontal components, and it would be rare if more than one peak were at the maximum reading.

On the other hand, a visual observation of figures 3 and 5 (at 5, 10-16) of that document, containing copies of accelerograms from the strong motion stations, confirms that the vertical accelerations were generally at a higher frequency. Whether this higher frequency ground motion, testified (Tr. 2003) to be predominantly at 10 hertz (cycles per second), is outside of the range that can damage the facility, cannot be verified from the

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33/ Differential Array and Array Stations 5, 6, 7 and 8.

record because no evidence was adduced regarding the natural frequencies of the safety systems. However, I have no reason to doubt the uncontradicted testimony that it was outside the range.34/

Although the stations reflecting high vertical readings at Imperial Valley may not have been anomalous with regard to representing the actual wave motion in the 1979 event, the event itself was unusual. Certainly, the high vertical readings are inconsistent with worldwide readings where vertical accelerations are generally less than 60 percent of horizontals. Tr. 2006-07, 2029-31. However, it would be impossible to determine on this record whether the high vertical readings are attributable to the soil conditions and the presence of the Brawley fault, or whether, as suggested by one witness (Tr. 1647-49), the Imperial Valley event and more recent events show higher vertical readings because the strong motion instruments were closer to the rupture surface than in the prior worldwide recordings and better reflect the vibratory motion that could be expected in the near-field.35/

34/ See, however, Diablo Canyon, supra, 13 NRC at 975, where the natural frequencies for the Diablo Canyon interior containment structure and reactor pressure vessel were shown to be 10.0 hertz and 14.0 hertz, respectively, and the piping systems were shown to be in the range of 2.9 to 16.0 hertz.

35/ GE's chief seismological expert Dr. Kovach could not exclude the possibility that a magnitude 7.5 event or the Calaveras could generate a vertical ground motion at the GETR site greater than the 1.74 g motion recorded at the magnitude 6.6 Imperial Valley event. Tr. 540-41.

With regard to the latter position, it might be noted that, in addition to the Imperial Valley event of 1979 where the peak vertical acceleration exceeded the peak horizontal accelerations, the Gazli earthquake of 1976 recorded a peak vertical acceleration of 1.3 g, as compared to peak horizontal values of .75 and .67 g, at a distance of 3-1/2 to 4 kilometers from the rupture surface. Tr. 618-19; Lic. Ex. 1 at 20.

In the absence of more than a few recent events in which recordings of vertical accelerations exceed horizontals and of engineering testimony that the high vertical accelerations are as capable of causing structural damage to the facility as are horizontal accelerations, I would not require a revision of the standard engineering practice of using two-thirds of the maximum horizontal component as the vertical component in the design basis of this facility. I certainly recommend, however, that the Staff review its requirements for future licensing to determine whether a ratio closer to 1, of vertical to horizontal accelerations, should be required in the design requirements where there are faults in the near-field, especially where vertical displacements might be expected.

Although I accept the two-thirds ratio of vertical to horizontal, I would emphatically reject one of the arguments advanced by Staff and GE, that the two-thirds figure is justified because buildings in general are inherently strong in the vertical direction. Lic. Prop. Find. 36; Stf. Prop. Find. 112. If the facility is sufficiently strong in the vertical direction to withstand an increased vertical loading, that strength should be reflected in the facility's response to the load cases used in analysis. To reduce the seismic loading inputs to account for increased structural capacity courts the risk of taking double credit for the same structural capacity values, although that apparently was not done in this case. It would be a far better procedure, in my opinion, to develop the load cases on the basis of realistic seismic inputs and to correlatively utilize realistic structural values to analyze the facility.

As may be apparent, my reservations concerning the ground motion parameters recommended by Staff relate primarily to the manner in which they were presented to the Board. I have no hesitation in concluding that the preponderance of evidence supports the continued use in this case of two-thirds of the horizontal ground motion as the vertical component, in accordance with general engineering and NRC practices. Similarly, no probative evidence has been adduced that would undermine the use of .75 g and .6 g effective horizontal acceleration anchor points for the Calaveras and Verona faults, respectively.

II. THE ABILITY OF GETR TO MEET THE DESIGN BASIS CRITERIA

As indicated at the beginning of my opinion, I recommend the removal of the show cause order even though I would increase the surface offset design parameter from Staff's recommended one meter to 2 meters. I base my conclusion that the GETR can be restarted, with the structural modifications proposed by GE and with further modifications to the flexible piping, on the evidence adduced with regard to the ability of the modified GETR's safety systems to withstand the seismic stresses postulated by GE and Staff. The stresses on the safety systems would apparently not be changed in any material manner by the increase in surface offset design parameter from 1 to 2 meters. Notwithstanding this ultimate conclusion in favor of a resumption of operations, I must express certain reservations with regard to the manner in which the structural analyses were presented to the Board by Staff and GE (and adopted by the Board majority), and with regard to the analyses themselves.36/

36/ Intervenors presented only one witness on the structural integrity of the GETR. The substance of his testimony was that as a structural engineer he could not guarantee that a structure such as GETR would resist the postulated earth movement without some structural damage. He offered no specific evidence that could be construed as meeting the burden of proving that the show cause order should be sustained. Tr. 2181-93.

One major point that has been obscured in the Staff's and GE's presentations (and the majority opinion) is that the modified GETR has not been shown to be structurally capable of meeting the design basis parameters. Rather, although the surface offset design parameter has been set by the Staff and GE (and adopted by the majority) as 1 meter, the structural analysis has been found to be satisfactory only with regard to a zero displacement underneath the foundation mat.37/

The structural analysis originally presented by GE to the Staff (in which an offset was considered as intersecting the foundation mat) contained a soil bearing capacity analysis in which the soil strength was taken to be 20 ksf. It was hypothesized by GE that an offset occurring directly underneath the GETR foundation could cantilever the reactor building but not beyond an unsupported length of 20 feet because the soils would collapse if an offset

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37/ Presumably the reason for not requiring the structure to withstand the full postulated design basis is the provision in 10 C.F.R. Part 100, App. A, Part VI(b)(3) which requires that the design provisions for the structure be based upon the design basis for surface faulting "unless evidence indicates this assumption is not appropriate." Apparently, because of the fault deflection analysis, discussed later, the assumption that a 1-meter offset could occur underneath the foundation mat was not considered "appropriate" and was eliminated from the structural analysis.

An alternative interpretation of GE, Staff and Board position is that the design basis is being modified because of the fault deflection analysis so as to include a 1-meter offset surfacing only beyond the perimeter of the foundation mat, with a zero offset being considered underneath the foundation mat.

were to lift the reactor at a point closer to the center of the foundation mat. This would create a situation in which the building would be supported by the soil, resulting in minimal loadings on the foundation.

The Staff rejected the 20 ksf value for soil strength proposed by GE as being too low. Because a higher value would allow for a greater unsupported length, creating greater cantilever stresses on the reactor building than had been analyzed by GE, the structural analysis was not accepted. However, GE later submitted a fault deflection analysis which demonstrated to the Staff's satisfaction that no credible fault would surface underneath the reactor. Stf. Ex. 1-D. Thereupon, Staff concluded that the structural analysis was acceptable. Id. at 6. I cannot accept these circumstances as amounting to the GETR's satisfying the 1-meter design basis parameter for surface displacement. Staff has not, in fact, required that the ability to withstand a 1-meter offset be included in the GETR's structural requirements.

Another matter obscured in GE's and Staff's presentations is in the suggestion that the total surface offset and vibratory ground motion were considered to occur concurrently in the structural analysis. Stf. Prop. Finds. 58, 59; Lic. Prop. Finds. 4; Stf. Ex. 1-B, Section A at 6; Justus and Jackson, ff. Tr. 996 at 11; Tr. 1048-53. Rather than this alleged assumption of co-seismicity, GE and Staff actually took into account considerably less than the estimated peak effective vibratory motion in conjunction with surface offset. Instead of assuming that the design basis parameter of .6 g effective acceleration on the Verona fault would occur in combination with the postulated surface offset, GE and Staff actually analyzed only a .3 g effective ground acceleration for a co-seismic loading.

I cannot accept the conclusion that this amounts to considering the combined loads caused by fault offset and ground vibratory motion as acting simultaneously. The Board majority is, in fact, not requiring the GETR to meet this design basis parameter. However, because of the fault deflection analyses, I agree that the co-seismic loading will not develop at the foundation mat and cannot otherwise affect the GETR's seismic safety systems if they are properly modified.

I will elaborate further on my reservations.

A. <u>GE's Structural Capacity Analysis</u>

GE undertook a program of investigations to demonstrate the adequacy of the concrete core or shield structure to withstand seismic events postulated for the site. The concrete core structure was analyzed to insure its integrity once subjected to vibratory ground shaking and surface rupture offset that might be expected from the Calaveras or Verona faults. Lic. Ex. 22 at 47-48; Lic. Exs. 23-41. GE examined three load cases on the assumption (1) that there would be only a ground acceleration from an event on the Calaveras fault, and (2) that there would be ground motion in combination with a 1-meter offset from an event on the Verona fault that might result in a cantilever effect on the reactor building creating an unsupported length of part of the reactor foundation. The ground acceleration was considered as a point on which to anchor the standard response spectra of Reg. Guide 1.60. The three load cases for unsupported cantilever length and horizontal[38/] vibratory ground motion were, as follows:

Case 1.[39/] -- Ground Acceleration = 0.75 g
-- Unsupported Length = 0 feet

Case 2. -- Ground Acceleration = 0.30 g
-- Unsupported Length = 17 feet

Case 3. -- Ground Acceleration = 0.0 g
-- Unsupported Length = 20 feet

[38/] GE performed the analyses using vertical accelerations of two-third's the horizontals.

[39/] For Case 1, GE performed a linear elastic analysis for a ground acceleration of .8 g. The dynamic analyses were performed for 2 horizontal (northeast and northwest) components and the vertical components (at 2/3 the horizontal) independently. Lic. Ex. 37, p. 2. The analysis for Case 2, involving a ground acceleration of .3 g and unsupported length of 17 feet, was performed concurrently for three components of earthquake motion and indicated that the vertical component (at 2/3 the horizontal) influences the principal stresses on the facility by about 10%. GE, therefore, concluded that it was unnecessary to make additional stress analyses for the three components of earthquake motion acting concurrently at .75 g and that it could, instead, use the .8 g analysis of the independent components as equivalent to a .75 g analysis of the three components acting concurrently. Id., pp. 3-4.

From these three load cases, which GE's analysis indicated the plant could withstand sufficiently for a safe shutdown, GE drew a curve representing a capacity contour of the plant from the .75 g point on the vertical "Ground Acceleration" axis to 20 feet on the horizontal "Unsupported Length" axis, and passing through the coordinates of 0.3 g and 17 feet. Lic. Ex. 34, Fig. 11; Lic. Ex. 39, Fig. 1. See Fig. 1 below.

The 20 feet of unsupported length was determined to be the maximum unsupported length of the 72-foot wide reactor building that could be supported by the soil before the soil collapsed, based upon the assumed 20 ksf strength of soil. Once the soil collapsed and the reactor settled, it would not be in a cantilevered position but would be supported by the soil and, according to GE, would be in a condition that could easily be tolerated without distress in either the soil or the structure. Lic. Ex. 38 at 3-4. GE performed a series of analyses of soil pressure underneath the reactor building for different combinations of horizontal ground acceleration and unsupported lengths of reactor building. The soil pressures examined were calculated to be the result of the vertical weight of the structure and the overturning moment produced by the horizontal seismic forces. The purpose was to determine the maximum load combinations that the soil could withstand before collapsing and permitting the reactor building to settle.

As a result of the soil pressure analyses, GE plotted a band to represent the limits of soil bearing capacity using the same

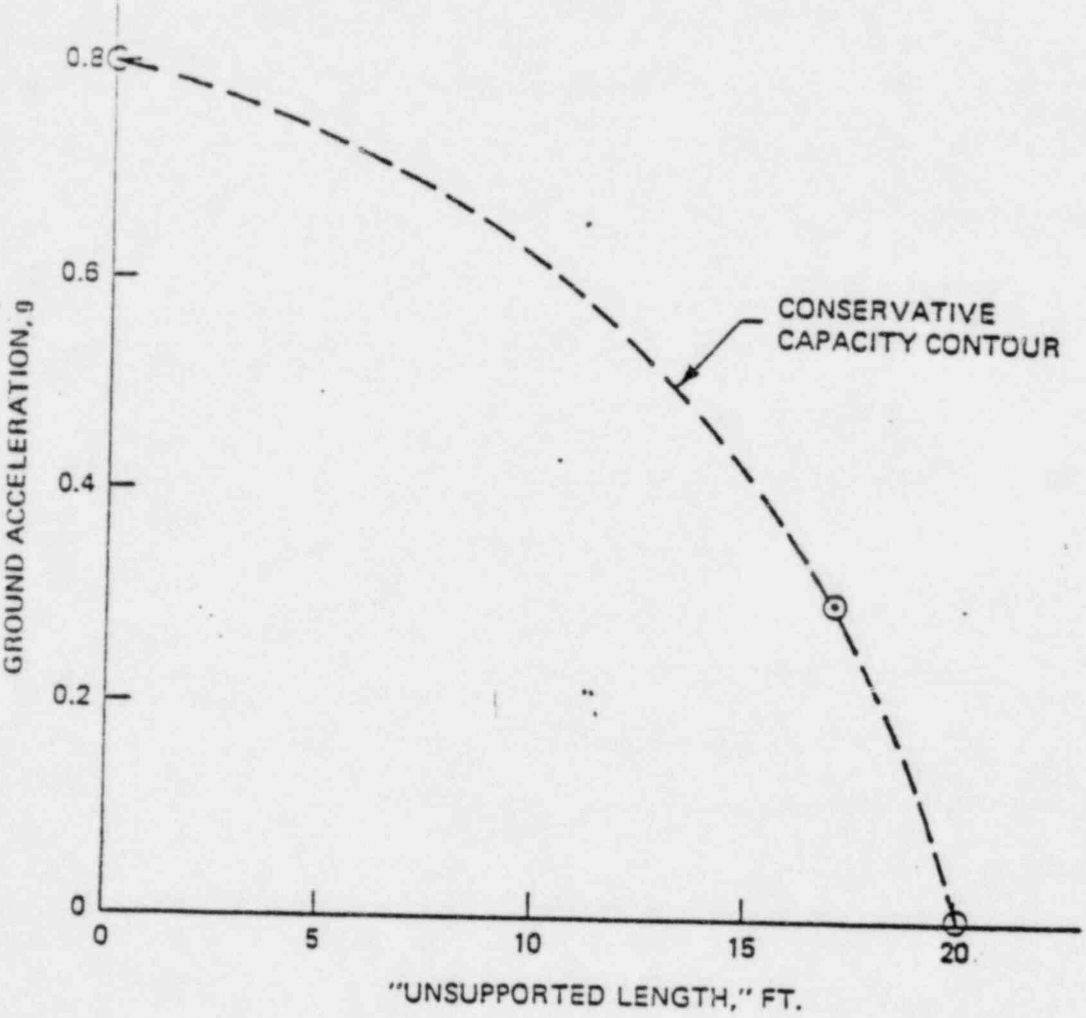

FIGURE 1. CAPACITY CONTOUR FOR COMBINED LOADING
(REPRODUCED FROM FIGURE 11 OF LIC. EX. 34)

axes (i.e., ground acceleration on the vertical axis, and unsupported length on the horizontal axis) it had used to draw the capacity contour curve for the structural capacity of the reactor building. (GE used a band for the soil pressure, rather than a line, to represent the load combinations on the soil between when there would be incipient local yielding of the soil and when there would be a total collapse of the soil.) Lic. Ex. 38. See Fig. 2, below. By plotting the capacity contour and the soil pressure failure band on the same graph, GE attempted to show that because the capacity contour was outside of the soil pressure band, the soil could not withstand any loading that would exceed the capacity of the plant. Therefore, no cantilever could develop that would exceed the plant's structural capacity.

The NRC Staff did not accept these analyses. It determined that they had been based upon a lower bearing capacity for the soil beneath the foundation than was justified and that a higher value of soil bearing capacity would likely result in a larger unsupported cantilever length of the foundation mat than had been analyzed by GE. Stf. Ex. 1-D. Although GE suggests otherwise (Lic. Prop. Finds. at fn. 61, pp. 132-33) no evidence was offered that higher soil bearing capacities were successfully analyzed by GE or

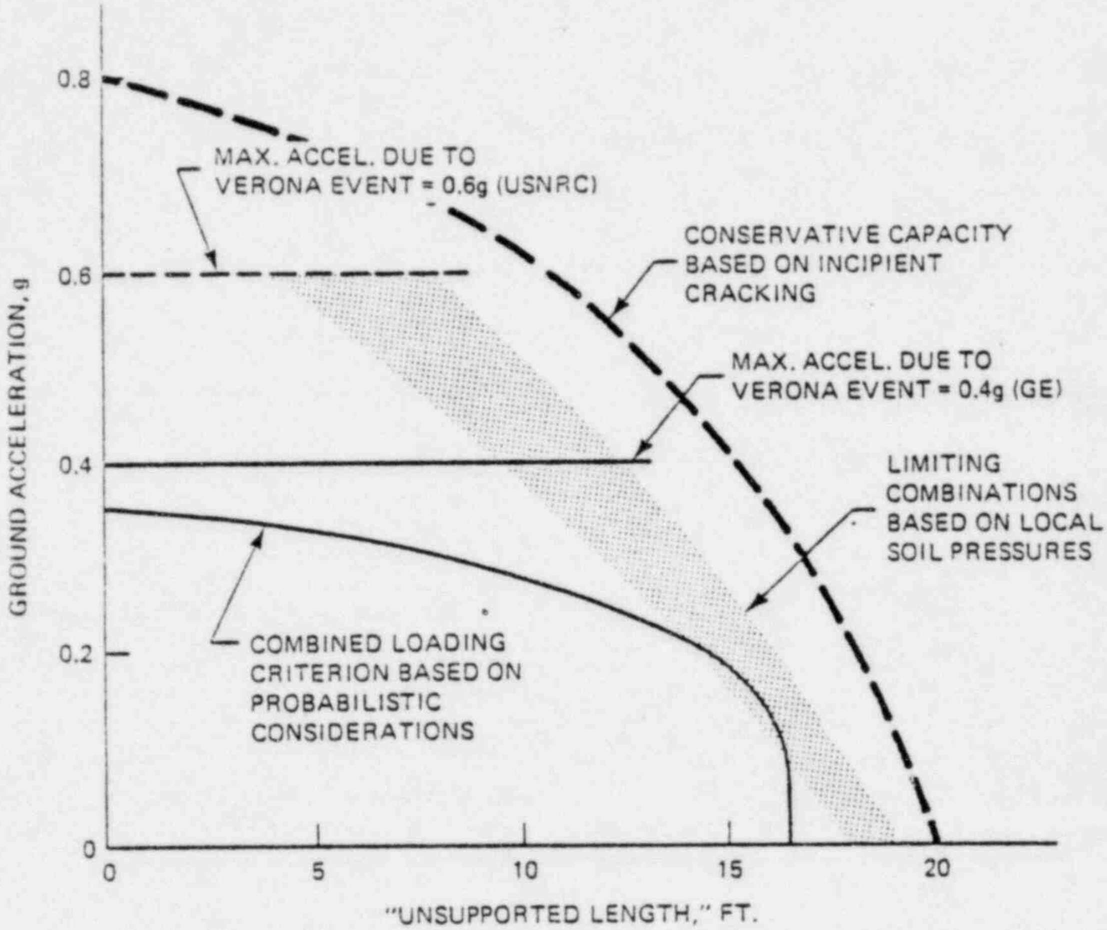

FIGURE 2. LOADING VS. CAPACITY
(REPRODUCED FROM FIGURE 6 of LIC. EX. 39)

that the Staff had found GE's conclusions acceptable because higher values had been analyzed.40/

I question GE's structural analysis on grounds other than use of an insufficient 20 ksf value for soil strength. The only combination loading (unsupported length plus vibratory ground motion) analyzed by GE was at .3 g vibratory motion and 17 feet unsupported length. In the face of the Staff and GE's position that the design basis vibratory motion and surface offset were taken into account concurrently, it is surprising that the structural analysis did not take into account loadings attributable to a .6 g vibratory motion and 20-foot (or greater) unsupported length.41/ One justification for considering less than the

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40/ Legally no inferences should be drawn from the fact that no further analysis was presented to the Board with regard to a strength of soil exceeding 20 ksf. Nevertheless, I would be suprised if higher values were not analyzed and even more surprised that, if they were and the structural analysis were favorable, GE would not have offered the study into evidence.

41/ It is perhaps even more surprising that Staff did not inform the Board that the design basis parameters were not taken into account concurrently and even suggested the contrary. See Stf. Prop. Find. 185, which states, inter alia:

> 185. Analyses of the reactor building for the effects of the design parameters related to the Verona fault were performed by combining the effects resulting from the vibratory motion with those resulting from surface rupture.

Staff neglects to inform us that the "effects" of the design parameters are something other than the design parameters themselves.

design basis parameters acting concurrently on the structure was GE's conclusion that a combination of ground motion and unsupported length for cantilever loading at the "worst cases" (i.e., design basis) are "unrealistic and overly conservative." Lic. Ex. 34 at 2. GE, therefore, selected the combination of 17 feet unsupported length and .3 g horizontal ground acceleration "since it is conservative from probabilistic and physical points of view." Id. at 3. No evidence was offered to demonstrate the reasonableness of this probabilistic conclusion.

As to a "physical" rationale, GE had earlier attempted to justify to Staff the use of less than the combined design parameters for vibratory motion and surface offset on the ground that evidence from earthquake studies indicates that fault displacement takes place only after the occurrence of the strong vibratory ground. Lic. Ex. 23 at Part 1. (If they were to take place concurrently or the displacement were to take place first so as to place the reactor in a cantilevered position before the onset of the maximum vibratory motion, the maximum loadings on the reactor would have to be taken into account simultaneously.) If GE relied upon the theory that the maximum vibratory motion would occur before displacement to justify using less than the peak vibratory motion from the Verona fault in combination with the ground displacement, that theory would appear to have been undermined at hearing. The USGS experts testified that the ground motion and surface displacement were simultaneous at San Fernando, that co-seismicity is the rule for strike-slip and normal dip-slip faults, and that there is very little data on which to form a general opinion with regard to reverse dip-slip faults (as is hypothesized for the Verona fault). Tr. 1051-53.

Even assuming the propriety of using less than maximum vibratory ground motion in combination with cantilever loading, GE's capacity contour is less than illuminating for another reason. I would have considerable difficulty in accepting a curve that is drawn through only 3 points, two of which are on the respective vertical and horizontal axes. One represents only vibratory ground motion, and the other represents only unsupported length. More specifically, I do not see how an assumption can be made that, because the structure can withstand a horizontal ground acceleration of .75 g in a non-cantilevered position and can withstand a .3 g vibratory motion at an unsupported length of 17 feet, the structure can withstand any ground motion in excess of .3 g while in a cantilevered position. It appears to me that the dynamic loadings for vibratory ground motion represented by the vertical axis and the static loadings for the unsupported cantilever lengths represented by the horizontal axis appear too dissimilar to permit use of that simple curve drawn by GE. More importantly, the non-uniformity of the reactor building as far as weight distribution and varying strengths at different locations would suggest some caution in treating the building as a simple cantilever whose loadings increase proportionately with increases in unsupported length. Many more curves than the one applied by GE can be used to connect the three points.42/

Be that as it may, the Staff's rejection of the structural analyses served as the impetus for GE's fault deflection analysis, which appears to make the deficiences in the bearing capacity analysis immaterial.43/

42/ GE later adjusted the curve shown in Figure 2, above, by flattening the curve at the top (at .75 g). This was done by assuming that short unsupported lengths will result in a very small loss of support and, thus, will have little influence on concrete stresses. The flattened curve suggested that the reactor had the same capacity to withstand a vibratory motion of .75 g at approximately a 7-foot unsupported length, as it had at the zero unsupported length at which it was actually analyzed. See Lic. Ex. 39 at 3 and Fig. 3; Lic. Ex. 41.

43/ At its meeting of November 6-8, 1980, the ACRS reviewed GE's request to restart and operate GETR. Stf. Ex. 2 (ACRS recommendation of November 12, 1980). The ACRS had before it at that time Staff's draft of its October 27, 1980 SER in which original page c-8 of Part II supported GE's soil pressure/capacity contour analysis and indicated that the evaluation supporting a favorable conclusion was attached as App. B. The Staff's cover letter indicated that the SER was being given only draft status because the Staff had not yet completed its evaluation of GE's structural analysis. Only a cover page for App. B was included in the draft SER with an indication that the Appendix would be provided by separate letter.

The ACRS recommendation seems to be based on a belief that the Staff required the GETR to be capable of withstanding a ground level acceleration of 0.6 g simultaneously with a surface displacement of 1 meter (a load case which apparently had never been analyzed). The ACRS letter recommended that the GETR be restarted and operated subject to the resolution of the issue involving the characteristics of the soil beneath the GETR foundation. The ACRS position was that "plant as modified should be able to withstand the postulated seismic events with no significant release of radioactive material."

[Footnote continued.]

B. The Fault Deflection Analysis

GE's fault deflection analysis was based upon the theory that the heavy weight of the reactor would interact with the soil and distort it so as to deflect any fault from surfacing at the reactor foundation. According to GE's theory, if a heavy structure such as GETR were founded on rock and a fault moved to intersect the foundation, the foundation would be suspended or loaded in a cantilevered position. If, on the other hand, a heavy structure such as GETR were founded in soft mud or loose sand, the same fault motion would not suspend or cantilever the foundation. The weight of the structure would cause the soil to flow and would deflect the fault around the reactor foundation, *i.e.*, the fault would seek the path of least resistance. The GETR is founded on neither hard rock

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[Footnote continued.]

There is no indication that the Staff ever requested a further recommendation from the ACRS with regard to restarting the GETR in the circumstance of not having to satisfy the design basis criteria (1) because the design basis values for ground motion and surface displacement from the Verona fault were never taken into account concurrently and (2) because the fault deflection analysis was used in place of requiring the structure to fully withstand the postulated seismic event.

nor soft mud or sand. Rather, it is founded on clay, sand and gravels, the properties of which lie somewhere between hard rock and soft mud. GE, therefore, presented its deflection analysis to demonstrate that all fault planes which intersect the foundation would require a greater force to failure than all fault planes which did not intersect the foundation, and that the fault would deflect around the foundation.

GE's deflection analysis assumed that the GETR site is geologically capable of thrust faulting, with thrust fault angles dipping from 10 to 45°, dip being measured at or near ground surface. The analysis visualized that the thrust fault forms a passive Rankine wedge of soil that is pushed by a major principal stress. The inputs into the calculations were the weight of the soil, the strength properties of the soil, the location of the groundwater table and the weight of the reactor. The principal special condition that exists at GETR is the weight of the reactor, which produces a downward load of 4,000 lbs. per square foot. Lic. Ex. 20 at 4; Pichumani ff. Tr. 996 at 5; Tr. 2289; Lic. Ex. 1 at 84-94.

The importance of this fault deflection study should not be underestimated. Although Staff apparently believes otherwise (Tr. 1701-07, 1775-83), the fault deflection analysis, if accepted, would moot the question of the size of the offset that can be withstood by the reactor building. Except for certain flexible piping used for the fuel flooding system (see Lic. Ex. 30 at 2-4 to 2-5), which is located outside of the reactor building and was analyzed only at a 1-meter surface displacement, it does not appear that any other structure or equipment that is related to the seismic safety of the GETR is located outside of the reactor building and would be affected by an offset that deflects around the building. It is likely that the flexible water piping that might be affected by an offset surfacing outside of the reactor foundation could easily be modified to accommodate a greater displacement of 2 meters. With regard to the reactor building itself, the deflection around the building would preclude the offset from intersecting the foundation mat, but not the portion of the containment structure (the outer ring wall) beneath the ground surface. However, as more fully discussed below, the ring wall is not considered a safety structure whose integrity must be maintained during a seismic event.

Notwithstanding the Staff's acceptance of GE's deflection study and the absence of any intervenor testimony critical of the study, I have some reservations. Although it had been testified that GE's method of wedge analysis is based on sound soil mechanics principles (Pichumani ff. Tr. 996 at 5), the only known instance of this phenomenon, of a fault deflecting around a structural foundation during a seismic event, was a bank vault in Nicaragua where this phenomenon was believed to have occurred. Lic. Ex. 1 at 89-90; Pichumani ff. Tr. 996 at 7-8; Tr. 467-69, 1610-11. Even that one instance can only be theorized as being a fault deflection due to the weight of the vault, rather than considered as a definite observation that this phenomenon occurred.

Tr. 1612. Moreover, none of the witnesses appearing at the hearing had actually observed such an occurrence or could cite another example where this phenomenon might have occurred. Tr. 1610-13, 1629-33, 2035-36, 2269-72. GE had made considerable attempts to find some evidence supporting this deflection analysis but was not successful. Tr. 2271-72. In contrast, the San Fernando earthquake of 1971 was in large part a thrust faulting event (similar to what could be expected from the Verona fault) and came up under quite a few buildings. In each case, the fault was not troubled at all by the existence of the structure and simply went through the structure or lifted it and broke it in half. Tr. 2275.

The deflection analysis, itself, raises some questions about its reliability. The favored planes (those requiring the least force to failure) immediately outside of the foundation appear, for some of the postulated Rankine wedges, to require on the order of only about 10% less force than the failure planes underneath the reactor. Lic. Ex. 1 at Fig. 51, p. 91; Lic. Ex. 20 at Figs. 4-7. GE had varied the locations for the failure planes at an assumed wedge depth of 70 feet below the reactor foundation slab. Stf. Ex. 1-D at 4. The Staff reviewed the analysis and performed additional calculations for an assumed wedge depth of 100 feet and apparently found the differences between the failure planes underneath the reactor and those alongside of it even less, so as to cause Staff to condition its approval upon the presence of a 21-foot high surcharge within about 170 feet of the reactor building. Id. at 4-5. Considering that the degree of certainty in soil mechanics is considerably less than in structural engineering because of the variability of natural materials compared to steel and concrete (Tr. 2284), one might question whether the small differences between the postulated failure planes are sufficient to allow for a high degree of confidence that the deflections will occur as predicted.

Furthermore, certain of the assumptions implicit in the study are open to question. Unlike the allegedly analogous bank vault in Nicaragua which was buried in lightly cemented gravels and uncemented sands (Lic. Ex. 1, Fig. 50, p. 90), GETR is underlain by very dense clay, sand and gravel with occasional layers of very dense sandy and/or gravelly clay to a depth of 70 feet. Stip. para. 2.m. There is no indication in the record that GE's study took into account any inhomogeneities in this relatively cohesive soil, including even the possibility of existing shears within the postulated 70-foot depth of wedge that might influence the direction of a failure plane. If, for example, an existing shear shallower than the 70-foot depth were directed at the GETR foundation, the force required to move the failure plane along the existing shear might possibly be less than the force needed to create a new plane of failure.

GE's fault deflection analysis appears also to conflict with GE's October 31, 1980 analysis (Lic. Ex. 19) that was submitted to the NRC to further support the soil pressure/contour curve analysis that the Staff had begun questioning at that time. There, GE had postulated a fault plane (A) intersecting the foundation and a shifting of movement to fault plane (B), also intersecting the foundation. See Fig.3, below. As stated in the report (at 7-8):

> However, shifting of movement to (B) causes a new (and also untenable) load distribution, perhaps causing the most favored fault plane to return to (A). Here this analysis breaks down, for it does not model the curve failure planes, soil-structure interaction, etc. that define the true developing pattern of deformation.

GE concluded with regard to this Rankine wedge analysis (corrected p. 11):

> Simplified wedge analysis of faulting beneath the reactor indicates a tendency of faults to steepen in such a manner that they erupt on the near (right) side of load concentrations. This suggests that faults surfacing 15-20 ft. from the left side of the reactor foundation evolve into ground deformations which tilt the reactor to the left, rather than lifting it without rotation.

These observations suggest that, in certain cases, the favored fault planes shift to the right within the boundaries of the reactor foundation but cannot be further analyzed to determine their precise final locations. They may even return to their original locations. Apparently, however, GE must have resolved these uncertainties by its further modelling of the Rankine wedges in the fault deflection analysis upon which it now relies.

While the conclusion of this further analysis is apparently justified, that the favored fault planes lie outside of the reactor foundation, the small differences in force values between the favored failure planes outside of the foundation and those which intersect the foundation, the possible inhomogeneities in the soil, the lack of knowledge about possible existing shears beneath the reactor, the lack of historical observations to support this

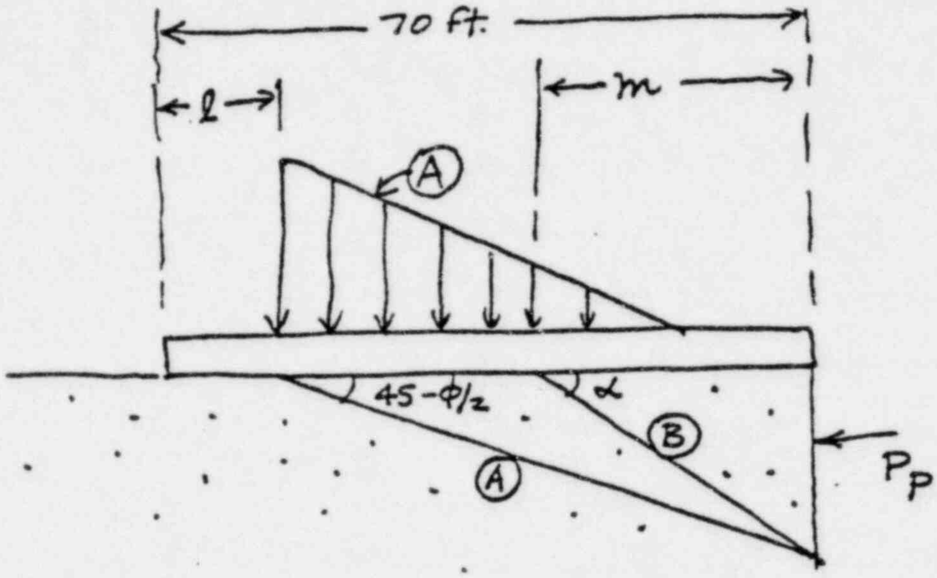

FIGURE 3. RANKINE FAULT MODEL
(REPRODUCED FROM FIGURE 5 OF LIC. EX. 5)

postulated phenomenon, the absence in the literature of any similar analyses upon which structural engineers have relied, and the uncertainties expressed by GE in its October 31, 1980 report concerning the anticipated paths of the failure planes, suggest some caution in relying upon this analysis to eliminate the possibility of a surface offset from the Verona fault intersecting the foundation.

Presumably, Staff reviewed GE's fault deflection analysis with the requisite caution and considered all of the matters on which I have expressed my concern.[44/] Had the Board not been satisfied at hearing with Staff's review, it would have questioned GE and Staff at length on the structural analysis, as it did on the geological analysis. I raise these matters at this point only to place the structural analysis in its proper perspective, without the appearance of certainty suggested by the majority findings. However, none of my reservations can, or are intended to, indicate disagreement with the majority's ultimate conclusion that the GETR's safety related structures, systems and components, as modified, meet the requirements to assure that the reactor can be safely shut down and maintained in the safe shutdown condition during and after the design basis seismic event. The burden of proving otherwise has clearly not been met.

44/ Had Staff discussed these matters at hearing and indicated its bases for resolving them, I would not have to raise them at this juncture. See my discussion of the role of Staff in Part III, *infra*.

It is, perhaps, unfortunate that Staff chose not to elaborate fully at hearing upon what may have been its own reservations on the fault deflection analysis and the steps it took to resolve them. Nor did Staff even explore at hearing its rejection of the bearing capacity analysis. However, the Commission's regulations do not require a comprehensive presentation by Staff, and Staff has satisfied its regulatory requirements to the letter.

In view of Staff's rejection of the soil pressure bearing capacity analysis, I find very curious Staff's Proposed Findings 79 and 93, which suggest that the Staff accepted the assumption of surface offset as a "conservatism." Prop. Find. 79 states:

> 79. A final conservatism in the Staff's proposed design is the consideration of surface offset even though geotechnical engineering considerations indicate that a fault will deflect around the reactor.

Staff's Proposed Finding 93 states, <u>inter alia</u>:

> Accordingly, the Board agrees that the assumption of surface offset occurring beneath the GETR is conservative in light of the above geotechnical engineering considerations.

Obviously, Staff did not assume that the offset will occur beneath the reactor. Otherwise, it would not have recommended the restart of GETR because Staff did not accept GE's structural analysis as demonstrating that the GETR could withstand Staff's design basis parameters for surface displacement and effective acceleration. Staff accepted the fault deflection analysis as the <u>sole basis</u> for assuming that the GETR could maintain its structural integrity in the face of the postulated surface displacement design basis, and did not also assume as a "conservatism" that an offset could occur under GETR.

Similarly, it is because of the fault deflection analysis that I concur with the Board majority that the GETR can be successfully modified to be safely shut down in the event of the design basis earthquake on the Verona fault.

C. Containment Failure

A deflection of an offset from the Verona fault, as postulated in GE's fault deflection analysis, would not eliminate the possibility of damage to the outer ring wall of the containment building. In addition to considering a possible cantilever effect upon the facility of a ground offset from the Verona fault, GE also considered a situation in which the offset would bypass the foundation mat on either side of the reactor building and create horizontal soil pressure loading on the exterior ring wall. In either case (where the offset goes beneath the reactor building and surfaces on the far side, or surfaces on the near side without going underneath the reactor building), the postulated one-meter offset from the Verona fault was considered capable of cracking and deforming the ring wall between the basement and first floor levels. Lic. Ex. 22 at 56-60, Lic. Ex. 25 at Parts 3 and 4; Lic. Ex. 4. However, because GE concluded (with Staff's agreement) that the core structure does not require the outer ring wall for its support, the postulated cracking and deformation were considered acceptable.45/

In the SER of October 1980 (Stf. Ex. 1-C at C-3), Staff indicated that the GETR, under the proposed modifications, would meet the acceptance criteria consistent with 10 C.F.R. Part 50, Appendix A, Criterion 2, notwithstanding that the containment shell might not maintain its integrity under the postulated seismic event. On Board questioning, GE's structural witness Gilliand indicated that GE's Final Safety Analysis Report had relied upon maintaining the integrity of the containment for certain of the design basis accidents described therein. Tr. 1967.

Staff agreed that the FSAR relied upon maintaining containment integrity, but argued that maintaining the integrity of the containment in the event of a design basis seismic occurrence was not necessary because a breaching of the containment in the seismic event would not result in releases beyond the guidelines permitted by the regulations. Tr. 2211-21. Apparently, a seismic event would not cause releases beyond those guidelines, as a design basis

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45/ It is perhaps because of the situation involving offsets that might surface to the sides of the reactor building that Staff Witness Hall indicated that the Verona offset need not surface beneath the reactor, but need only be in near field to cause damage to the reactor. Tr. 1748. Why he limited his endorsement of the structural capacity of the GETR to withstanding only a one-meter offset (Ibid.), in view of the Staff's acceptance of the fault deflection analysis and the assumption that the outer ring walls are not necessary for the safety of the facility, was not explained.

accident might, because the postulated earthquakes would initiate the seismic scram system that would immediately trip the reactor. Some design basis accidents might not initiate a reactor trip. Tr. 2218-19; Stf. Ex. 1-C at A-2.

Upon further questioning by the Board, Staff conceded that it had not considered an occurrence of a design basis accident for which the containment might be needed with the simultaneous occurrence of a postulated seismic event. It had not even considered the occurrence of a design basis accident (such as at Three Mile Island), which relied upon the containment to prevent excessive releases, with the subsequent occurrence of a seismic event that would breach the containment. Tr. 2226-36. Staff further conceded that not considering the design basis accident in combination with the seismic event did not comply with 10 C.F.R. Part 50, Appendix A, Criterion 2. Ibid.

Criterion 2 states, as follows:

> Criterion 2--Design bases for protection against natural phenomena. Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (3) the importance of the safety functions to be performed.

Criterion 16 also appears relevant and states, as follows:

> Criterion 16--Containment design. Reactor containment and associated systems shall be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

Staff indicated that, as a legal matter, compliance with the General Design Criteria established by Appendix A to Part 50 was not necessary for the GETR since the Criteria apply only to water-cooled nuclear power plants. Tr. 2228. As a further substantive explanation of why the Staff chose not to consider the accident and seismic events simultaneously, Staff referred to the differences between the GETR and nuclear power plants, such as power levels, fission product inventory, the seismic scram system at GETR, the lack of need for complex systems to mitigate accidents at GETR, and the lower operating temperature at GETR. Tr. 2229. Finally, Staff indicated that it felt no need to postulate very low likelihood events occurring simultaneously. Tr. 2230.

Although Appendix A to Part 50 does not further define "appropriate combinations" (of the effects of accident conditions with the effects of natural phenomena), referred to in Criterion 2 (2), I would agree with Staff that they would include a consideration of the design basis accidents for which the containment is necessary in conjunction with the postulated seismic events which would breach the containment. Consequently, even under the Board majority's geologic design bases the containment would be breached and General Design Criterion 2 would not be met. Similarly, Criterion 16 establishes an absolute requirement for a leak-tight reactor containment and would appear to be violated by adopting seismic design parameters that permit the containment to be breached. Therefore, if Appendix A to Part 50 applies to GETR, the reactor could not restart.

I and my fellow Board members agree with Staff and Applicant that Appendix A to Part 50 and related Appendix A to Part 100 do not apply to the GETR.[46/] Although suggested otherwise by GE (Lic. Prop. Concl. 1-11), the GETR is a "testing reactor," as defined by 10 C.F.R. § 50.21(c) because its original license was issued under Section 104c of the Atomic Energy Act. As a testing reactor, it would be subject to the general provisions of Parts 50 and 100 of the Commission's regulations. However, 10 C.F.R. § 50.34(a)(3)(i) and 10 C.F.R. § 100.10(c)(1) apply Appendices A of their respective Parts only to "nuclear power plants"--not to testing reactors. Similarly, Appendices A to Parts 50 and 100, by their own language, appear to exclude from their ambit any nuclear reactors that are not necessary for electric power generation.

Furthermore, the General Design Criteria for Nuclear Power Plants, Appendix A to Part 50, were adopted on February 20, 1971. 36 Fed. Reg. 3256. The Seismic and Geologic Citing Criteria for

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46/ The entire Board joins in this portion of the concurring opinion which indicates why Apps. A to Parts 50 and 100 do not apply to GETR.

Nuclear Power Plants, Appendix A to Part 100, were adopted on November 13, 1973. 38 Fed. Reg. 31281. Neither of the Appendices A applies to licenses issued prior to its effective date in the absence of a specific requirement by the Commission that the facility be backfitted to meet the requirements of the Appendix.47/ See 10 C.F.R. §§ 50.109 and 100.2(a).

We are concerned in this proceeding with a license issued on January 7, 1959, more than 10 years before the effective dates of Appendices A to Parts 50 and 100. Although the license was due to expire on October 6, 1976, GE filed an application for renewal on October 20, 1975, almost a year before the expiration date. Under 10 C.F.R. § 2.109, the existing license is deemed to continue until an application for renewal, filed at least 30 days before the expiration date, has been ruled on. Consequently, the show cause order applies only to the existing license, to which Appendices A to Parts 50 and 100 would not apply because they are not retroactive, even if the facility were a nuclear power plant (rather than a testing reactor). The Board, therefore, concludes that the failure of GETR to meet the requirements of General

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47/ An argument can be made that, by requiring a determination of the proper "seismic and geologic design bases" for the GETR, a term of art indigenous to Apps. A of Parts 50 and 100, the Commission intended to apply those Appendices in toto to GETR. See Comm. Memorandum and Order of February 13, 1978. There is, however, no reason to suppose that the Commission intended to single out this testing reactor for the more stringent requirements imposed upon nuclear power reactors.

Design Criteria 2 and 16 in the event of a design basis earthquake does not preclude the resumption of its operations.

As a non-technical person, I must confess some difficulty in accepting the proposition that the containment structure is totally unnecessary for maintaining the integrity of the concrete core structure containing the bulk of the seismic safety system. Nevertheless, the uncontradicted evidence presented by the qualified experts in this area is to that effect. They had even conservatively assumed that the concrete core structure would have to resist the seismic forces induced by the weight of all structural components exterior to the core structure (including the weight of the collapsed containment walls and floor slabs they supported), to survive the design basis earthquake. See Lic. Ex. 25 at Part 3.

I conclude, therefore, that the structural modifications proposed by GE would be sufficient to withstand the design basis parameters I recommend if GE can modify the flexible piping, discussed above, to withstand a 2-meter surface displacement, instead of the postulated 1-meter displacement adopted in the majority opinion.

III. ROLE OF THE STAFF

Staff's presentation at the hearing raises some troubling questions regarding its role in the adjudicatory process. Previously, it had been my impression that Staff presents itself in these proceedings as a purveyor of objective truth, rather than as a mere advocate--in the words of GE's counsel, a "guardian of the record." Prehearing conference of January 5, 1981 at Tr. 167. See also the Board's discussion at hearing of the role of the Staff's experts, at Tr. 989-91.

In my opinion, however, Staff did not meet those expectations. It offered into evidence an expurgated version of its Geosciences Branch Safety Evaluation Report, from which substantial portions of expert analysis were deleted because they did not support Staff's changed conclusions. Stf. Ex. 1-A; Tr. 986-89. It conducted a minimum of cross-examination of GE's experts, despite the obvious competence of Staff counsel and the reservations that had earlier been expressed in the Staff reports about certain of GE's positions. Similarly, Staff presented very little direct testimony to support those previously-expressed reservations about GE's case. Especially in the area of the GETR's structural capability to withstand the postulated design basis events, Staff's direct presentation was meager. From the testimony given, it would be difficult to discern that Staff had rejected GE's bearing capacity analysis and had accepted in its stead the fault deflection analysis.[48/] It is only because of the presence of the USGS experts, Drs. Earl Brabb and Darrell Herd, that the testimony was illuminating with regard to the geologic design parameters. However, they participated in the hearing only because of the insistence of the Licensing Board. Staff had intended that they not appear as witnesses in the proceeding although they had conducted Staff's geologic investigations together with NRC's Dr. Jackson. Prehearing conference of January 5, 1981, Tr. 155-61. Even Staff's disclosure that the modified GETR would not meet the General Design Criteria of Appendix A to Part 50, a matter that must have been known to Staff before the hearing and had been stated otherwise in its October, 1980 SER (Stf. Ex. 1-C at C-3), was made to the Board only after persistent Board questioning. Tr. 2211-20, 2226-34.

On the record before us, it is difficult to distinguish between Staff's presentation and that of a typical private litigant, whose counsel might be expected to present only evidence favorable to its position and to caution its witnesses not to volunteer unfavorable information or opinion.

48/ Staff's discussion of the non-acceptability of GE's bearing capacity analysis is confined to a carefully worded paragraph in Staff witness Pichumani's prefiled testimony (ff. Tr. 996 at 4). The "difference" between GE's figure of 20 ksf for soil strength and Staff's higher value is noted. Not mentioned is the fact that the soil strength value was critical to the entire bearing capacity analysis and that Staff rejected the analysis because of its difference with GE on that value.

At the same time, we are now faced with some recent dicta[49/] of the Appeal Board that would severely restrict the ability of licensing boards to call their own experts. Under the scheme envisioned by the Appeal Board, before an adjudicatory Board can call its own outside experts it must give the Staff every opportunity to explain, correct, or supplement its testimony, and then must articulate good reason to suspect the validity and completeness of the Staff's work. See fn. 49 supra, Summer, ALAB-663, 14 NRC at 1156. Even then, a licensing board may call independent consultants only in "that most extraordinary situation in which it is demonstrated beyond question that a Board simply cannot otherwise reach an informed decision on the issue involved." 14 NRC at 1146, 1163.

If the Commission adopts as Commission policy this unprecedented[50/] scheme for restricting the right of a

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49/ South Carolina Electric and Gas Co. (Virgil C. Summer Nuclear Station, Unit 1), ALAB-663, 14 NRC 1140 (1981). ALAB-663 contains a series of Appeal Board memoranda addressing NRC Staff's motion for directed certification that challenged the Licensing Board's decision to call its own seismic experts. Although it expressed disapproval of the Licensing Board's decision, the Appeal Board let the Licensing Board's order stand, and dismissed Staff's motion to overturn it. The Commission declined to review ALAB-663. CLI-82-10, 15 NRC __ (June 22, 1982).

50/ See the Licensing Board's opinion in Summer, supra, LBP-81-47, 14 NRC 866, 872-3 (1981), which reviews the precedents and demonstrates their unanimity in upholding the unrestricted right of trial courts, administrative judges and NRC licensing boards to call their own experts--a common law practice that dates back to the 14th century.

licensing board to call its own experts, licensing boards will have to rely even more upon Staff's willingness to volunteer information and opinions that may not fully support its ultimate conclusions. Where Staff is not so willing, as it apparently was not in this case, the ability of a licensing board to do more than suspect the validity and completeness of the Staff's work, much less articulate good reasons for its suspicion, is doubtful.

It appears to me that the performance of Staff at this hearing was inconsistent with the premise underlying the Appeal Board's recent pronouncements. That premise, that the Staff can be relied upon to disclose fully all of the facts and considerations that are apparent to its personnel, even those which may contribute to reservations regarding Staff's ultimate conclusions, has not been validated in this case. It appears doubtful to me that Staff considers such full disclosure as its obligation. Nor has it been shown to my satisfaction in this proceeding that the witnesses Staff intended to produce for hearing were those that were most qualified to analyze the issues before the Board, even of those experts available to Staff.

IV. CONCLUSION

Except for the matters specifically discussed in my opinion, I agree with the findings and opinion adopted by my fellow Board members. For the reasons discussed above, I dissent from only their geologic design parameter of a 1-meter offset from the Verona fault, which I would establish at two meters. Because of that difference in design basis, I would condition my approval of the structural ability of the modified facility to withstand the postulated seismic design basis events, upon a modification of the flexible fuel flooding piping located outside of the reactor building to withstand the 2-meter surface displacement.

Herbert Grossman, Chairman
ADMINISTRATIVE JUDGE

Dated at Bethesda, Maryland
this 16th day of August 1982

VIII. COMMENTS ON THE SEPARATE OPINION[51/]

We believe differences between the Majority and Separate Opinions stem primarily from the weights given to the testimony by various witnesses as well as approaches employed in estimating the likelihood of, extent of, and hazards caused by, future possible seismic events at the GETR site.

I. Geologic and Seismic Design Basis

The Staff's recommended design parameter of a 1-meter surface displacement from an event on the Verona fault is rejected in the Separate Opinion and a 2-meter surface displacement would be adopted in its stead (Sep. Op. at 107).[52/] The rejection is based, in part, upon disagreement with the Staff's reevaluation of its previous position regarding appropriate design parameters.

It is stated in the Separate Opinion that "Upon the urging of a member of the Advisory Committee on Reactor Safeguards, to which Staff had referred its recommendation, Staff reversed its position of not accepting probabilistic studies as a significant element in formulating its conclusions." (Sep. Op. at 107)

The Staff had previously recommended that a 2-1/2 meter maximum surface displacement be used as a design parameter (Stf. Ex. 1A). Based

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51/ By the Board majority.

52/ References to the Separate Opinion are cited as Sep. Op. with the appropriate page number. An example is Sep. Op. at 108.

upon a review of additional information, including probabilistic analyses, Staff modified its position and recommended a 1-meter displacement design parameter (Stf. Ex. 1B). Probabilistic analyses showed that maximum displacements are extremely unlikely to occur. The Staff concluded that appropriately determined mean values of relevant geologic analogies may be used to establish the design parameter. In particular, Staff relied upon the means of the surface displacements from the 1971 San Fernando event; the characteristic offsets of from 2 to 3 feet observed in the trenches at the GETR site; the probability that in a future event the surface displacements would be distributed between different splays in the Verona fault zone rather than on a single splay beneath the reactor; the probability that the Verona fault would not rupture over its entire length based on comparisons with worldwide earthquake data. Justus and Jackson, ff. Tr. 996 at 8-11; Tr. 1387-95, 1888-92.

In the Separate Opinion, the probabilistic analyses are given little weight. We are of the opinion that the use of probability analyses in the determination of design parameters is proper. We believe the Staff's consideration of such analyses appropriate. That such consideration may have been "almost mandated" by the ACRS is of little concern. Independent consultants, employed by the Licensee and the Staff, have performed probabilistic analyses and have obtained similar results. A simplified expression for computing the probability (P) that an offset will occur beneath GETR is[53/]

$$P = \frac{N}{t} \cdot \frac{1}{N} \cdot \frac{72 \text{ ft}}{1320 \text{ ft}}$$

The concern, expressed in the Separate Opinion, which led to the suggestion that the probabilistic analysis should be given little weight, relates to the mathematical form of the second term in the above expression. In general, the probability that an event A will occur in a succession of N total events is, by definition, equal to N_A/N, where N_A is the number of times event A has occurred in the succession. Thus, the probability that a future offset will occur between shears as a result of movement on the shear is N_A/N, where N_A is the number of splaying offsets observed between shears and N is the number of events occurring on the shears. Since no splays were observed between shears (i.e., N_A=0) in the time period t during which N events have occurred on the shear, the calculated probability is zero, however, as a conservative estimate the Licensee assumed N_A = 1 yielding a probability of 1/N.[54/]

53/ A more rigorous expression for the probability is given in Lic. Ex. 14. Also see Sep. Op. at 114 for definition of parameters.

54/ It is recognized that this simplistic argument has a more rigorous basis. See Lic. Ex. 14 for development of the term $P_{i\ BS/ON}$.

Two mechanisms were postulated as causes for offsets beneath the reactor. The first mechanism assumed that a future offset off the shears can be caused by motion on the shears. This may be envisioned as a splaying of the existing shear. The Separate Opinion states (Sep. Op. at 115) that "the relationship assumed by G.E. of 1/N to N/t, a simple inverse relationship, is based upon the assumption that the offsets on the shears were not accompanied by offsets between the known shears (i.e., within the 1320 foot zone between shears B-1/B-3 and B-2)." We disagree. As discussed above, in obtaining the term 1/N the Licensee has conservatively assumed that one splaying offset had occurred between the known shears despite the fact that none had been observed.

A second mechanism is assumed which may lead to future offsets occurring beneath the reactor. This mechanism postulates yet unknown-undiscovered shears to exist in the region. Clearly, the probability that these will give rise to offsets beneath the reactor may be estimated in the manner already described. Although the Licensee's analysis assumed a single undiscovered shear to occur within the 1320 foot region between existing shears, conceivably more than one may exist. An estimate of this number can be made and a total probability calculated. It is apparent that any reasonable assumption as to the number of unknown-undiscovered shears that may exist in the region cannot greatly affect the probability estimate since t, the time period (128,000 years to 195,000 years) for which no events have occurred between the existing shears, is the dominant parameter in the calculation.

The probability of an offset surfacing beneath the reactor was determined by the analysis performed by G.E. to be approximately 10^{-6} per year. (Lic. Ex. 1 at 79)

Considerable discussion is devoted in the Separate Opinion to the manner in which the Staff compared observations at the GETR site with the 1971 San Fernando earthquake and other worldwide events. (Sep. Op. 129-141) Much of the criticism appears to us to be speculative and one is hard put to draw useful inferences from these speculations. We believe the Staff appropriately rejected the worst case events and used characteristic or mean values for offsets in arriving at its recommended design criteria. The basis for this approach was the low probability of occurrence for the worst case. During the hearings, the Staff re-emphasized its belief that displacments larger than its recommended 1-meter design criteria may be exceeded at some place during a seismic event in the fault zone, but that the probability of a 1-meter offset beneath the reactor is very low (less than 10^{-4}) (Tr. 1394-95, 1403-8; Bd. Find. 47-54) Furthermore, the worldwide earthquake data set compiled by Dr. Slemmons relating fault length, magnitude and surface rupture suggests a likely maximum event of approximately 6.5 magnitude for the Verona which would in turn correlate with a displacement of 1-meter. (Tr. 1187)

The Staff assumed that the Verona will rupture to a length of 12-to-15 kilometers, despite the fact that worldwide data indicates that actual rupture can be substantially less than the total length of the fault. (Stf. Find. 45) It should be pointed out that the relationship between maximum surface displacement and length of fault rupture, as developed from the worldwide data set, is logarithmic and changes in rupture length would have to be large in order to significantly affect estimated surface displacements. Speculating upon the possibility of a fault rupture greater than the mapped length of the Verona, the Separate Opinion states that "we must recognize the possibility, however, slight, that the Verona and Las Positas combined, of from 23 to 29 kilometers, might be the controlling length of fault for influencing the magnitude and, hence, the amount of surface displacement in a future event" (Sep. Op. at 144) We believe the evidence presented at the hearing supports the view that the Verona and Las Positas faults are not connected (Bd. Find. 18).

The Staff performed an independent probabilistic analysis using a different methodology. This analysis was conducted by the TERA Corporation. TERA calculated the likelihood of various size displacements occurring on the Verona fault from a knowledge of the slip rate. The slip rate was calculated using the topographic expression between the Vallecitos hills and the valley within which the GETR is located. As an independent check, the results of this calculation were compared to the information obtained from trenches dug on the GETR site (Tr. 1804). Dr. Slemmons, when asked if he considered the use of slip rate to determine the probability of earthquakes occurring to be a very reliable method, testified that he could not assess the reliability but believed that it is a valid method that has a sound basis and seems to fit empirically reasonably well with field observations (Tr. 1824-25).

In response to a question of how much weight he would give to the probability analysis performed by TERA, Dr. Slemmons responded that he thought it is an important adjunct method that should be used in conjunction with deterministic geological methods, and that, while he would not use it as the prime method for establishing the risk at major vital sturctures, he believes it gives supporting data that has value (Tr. 1822). The Separate Opinion has misconstrued Dr. Slemmons' remarks on this matter (Sep. Op. at 122). Furthermore, he agreed with the method used by the TERA Corporation for determining slip rates and believes their results are conservative (Tr. 1826-7).

The Separate Opinion criticizes the probability analysis as being highly dependent on uncertain geologic parameters and states that the USGS experts had reservations about the sufficiency of the geologic information on which the probabilistic analyses were based (Sep. Op. at 119). Dr. Brabb, the USGS expert, testified that he was not qualified to review the mathematical parts of the probabilistic analysis and, although in the beginning he had looked at the geologic parameters and felt that the figures being used were unrealistic, in later documents on probability analysis he felt that the figures were more realistic in terms of geologic parameters. He stated that he had not reviewed everyone (nor was he asked) to make certain that they conform to the geologic information (Tr. 1533). While the USGS experts were uneasy about the sufficiency of the geologic information avilable at the site, they made it abundantly clear that they were not deciding whether the data by itself was adequate, coupled with probabilistic studies, to assess surface offset nor were they asked to make calculations of the expected displacement underneath the reactor (Tr. 1562-63).

Probabilistic estimates were obtained for the occurrence of a surface offset beneath the GETR. It is significant that the estimates obtained from the models used by both Staff and Licensee agreed to within an order of magnitude and neither model yielded probability estimates with an upper bound greater than 10^{-4} even under the most conservative considerations. Sensitivity analyses gave further credence to the validity of the models used by illustrating that in order to achieve probability values greater than 10^{-5} per year, highly unrealistic values for geologic input parameters would have to be selected.

II. Structural Analysis

We turn now to criticisms of the structural analysis of the GETR facility as they are found in the Separate Opinion. The criticisms focus almost entirely on the analyses performed to demonstrate the ability of the concrete core structure to withstand the postulated design basis seismic event. This core structure consists of the biological shield surrounding the reactor pool and fuel storage canal together with radial walls extending from the foundation slab to the third floor of the containment building. The integrity of this structure, which supports other safety-related systems and components, must be maintained during the seismic event.

It is asserted that a major point has been obscured in the presentations of the Staff and Licensee, namely, "that the modified GETR has not been shown to be structurally capable of meeting the design basis parameters. Rather, although the surface offset design parameter has been set by the Staff and GE (and adopted by the majority) as 1-meter, the structural analysis has been found to be satisfactory only with regard to a zero displacement underneath the foundation mat" (Sep. Op. at 162).

We believe the difficulty with the structural analysis expressed by this criticism stems from a misreading of the record. In the following discussion we highlight portions of the record which pertain to analysis of the core stucture.

Detailed state-of-the-art investigations were undertaken by the Licensee to verify that the concrete core structure meets appropriate design criteria. These investigations were:

1. a structural analysis based on core structure materials
2. a structural analysis based on soil properties
3. a structural analysis based on probability considerations.

The design criteria are:

Criteria 1. The Regulatory Guide 1.60 spectra anchored to 0.75g as a effective vibratory ground motion at the site. This is set in motion on the Calaveras fault.

Analysis:

The reactor building concrete wall cracking capacities were determined using maximum allowable compressive stress values of 5400 psi, 3400 psi and 5000 psi for the ordinary concrete, magnetite concrete and ferrophosphorus concrete, respectively. These were the values obtained from compression tests of concrete core samples taken from the reactor building walls or at the time of construction. Analyses were performed to determine whether the concrete walls would withstand the effects of the above design criteria. In this analysis an effective peak ground acceleration value of 0.8 g was used. (It was later determined that the results of this analysis represent a conservative bound for the effects expected at lower values of ground shaking and that reanalysis for a smaller acceleration of 0.75 g, as specified in the criteria, was unnecessary.) Linear elastic, time-history dynamic analyses were performed using a lumped-mass cantilever model with foundation soil springs. Torsional effects were considered by including the eccentricity between the center-of-mass and shear center at each floor level. Shear forces and overturning moments were computed for all members and response spectra were generated for each floor elevation. Parametric studies were performed to investigate the influence on the response of the structure to variation in soil shear modulus and average area of contact between the base slab and the underlying soil. The effects of torsion and foundation embedment on the structural response were also investigated. Additional parametric studies were performed to investigate the influence of the variation in modal damping effects on the structural response.

The potential nonlinear effects were investigated by performing nonlinear analyses using appropriate analytical models. The objectives of the nonlinear analyses were to confirm the conservatism of the results of the linear elastic analyses.

Stress analyses were performed using a detailed finite element model consisting of three-dimensional elements. The analyses were based on a 0.8 g effective peak horizontal ground acceleration and 2/3 of this value for acceleration in the vertical direction. The ground response spectra was anchored to Regulatory Guide 1.60. The result of the analyses showed that the induced stresses in the portion of the concrete core stucture which surrounds the pool and storage canal, and which also supports and protects the safety-related equipment and components necessary for safe shutdown, were much smaller than the cracking stresses. These stresses were determined from the forces obtained from the linear elastic dynamic analyses. The forces obtained from the nonlinear analyses were smaller than those obtained from the linear analyses. Furthermore, these analyses showed that, although some cracking of slabs may occur exterior to the safety-related portion of the structure, the ductility demand for these slabs will be low resulting in minor cracking. Find. 155-157, Lic. Ex. 25 at 2-1.

Based on the results of these analyses, we conclude that the concrete core structure meets design Criteria 1.

Criteria 2. A surface displacement of one (1) meter of reverse-oblique net slip along a fault plane which could vary in dip from 10 to 45 degrees and which could occur on a Verona fault zone strand (splay) beneath the GETR during a single earthquake.

Analysis:

An analysis of the reactor building for effects of a hypothetical surface rupture offset was performed using a finite element model of that portion of the reactor building which supports and protects the safety-related equipment and components necessary for safe shutdown. A one (1) meter surface rupture was assumed as the basis for the analysis. The surface rupture plane was considered to be at an angle of 15 degrees with the horizontal, however, the angle of rupture does not affect the results of the analysis.

Three principal cases were analyzed:

<u>Case 1</u>. The surface rupture was considered to intersect the reactor building on the near side.

For this case, the near side basement walls would be heavily loaded and would crack. The horizontal thrusts associated with the wall pressures would be resisted by shear forces due to friction under the basement mat. The soil pressures on the far side of the basement walls would not be significant and cracking of these walls would not occur.

<u>Case 2</u>. The surface rupture occurs on the far side of the reactor building.

In this instance, the horizontal soil pressures would be large and might cause the basement wall to deform on the far side. The horizontal force caused by the soil pressures on the exterior basement wall would be resisted by the shear forces mobilized by friction between supporting soil and the bottom of the foundation mat.

<u>Case 3</u>. The offset was assumed to occur near the center-of-gravity of the reactor building.

This case may create a cantilever effect since the far portion of the reactor building might be unsupported between the edge and the area where the soil makes contact with the foundation slab. The maximum stresses in the concrete core structure are produced for the cantilevered configuration. The length of the cantilever is dependent upon the soil bearing capacity beneath the reactor building. If the hypothetical surface rupture offset intersected the foundation mat between the far side of the reactor building and its center of gravity the result may be an uplift of the building. To verify that the concrete surrounding the pool and canal could resist a cantilever situation, an analysis of the core and radial wall concrete was conducted to verify that the weight of the cantilevered portion of the building could be resisted. All computed stresses for the cantilever load cases were well below cracking threshold capacity values.

If the offset intersects the foundation mat closer to the near side, the reactor building would tilt and be supported in a simple beam configuration. It has been shown that if the foundation mat were to span as a simple beam, the foundation mat and reactor building floor slabs would yield until the concrete core structure settles down to the supporting soil. Soil pressures on both sides of the basement wall would be large and cracking would probably occur.

The Licensee performed a detailed analysis of concrete cracking patterns which are expected to occur in the event of the postulated surface rupture offset. It was found that the reinforcement in the base slab would yield first at a loading equal to, or less than, one-tenth of the weight of the reactor building. A soil bearing capacity of 20 ksf was assumed in the analysis. Even if the ultimate capacity of the soil were increased, a higher value of soil bearing capacity would not change the results since the base slab has already yielded. The concrete cracking patterns were shown to occur in such a manner as not to affect the interior portion of the structure surrounding the pool and canal. Excessive deformation of the basement walls would not adversely affect the concrete core structure since these exterior walls are not essential to the integrity of the structural system which supports the pool and storage canal. Find. 158-164, Lic. Ex. 25 at 3-1.

Thus design Criteria 2 is satisfied since stresses induced in the concrete core structure, due to a hypothetical surface rupture of one (1) meter occurring beneath the reactor buiding, will not cause cracking in this structure. We do not agree with the assertion that the concrete core structure has not been shown to be capable of withstanding a 1-meter surface offset.

Criteria 3. An effective vibratory ground motion of 0.6 g, anchoring the Regulatory Guide 1.60 spectra, together with a fault displacement of one (1) meter as described in Criteria 2.

Analysis:

The Licensee performed several analyses for loadings on the reactor building which result from the combined effects of vibratory ground motion together with a surface rupture of one (1) meter occurring beneath the buiding. One approach used was to assume that the vibratory ground motion occurred subsequent to the surface rupture. In this analysis, an effective peak ground acceleration of 0.8 g (higher than the 0.6 g value of the design criteria) was used. Furthermore, it was assumed that the damage caused by the surface offset had occurred prior to the ground shaking and that only the undamaged structure would resist the vibratory ground motion. The effective peak ground acceleration value of 0.8 g was anchored to Regulatory Guide 1.60 Spectra.

Several conservatisms were introduced into this analysis. Although it was assumed that the rest of the structure, including all concrete slabs and walls exterior to the concrete core structure area had lost their structural resisting capacity, due to the surface offset effects, the total masses for the complete structure were used in the analysis model. Further assumptions were made to exclude the effects of building embedment in the analysis and to assume that the interior concrete structure rotates as a rigid block over a rigid base slab. These assumptions introduced additional conservatisms into the analysis.

It was found that the safety-related portion of the structure would be stable and that the forces and corresponding stresses induced by the post offset vibratory motions would be below the threshold of concrete cracking.

The Licensee performed additional studies to analyze the stability of the concrete core structure. Several questions have arisen regarding these studies.

As mentioned earlier (Case 3, p. 207), if the surface rupture intersects the foundation slab near the center-of-gravity of the reactor building, the building may exist in a cantilever configuration since the far portion of the building might be unsupported between the edge and the area where the soil makes contact with the foundation slab. A soil pressure analysis was performed to determine the physical load limits on the combined load case comprised of a ground acceleration and a surface rupture offset, the latter being represented analytically as the cantilever length. In these analyses, "incipient local yielding" of the soil was defined as the loading combination which produces bearing pressure at the edge of the supporting soil equal to the ultimate bearing capacity (taken to be 20 ksf). Results were obtained for several cases of cantilever length and horizontal earthquake accelerations at which incipient yielding of the soil occurs. Additional analyses were performed to determine the combinations of ground acceleration and cantilever length at which complete local soil yielding will occur. Combinations higher than those obtained from this analysis would cause the structure to settle down and be either partially, or completely, supported by the soil; a condition easily tolerated by both soil and structure. These results are depicted in Figure 4. These soil pressure analyses, performed by the Licensee, demonstrated that there are physical limits on the soil bearing capacity when combined loading represented by ground vibratory motion and cantilever length of the reactor building are considered to occur coseismically.

The Staff questioned the soil bearing capacity analysis performed by the Licensee. This questioning concerned the correctness of use of the value 20 ksf in the analysis for the ultimate bearing capacity of

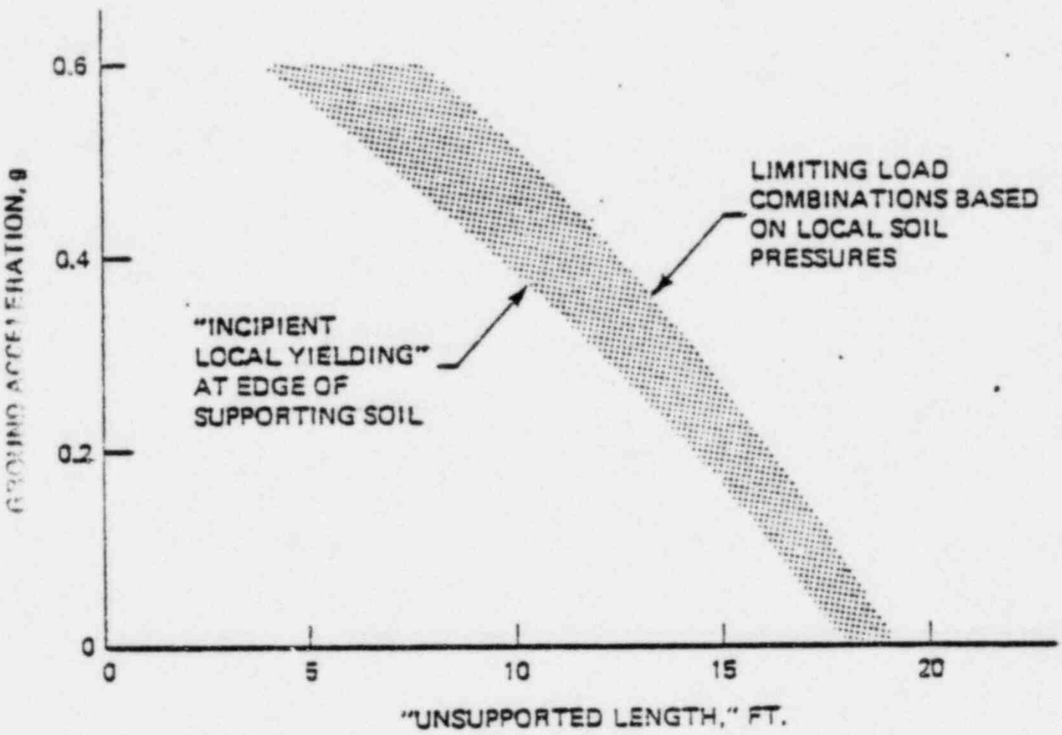

FIGURE 4. RESULTS OF SOIL PRESSURE ANALYSES

(REPRODUCED FROM FIGURE 4; LIC. EX. NO. 38) the subgrade soils beneath the reactor. This question arose because the undrained strength values, used by the Licensee, were the lowest tested soil strengths and because overburden soils, that would contribute to the bearing capacity, were not considered. A higher value of the bearing capacity would likely result in a larger unsupported cantilever length of the GETR foundation mat. The Licensee's witness testified that analyses were performed using a higher (30 ksf) value of the soil bearing capacity although this value is believed to greatly exceed those characteristic of the soils beneath GETR (Tr. 2295; Lic. Ex. 19 at 11).

To address the Staff's concern regarding the analysis, the Licensee performed an additional analysis of the subgrade rupture mechanism resulting from the postulated Verona fault event. This analysis consisted of a comparison of the static stability of two-dimensional soil wedges formed by thrust fault planes meeting the reactor foundation at different locations (Rankine Fault Model). The hypothetical thrust fault was visualized as a passive Rankine wedge being pushed by a major principal stress, Pp. For drained soil strength parameters c'=0, and Ø=36° the preferred failure surface (defined as the plane requiring a minimum value of Pp) is inclined at an angle=45-Ø/2 when there is no surcharge. By trial and error the most probable failure plane corresponding to the minimum value of Pp was obtained by GE for the low water table (drained) case. The locations of the failure planes were varied for an assumed wedge depth of 70 feet below the reactor foundation slab. The results of the analyses by GE showed that, for the 21 feet of surcharge at the GETR, the preferred failure plane passes through the edge of the slab. Therefore, GE argued that a thrust fault plane will be deflected away from the base of the reactor slab because of the weight of the GETR and the surcharge. GE also performed calculations using assumed undrained strength parameters of c'=4000 psf and Ø = 0° that would be appropriate for very rapid loading of a saturated subgrade for the high water table condition. In this case, GE also found that the preferred failure planes (those requiring minimum passive pressure) did not fall beneath the reactor or within the zone that may create a cantilever span of the reactor mat.

A further detailed investigation of the subgrade rupture mechanism was undertaken to determine the sensitivity of the fault deflection analysis to various parameters related to soil conditions and fault location. In this investigation both undrained and drained soils were considered as well as the effects of faults which intersected the reactor foundation at different locations. It was determined that the Rankine Fault Model predicted, in each case, that the preferred planes surface on either the right or left side of the reactor foundation.

The Separate Opinion draws attention to the analysis reported in Lic. Ex. 19 regarding bearing capacity of the soil beneath GETR (Sep. Op. at 178). It highlights features of the analysis of fault behavior as "uncertainties . . . concerning the anticipated paths of the failure planes" (Sep. Op. at 181). This characterization may result from an incomplete reading (and comprehension) of the report. Portions of the report, which are omitted in the Separate Opinion, describe the idealized conditions assumed in the simple model used for the analysis.

Those portions also provide an analytical approach for examination of the tendency for the fault to move either to the right or left.

The Staff reviewed the Licensee's fault deflection analysis and concurred with the findings that the previously hypothesized cantilever condition should not occur. As a check on the Licensee's work, the Staff performed additional calculations for an assumed wedge depth of 100 feet using similar soil conditions and determined that the findings were correct for the 21 feet surcharge load. The Staff noted that this result was dependent on the presence of the 21 feet high surcharge within about 170 feet of the reactor building. If, for any reason, a significant part of this surcharge were excavated a reevaluation would be necessary. The Staff also analyzed the three-dimensional aspects of the failure plane deflection around the GETR and found that the conclusion based on a two-dimensional analysis remains valid. Because of its concurrence with the fault deflection analysis performed by the Licensee, the Staff concluded the use of results of the soil pressure analysis, obtained by the Licensee, are acceptable for use in comparison with the inputs to the structural evaluations since they postulate a greater loading on the foundation mat than that predicted by the fault plane analysis. The use of these curves is acceptable to the Staff since it results in placing a conservative limit on the load combinations from the specified design basis event on the Verona fault. Stf. Ex. 1C.

Probabilistic analyses were performed to investigate the likelihood that the concrete core structure will withstand the seismic design event. The results are reported in Lic. Ex. 39. (See Sep. Op. Figure 2 for a graphical presentation of these results.)

Analyses were performed to assure that the facility can withstand the load combinations expected to occur. The capacity of the facility was determined based on evaluation of various sets of load combinations selected to conservatively represent the input parameters defined in Figure 4 and the probabilistic analyses. These included evaluations for the following combined input parameter cases.

a. Ground acceleration = 0.75 g
   Unsupported length = 0 feet

b. Ground acceleration = 0.0 g
   Unsupported length = 20 feet

c. Ground acceleration = 0.30 g
   Unsupported length = 17 feet

Other selections for input parameters could have been made (for example, 0.6 g vibratory motion and 20-foot unsupported length). We believe the selection of parameters that was made reasonably bound the limiting load combinations representing the hazard caused by the seismic design event. It was determined that the capacity of the concrete core structure would tolerate these load combinations, where capacity is defined as the point where concrete cracking is initiated.

Numerous conservatisms were introduced in the procedures used to evaluate the adequacy of the core structure. The effect of these conservatisms is cumulative which yields a total margin of safety greater than that determined by the analyses which were performed.

In summary, we find that all applicable loadings and effects of imposed deformations resulting from the design basis faulting and/or shaking were considered in a manner consistent with current practice and that the integrity of the concrete core structure will be maintained to permit it to carry out its intended function.

APPENDIX A - LIST OF EXHIBITS

EXHIBITS

Staff Exhibits

Exhibit No.	Description	Received in Evidence
1-A	Geosciences Branch Safety Evaluation Report Input dated September 6, 1979.	993
1-B	Safety Evaluation Report for the General Electric Test Reactor - enclosure to letter dated May 23, 1980.	993
1-C	Safety Evaluation Report - enclosure to Staff Letter dated October 27, 1980.	993
1-D	Safety Evaluation Report - enclosure to Staff Letter dated January 15, 1981.	993
2	Letter from Milton S. Plesset, Chairman, NRC Advisory Committee on Reactor Safeguards to John F. Ahearne, Chairman NRC, dated November 12, 1980 Re: Report on the Restart of the General Electric Test Reactor.	993

Staff Exhibit No.	Description	Received in Evidence
5A&B	Photographs of the T-1 Trench: A-vertical depiction and B-horizontal depiction of trench.	1770
6-1 to 6-11	Color plates of Figure 13, App. B to May 23, 1980 Safety Evaluation Report.	1770
7	Annotated version of a portion of the T-1 trench log.	1770
8	Regulatory Guide 1.60 Response Spectra and earthquake record at Pacoima Dam, February 9, 1971.	1768

Licensee's Exhibits

1	Testimony of Richard C. Harding, Richard H. Jahns, Richard L. Meehan, John W. Reed, and Dwight L. Gilliland Concerning Issue 1 (Surface Displacement). Submitted on behalf of the General Electric Company (May 1, 1981).	501

Licensee's Exhibit No.	Description	Received in Evidence
2	Earth Sciences Associates, Geologic Investigation of the General Electric Test Reactor Site (February 1978).	501
3	Earth Sciences Associates, Addendum I to ESA Geologic Investigation of the General Electric Test Reactor Site (April 1978).	501
4	Earth Sciences Associates, Landslide Stability at the General Electric Test Reactor Site (July 1978).	501
5	General Electric Company, Responses to USNRC Requests for Additional Information (October 1978).	501
6	Earth Sciences Associates, Geologic Investigation, Phase II, General Electric Test Reactor Site (February 1979).	501
7	Richard H. Jahns, Evaluation of Seismic Hazard at the General Electric Test Reactor Site (February 1979).	501

Licensee's Exhibit No.	Description	Received in Evidence
8	Earth Sciences Associates, Errata Sheets for Geologic Investigation-Phase II Report (March 1979).	501
9	General Electric Company, Responses to Comments Raised by NRC Staff and Consultants Concerning GETR Geologic Investigations at Meeting March 20, 1979 (March 1979).	501
10	Engineering Decision Analysis Company, Probability Analysis of Surface Rupture Offset Beneath Reactor Building, General Electric Test Reactor (April 1979).	501
11	General Electric Company, Responses to Questions Raised by NRC Staff and Consultants Concerning GETR Phase II Geologic Investigation (June 1979).	501
12	General Electric Company, Response to Letter from David B. Slemmons to Robert E. Jackson Dated August 8, 1979 (September 1979).	501

Licensee's Exhibit No.	Description	Received in Evidence
13	Roy J. Shlemon and Associates, Review of Commentary Regarding Late Quaternary Stratigraphy at GETR Site by Dr. David B. Slemmons (September 1979).	501
14	Jack R. Benjamin and Associates, Additional Probability Analyses of Surface Rupture Offset Beneath Reactor Building-General Electric Test Reactor (March 1980).	501
15	General Electric Company, Letter to Darrell G. Eisenhut (NRC) from R.W. Darmitzel regarding "Analysis of the General Electric Test Reactor (GETR) Foundation Excavation Photographs" (April 1980).	501
16	General Electric Company, Responses to NRC Questions on Additional Probability Analyses of Surface Rupture Offset Beneath Reactor Building - General Electric Test Reactor (April 1980).	501

Licensee's Exhibit No.	Description	Received in Evidence
17	General Electric Company, Letter to Darrell G. Eisenhut (NRC) from R.W. Darmitzel concerning "Soil Shear Modulus and Bearing Capacity Values for the Soil Beneath the General Electric Test Reactor (GETR) with attached letter to Dwight Gilliland from Garrison Kost (EDAC) regarding GETR Soil Properties, EDAC Project 117-258 and attached letter to Gary Kost from Richard L. Meehan (ESA) regarding Subgrade Soil Values (August 1980).	501
18	Earth Sciences Associates, GETR Landslide Stability Analysis (August 1980).	501
19	General Electric Company, Letter to Robert A. Clark (NRC) from R.W. Darmitzel with attachments - (1) Attachment to Response to Additional Information Request Regarding Bearing Capacity Values for Soil Beneath the GETR and (2) Review of	501

Licensee's Exhibit No.	Description	Received in Evidence
	GETR Soil Property Effects (October 1980).	
20	R. Meehan and M. Traubenik, Earth Sciences Associates, Analysis of the Subgrade Rupture Mechanism at the General Electric Test Reactor (December 1980).	501
21	Testimony of Robert L. Kovach, Charles F. Richter, Garrison Kost, and Dwight L. Gilliland Concerning Issue 1 (Seismic Design). Submitted on behalf of the General Electric Company (May 1, 1981).	501
22	Testimony of Garrison Kost, Harold Durlofsky and Dwight L. Gilliland concerning Issue 2. Submitted on behalf of the General Electric Company (May 1, 1981).	501
23	Engineering Decision Analysis Company, Seismic Analysis of Reactor Building General Electric Test Reactor, Phase I (EDAC 117-217.02 February 3, 1978).	501

Licensee's Exhibit No.	Description	Received in Evidence
24	General Electric Company, Update of Analytical and Modification Information (February 1978).	501
25	Engineering Decision Analysis Company, Seismic Analysis of Reactor Building Phase II (EDAC 117-217.03 June 1, 1978).	501
26	Engineering Decision Analysis Company, Seismic Analysis of Primary Cooling System and Reactor Pressure Vessel, General Electric Test Reactor (EDAC 117-217.05, June 30, 1978).	501
27	Engineering Decision Analysis Company, Seismic Analysis of Primary Heat Exchanger, General Electric Test Reactor (EDAC 117-217.06, June 23, 1978).	501
28	Engineering Decision Analysis Company, Analysis of Lateral Restraints to Contain Heat Exchanger HE 102, prepared for General	501

Licensee's Exhibit No.	Description	Received in Evidence
	Electric Company (GETR) (EDAC 117-217.10, June 30, 1978).	
29	Engineering Decision Analysis Company, Seismic Analysis of Reactor Pressure Vessel and Pool Drain Lines and Poison Injection Line, General Electric Test Reactor (EDAC 117-217.07, June 9, 1978).	501
30	Engineering Decision Analysis Company, Seismic Analysis of Fuel Flooding System, General Electric Test Reactor. (EDAC 117.217.08, June 30, 1978).	501
31	Engineering Decision Analysis Company, Qualification of Safety-Related Valves, General Electric Test Reactor, General Electric Test Reactor (EDAC 117-217.09, June 30, 1978).	501
32	Structural Mechanics Analysis, Structural Analysis of New Fuel Storage Tanks and Support System,	501

Licensee's Exhibit No.	Description	Received in Evidence
	General Electric Test Reactor (June 1978).	
33	Structural Mechanics Analysis, Structural Analysis of Third Floor Missile Impact System, General Electric Test Reactor (June 1978).	501
34	Engineering Decision Analysis Company, Additional Investigations to Determine the Effects of Combined Vibratory Motions and Surface Rupture Offset Due to an Earthquake on the Postulated Verona Fault (EDAC 117-253.01, Rev. 1, May 8, 1980).	501
35	Engineering Decision Analysis Company, Conservatisms in the Seismic Evaluations of the GETR Reactor Building (EDAC 117-254.02, April 30, 1980).	501
36	Engineering Decision Analysis Company, Summary Report - Structural Seismic Investigations of GETR (EDAC 117-258.02, July 8, 1980).	501

Licensee's Exhibit No.	Description	Received in Evidence
37	Engineering Decision Analysis Company, Additional Investigations to Determine Effects of Vibratory Motions Due to an Earthquate on the Calaveras Fault EDAC 117-253.02, Rev. 1, June 30, 1980).	501
38	Engineering Decision Analysis Company, Expanded Description of Soil Pressure Analyses (EDAC 117-253.01, Rev. 1, Suppl. 1, June 27, 1980).	501
39	Engineering Decision Analysis Company, Evaluations for 0.6g Ground Acceleration Case, Revision 1, Supplement 2 (June 1980)	501
40	Engineering Decision Analysis Company, Review of Seismic Adequacy of Piping and Equipment - GETR (EDAC 117-258.01, June 30, 1980).	501
41	Engineering Decision Analysis Company, Errata Sheet for EDAC Report 117-253.01, Revision 1, Supplement 2 (July 1980).	501

Licensee's Exhibit No.	Description	Received in Evidence
42	Graph of earthquake depth versus P-wave velocity, prepared by Licensee Witness Robert Kovach.	2301
43	Letter from Perry Amimoto, California Division of Mines and Geology, to J. Carl Stepp, U.S. Nuclear Regulatory Commission, dated October 28, 1977 and attached Division's field report on trenches at Vallecitos nuclear facility.	2301
44	NRC Memorandum to William P. Gammill from R.B. Hofmann and R.E. Jackson, dated October 31, 1977 concerning October 22, 1977 site visit to G.E. Test Reactor.	1524
45	Hand-drawn sketch of two parallelograms illustrating movement along shear in the T-1 trench.	1524
46	Hand-drawn sketch of two parallelograms illustrating movement along shear in the T-1 trench.	1524

Licensee's Exhibit No.	Description	Received in Evidence
47	Bruce A. Bolt and Roger A. Hansen Report, "Seismicity of the Livermore Valley in Relation to the General Electric Vallecitos Plant," March, 1980.	2071

Intervenors' Exhibits

1	Map of Quaternary Faulting along the Northern Calaveras Fault Zone by Darrell Herd, dated 1978.	1896
2	Figure 1 to Licensee's Exhibit No. 6, Geologic Investigation, Phase II, General Electric Test Reactor Site (February 1979).	1897
3	Licensee's Response to Intervenor's Interrogatories dated March 16, 1981. Interrogatories and Answers to No.7, 8, 9, 10, 11, 12.	1898
4	Chart Showing epicenters of earthquakes in the Livermore Valley from Open File Report 77-689 by Darrell Herd.	1903

Intervenor's Exhibit No.	Description	Received in Evidence
5	Written Testimony of Dr. David Brillinger.	Identified at 705
6	List entitled "some Documents Reviewed by David R. Brillinger in Connection with the Vallecitos Nuclear Reactor/GETR."	1898
8	Safety Evaluation Report, September 6, 1979	1530
9	Open File Map 77-689.	1901

APPENDIX B - EXPERT WITNESSES

WITNESSES

Staff Witnesses

Name	Position
Don L. Bernreuter	Leader of Engineering Sciences Group, Lawrence Livermore National Laboratory.
Earl E. Brabb	Geologist, U.S. Geological Survey.
John F. Burdoin	Reactor Inspector, U.S. Nuclear Regulatory Commission.
James F. Devine	Assistant Director of Engineering Geology, U.S. Geological Survey.
William L. Ellsworth	Geophysicist, U.S. Geological Survey.
William J. Hall	Professor of Civil Engineering, University of Illinois.
Darrell G. Herd	Research Geologist, U.S. Geological Survey.
Robert E. Jackson	Chief of Geosciences Branch, Division of Engineering, Office of Nuclear Reactor Regulations, U.S. Nuclear Regulatory Commission.

Name	Position
Philip S. Justus	Staff Geologist, U.S. Nuclear Regulatory Commission.
Joseph A. Martore	Project Manager for Power Reactor License Applications, U.S. Nuclear Regulatory Commission.
Robert H. Morris	Geologist and Deputy Chief for Reactor Hazards Programs, U.S. Geological Survey.
Christian C. Nelson	Project Manager in Operating Reactors Branch, Division of Licensing, U.S. Nuclear Regulatory Commission.
Raman Pichumani	Geotechnical Engineer, U.S. Nuclear Regulatory Commission.
David B. Slemmons	Professor of Geology and Geophysics, University of Nevada.
William E. Vesely	Acting Chief, Methodology and Data Branch, Division of Systems and Reliability Research, U.S. Nuclear Regulatory Commission.
Lawrence H. Wight	Consultant, TERA Corporation.

LICENSEE'S WITNESSES

Bruce A. Bolt	Professor of Seismology, University of California, Berkeley.
Harold Durlofsky	Associate, Structural Mechanics Associates, Sunnyvale, California.
Dwight L. Gilliland	Operations and Plant Engineering Manager, General Electric Test Reactor.
Richard C. Harding	Vice President and Principal Engineering Geologist, Earth Sciences Associates, Palo Alto, California.
Richard H. Jahns	Professor of Geology and Applied Earth Sciences, Stanford University.
Garrison Kost	Vice President, Engineering Decision Analysis Company, Inc., Palo Alto, California.
Robert L. Kovach	Professor of Geophysics, Stanford University.

Name	Position
Richard L. Meehan	President and Principal Civil Engineer, Earth Sciences Associates, Palo Alto, California.
John W. Reed	President, Jack R. Benjamin & Associates, Inc., Consulting Engineers, Palo Alto, California.

Intervenors' Witnesses

David R. Brillinger	Professor of Statistics, University of California, Berkeley.
John B. Rutherford	President of a structural engineering consulting firm.