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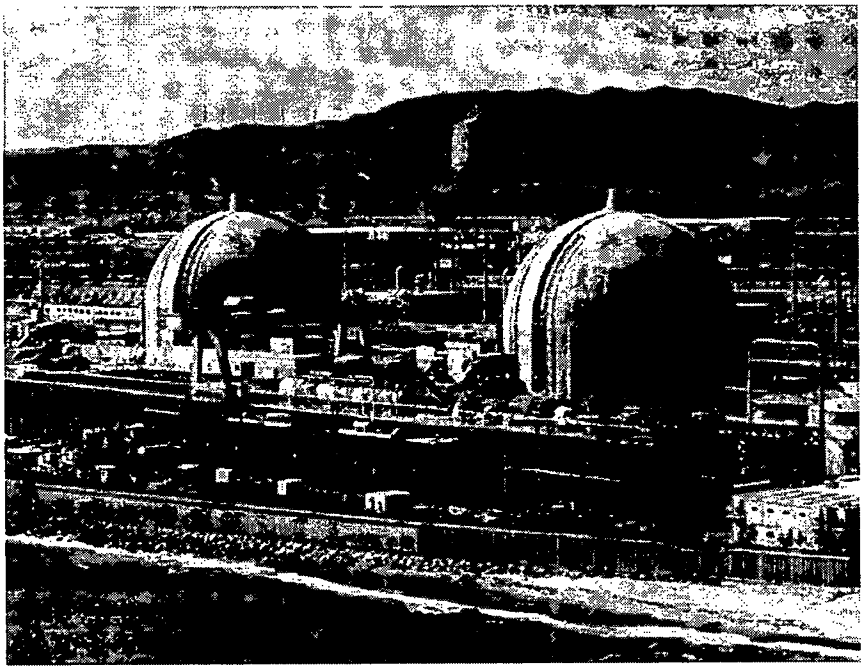
Southern California Edison's Evaluation of California Energy Commission AB 1632 Report Recommendations



February 2011

Southern California Edison's Evaluation of California Energy Commission AB 1632 Report Recommendations

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EXECUTIVE SUMMARY

Purpose

The following submittal was prepared in response to the California Public Utilities Commission's (CPUC) direction to SCE to address certain topics regarding the San Onofre Nuclear Generating Station Unit Nos. 2 & 3 (SONGS 2 & 3), and as recommended by the California Energy Commission's (CEC) 2008 report, "*An Assessment of California's Nuclear Power Plants: AB 1632 Report*" (AB 1632 Report).[1]

The CEC issued the AB 1632 Report in response to Assembly Bill (AB) 1632, which directs the CEC to "assess the potential vulnerability of California's largest baseload power plants, [including SONGS 2 & 3], to a major disruption due to a seismic event or plant aging."[2] The AB 1632 Report provides a number of other recommendations directed to SCE.

The CPUC stated that SCE's evaluations related to the AB 1632 Report recommendations would allow the CPUC to undertake "its AB 1632 obligations to ensure plant reliability."[3] The CPUC further indicated that it would also use SCE's studies in connection with its evaluation of the "overall economic and environmental costs and benefits of license extension for SONGS."[4]

Summary of Study Results

In accordance with the CPUC's request and the CEC's recommendations, SCE has addressed the following topics:

A. Seismic and Tsunami Evaluations
B. Emergency Preparedness
C. Low Level Radioactive Waste
D. Used Fuel Management

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1 Letter to Mr. Alan J. Fohrer, Chairman and Chief Executive Officer of the Southern California Edison Company dated June 25, 2009, from Mr. Michael R. Peevey, President of the California Public Utilities Commission (CPUC June 25, 2009 Letter to SCE); California Energy Commission's November, 2008 Commission Report, "*An Assessment of California's Nuclear Power Plants: AB 1632 Report*" (AB 1632 Report).

2 AB 1632 Report, p. 1; Cal. Pub. Resources Code § 25303(a)(8).

3 CPUC June 25, 2009 Letter to SCE.

E. Economic Impact
F. Nuclear Safety Culture
G. Ground Water Protection
H. Worker Training and Recruitment
I. Alternative Generation
J. Once Through Cooling
K. Adequacy of Maintenance Programs

The sections below briefly summarize the evaluations contained in this submittal. The evaluations demonstrate that SONGS 2 & 3 is operated in a safe and reliable manner, in accordance with federal, state, and local regulatory requirements, and that SONGS 2 & 3 can continue to provide reliable operation through a period of extended operation, if the NRC grants license renewal for SONGS 2 & 3.

A. Seismic and Tsunami Evaluations

To support the reliability study, SCE updated the relevant portion of the SONGS probabilistic seismic hazard analysis (PSHA) in 2010 using the most recent seismic data available from the "Uniform California Earthquake Rupture Forecast, Version 2" (UCERF-2), the National Seismic Hazard Program, and the current United States Geological Survey (USGS) analysis of the UCERF-2 data. The results from the SONGS 2010 PSHA are comparable to the SONGS 1995 PSHA, indicating that the assessment of SONGS seismic hazard risk has not changed. SCE plans to continue evaluating the SONGS seismic hazard for SONGS through its on-going seismic hazard analysis program, as indicated in SCE's 2012 General Rate Case.

SCE completed a study to identify any non-safety-related SONGS structures, systems or components (SSCs) that are important to reliability and could be the cause of a prolonged outage due to a seismic event.[5] The study results indicate that further evaluation of the offshore discharge conduits (pipes) is required to assess the conduits' seismic capacity. All

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Continued from the previous page
4 *Id.*

5 The scope of the study was limited to non-safety-related SSCs, consistent with the AB 1632 Report's scope description, which concluded that safety-related SSC are designed to withstand a very large earthquake.

other important-to-reliability, non-safety-related SSCs would not be the cause of a prolonged outage following a seismic event.

In addition to these studies, SCE reviewed the lessons learned from the Kashiwazaki-Kariwa nuclear power plant following the 2007 Niigata-Chuetsu-Oki earthquake in Japan. SCE's review included published reports of lessons learned prepared by the Institute of Nuclear Power Operations (INPO), Electric Power Research Institute (EPRI), and the International Atomic Energy Agency (IAEA). To determine SONGS' level of preparedness for a seismic event, SCE applied these lessons learned to SONGS. SCE's review of SONGS' design, processes, and procedures for earthquakes indicates that SONGS is well prepared for a seismic event. SCE's review of the lessons learned shows that the seismic hazard for SONGS is properly understood, and SONGS has appropriate design features, processes, and procedures to respond to earthquakes.

SCE also reassessed the tsunami hazard for SONGS by evaluating new data jointly prepared by the State of California Office of Emergency Services, California Geologic Survey, the University of Southern California Tsunami Research Center, and the National Oceanic and Atmospheric Administration. SCE determined that the seawalls for SONGS will provide ample margin for the highest potential tsunami, as determined by these independent parties, indicating that there is no potential tsunami impact to the SONGS site.

Appendices 1 – 5 provide further information regarding SCE's seismic and tsunami studies.

B. <u>Emergency Preparedness</u>

In the event of an emergency at SONGS, SCE's highest responsibility is safeguarding the surrounding communities and plant workers. SCE periodically reassesses the access roads and surrounding roadways near SONGS and confirms that they are adequate for allowing emergency personnel to reach SONGS and local communities and non-essential plant workers to evacuate when appropriate in the event of an emergency.

Further, SONGS' Emergency Preparedness Program is approved by the NRC and implemented pursuant to NRC and FEMA regulations. SCE and federal, state, and local authorities have successfully conducted periodic emergency-preparedness training drills for SONGS overseen by the NRC and FEMA. The results of these drills demonstrate the effectiveness of the emergency plans and coordination between SONGS and federal, state, and local agencies in implementing those plans.

Appendices 6-7 provide a copy of SCE's Evacuation Time Evaluation (ETE) Final Report, and an Annual Assessment of the SONGS ETE.

C. Low Level Radioactive Waste (LLW)

SONGS has adequate plans for the disposal of, and sufficient space on-site for the interim storage of all classes and types of LLW, including through the period of extended operation and subsequent decommissioning period in the event the NRC grants license renewal for SONGS 2 & 3.[6] SCE provides its forecasts for the volumes and disposal costs for LLW in Section III.C.

D. Used Fuel Management

SCE complies with all NRC requirements for used fuel storage. SCE will continue to adhere to its current used fuel management plan in which used fuel for SONGS 2 & 3 is stored in used fuel pools or dry cask storage containers. SCE transfers used fuel from the SONGS 2 & 3 used fuel pools to the dry cask storage (otherwise known as the Independent Spent Fuel Storage Installation or ISFSI) as necessary to maintain full core offload capability in the used fuel pools. SCE's used fuel management plan provides for the safe and secure storage of used fuel, until the U.S. Department of Energy (DOE) meets its acknowledged contractual obligations to remove the used fuel from the site.

E. Economic Impact

SCE studied the economic impact of SONGS 2 & 3 operations. The study showed that SONGS 2 & 3 operations affect a large number of sectors within the California economy. Overall, SONGS 2 & 3 operations directly and indirectly support approximately 9,400 jobs, and impact the California economy by more than $3.3 billion per year.

SCE cannot assess or compare the economic impact of alternate uses of the SONGS site because SCE leases the land for SONGS from the Department of the Navy under long-term agreements that specify SCE's use of the land. The future alternate uses of the land would be at the discretion of the Department of the Navy. At this time, SCE has no information

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6 The operating licenses for SONGS 2 & 3 expire in 2022. If the NRC grants license renewal for SONGS 2 & 3, the period of extended operation would be from 2023 to 2042.

regarding the alternate uses the Department of the Navy may consider once SONGS 2 & 3 is permanently shut down and decommissioned.

F. Nuclear Safety Culture

SCE is committed to preserving and improving a strong nuclear safety culture at SONGS. SCE is committed to ensuring an atmosphere exists that encourages workers to raise nuclear safety concerns. SCE has taken a number of actions to improve the nuclear safety culture including strengthening communications regarding nuclear safety culture and Safety Conscious Work Environment (SCWE); training station employees on nuclear safety culture, SCWE and the methods for raising nuclear safety concerns; and establishing mechanisms to monitor and assess nuclear safety culture, including the effectiveness of the aforementioned actions. SCE will continue to identify, through systematic reviews, actions to strengthen the SONGS nuclear safety culture.

The NRC continues to monitor SCE's nuclear safety culture efforts and overall plant performance through the NRC's Reactor Oversight Process (ROP). In their 2010 annual assessment letter, the NRC continued to affirm that SONGS has been operated in a manner that preserved public health and safety and fully met all cornerstone objectives. In December 2010, the NRC indicated that, while more improvement is needed, measurable progress has been made in addressing the SONGS performance issues. SCE concurs with this conclusion and continues to take actions to resolve remaining open issues and to achieve a stronger nuclear safety culture at SONGS.

G. Ground Water Protection

SCE has implemented the objectives of the nuclear industry Ground Water Protection Initiative (GPI) and the EPRI ground water protection guidelines at SONGS 2 & 3. The NRC has also assessed SCE's performance to meet the industry GPI and found that SCE met all of the objectives for a ground water protection program.

H. Worker Training and Recruitment

SCE is meeting the competitive challenge for hiring and training qualified nuclear workers in important and difficult to fill skill areas by continuing its: 1) recruitment programs for replacement of retiring workers for critical SONGS positions; 2) training programs for employees; and 3) ensuring knowledge and strong safety culture are instilled in new SONGS workers. These programs include educational partnerships with local southern California schools that provide a pipeline of highly qualified workers for critical positions. By investing in the intellectual capital of the next generation workforce, SCE ensures it will continue to maintain the reliable operation of the plant.

I. Alternative Generation

SCE plans to submit to the CPUC an application requesting funding necessary to submit and process a SONGS license renewal application at the NRC. The CPUC application, which SCE currently expects to file in early 2011, will include a cost-effectiveness analysis of alternative power generation that will allow the CPUC to determine that the extended operation of SONGS 2 & 3 would be beneficial for SCE's customers and the state.

J. Once Through Cooling

On May 4, 2010 the State Water Resources Control Board (SWRCB) adopted a policy on the use of coastal and estuarine waters for power plant cooling. In this submittal, SCE describes the policy requirements, which became effective October 1, 2010, and the need to proceed with SONGS license renewal activities as SCE addresses the implementation of this policy, as applicable to SONGS.

Consistent with the directives of the California Coastal Commission (CCC), SCE has fully mitigated for the impact of SONGS 2 & 3 on the marine environment. In addition, cooling towers are not feasible at SONGS 2 & 3 and an alternative means of compliance will be required to allow SONGS 2 & 3 to enter a period of extended operation in the event the NRC grants license renewal for SONGS 2 & 3.

K. Adequacy of Maintenance Programs

To ensure adequate maintenance programs of SSCs, SCE follows maintenance initiatives, standards, and methodologies issued by a number of entities, including but not limited to the NRC, EPRI, American Society of Mechanical Engineers (ASME), and Institute of Electrical and Electronic Engineers (IEEE). SCE assures the reliability of SONGS' SSCs by implementing maintenance programs that guide the performance of: (1) periodic, predictive, and planned maintenance; (2) corrective maintenance; (3) performance monitoring; and (4) periodic testing and inspection. SCE's implementation of these maintenance programs meets the nuclear industry maintenance standards and has resulted in reliable service for customers. The maintenance programs provide a solid basis for reliable plant operations through a possible period of extended operation.

Conclusion

SONGS 2 & 3 is operated in a safe and reliable manner, in accordance with federal, state, and local regulatory requirements, and provides the needed electricity to meet customers' demands. Rated at 1,070 megawatts (MW) and 1,080 MW, respectively for each unit, SONGS 2 & 3 generates enough electricity to serve 1.4 million average southern California homes every day. In addition, SONGS 2 & 3 generates clean, low-carbon electricity, in support of the state's environmental and greenhouse gas (GHG) policy objectives. Further, due to the location of SONGS 2 & 3 between two major metropolitan areas in San Diego, Los Angeles, Orange, and other counties in southern California, SONGS 2 & 3 is integral to adequately maintaining the reliability of the electric grid in southern California.

In response to the CPUC's request and the CEC's AB 1632 Report recommendations, SCE provides its evaluations of the above-referenced topics in this submittal. These evaluations demonstrate that SONGS can continue to provide reliable operation through a period of extended operation, if the NRC grants license renewal for SONGS 2 & 3.

I.

PURPOSE OF SUBMITTAL

The following submittal was prepared in response to the California Public Utilities Commission's (CPUC) direction to SCE to address certain studies regarding the San Onofre Nuclear Generating Station Unit Nos. 2 & 3 (SONGS 2 & 3),[7] and as recommended in the California Energy Commission's (CEC) 2008 report, "*An Assessment of California's Nuclear Power Plants: AB 1632 Report*" (AB 1632 Report).

The CEC issued the AB 1632 Report in response to Assembly Bill (AB) 1632, which directs the CEC to "assess the potential vulnerability of California's largest baseload power plants, [including SONGS 2 & 3], to a major disruption due to a seismic event or plant aging."[8] The AB 1632 Report provides a number of other recommendations directed to SCE.

The CPUC stated that SCE's evaluations related to the AB 1632 Report recommendations would allow the CPUC to undertake "its AB 1632 obligations to ensure plant reliability."[9] The CPUC further indicated that it would also use SCE's studies in connection with its evaluation of the "overall economic and environmental costs and benefits of license extension for SONGS."[10]

In accordance with the CPUC's request and the CEC's recommendations, SCE has addressed the following topics:

A. Seismic and Tsunami Evaluations
B. Emergency Preparedness
C. Low Level Radioactive Waste
D. Used Fuel Management
E. Economic Impact
F. Nuclear Safety Culture
G. Ground Water Protection
H. Worker Training and Recruitment
I. Alternative Generation

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7 *Id.*

8 AB 1632 Report, p. 1; Cal. Pub. Resources Code § 25303(a)(8).

9 CPUC June 25, 2009 Letter to SCE.

10 *Id.*

J. Once Through Cooling

K. Adequacy of Maintenance Programs

II.

OVERVIEW OF SONGS 2 & 3

SONGS 2 & 3 consists of two pressurized water reactor (PWR) nuclear power plants rated at 1,070 megawatts (MW) and 1,080 MW, respectively, enough to serve 1.4 million average southern California homes.[11] Each nuclear generating unit consists of a nuclear steam supply system, a turbine-generator, and all related equipment and facilities that are necessary for the safe and efficient generation of electrical energy.

SONGS 2 & 3 is jointly owned by SCE (78.21%), San Diego Gas & Electric (20%), and the City of Riverside (1.79%). SCE acquired the City of Anaheim's prior ownership interest in SONGS 2 & 3 pursuant to a December 20, 2005, Settlement Agreement, and in accordance with that agreement, the City of Anaheim retained all liabilities and obligations arising out of its prior ownership of SONGS 2 & 3.[12] SCE is authorized to act as agent for the other co-owners.

SONGS 2 & 3 is located on an approximately 84-acre site on the San Diego County coast, near San Clemente, California. The SONGS 2 & 3 site is located entirely within the boundaries of the United States Marine Corps Base Camp Pendleton, on property leased from the United States Government.

SONGS consists of the Plant Site and the Mesa Site. The Plant Site, which is on the west side of the I-5 freeway, includes the SONGS 2 & 3 unit reactors and electric generating facilities. The Plant Site also includes a Used Fuel Dry Cask Storage Facility,[13] electrical substation, and several administrative buildings. The Mesa Site, which is on the east side of the I-5 freeway, includes the Emergency Operations Facility, the Training and Education Center, the SONGS Warehouse, and administrative and support buildings. The Mesa Site is approximately 3.5 miles by road from the Plant Site.

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[11] SONGS operating reactors are two (2) out of 104 nuclear units in the U.S. that collectively generate almost 20% of the total U.S. electricity generation.

[12] Decision (D.) 06-11-025. These include the City of Anaheim's ownership interest in used nuclear fuel generated during the period it held an ownership share of SONGS 2 & 3, and its share of the costs necessary to store the used fuel in SONGS 2 & 3 used fuel pools and dry cask storage.

[13] The Used Fuel Dry Cask Storage Facility is also referred to as the Independent Spent Fuel Storage Installation (ISFSI).

III.

SCE'S EVALUATION OF CALIFORNIA ENERGY COMMISSION AB 1632 REPORT RECOMMENDATIONS

A. SEISMIC AND TSUNAMI EVALUATIONS

1. Introduction

This section addresses the seismic and tsunami recommendations[14] contained in the AB 1632 Report regarding SCE's:

- Update of the SONGS seismic hazard analysis
- Update of the SONGS tsunami hazard analysis
- Evaluation of lessons learned from the Kashiwazaki-Kariwa (KK) nuclear power plant following the 2007 earthquake
- Evaluation to identify any non-safety-related structures, systems and components (SSCs) that could be the cause of a prolonged outage due to a seismic event
- Additional seismic evaluations

2. Seismic Hazard Analysis

SCE updated the SONGS probabilistic seismic hazard analysis (PSHA). The PSHA uses the Uniform California Earthquake Rupture Forecast, Version 2 (UCERF-2),[15] the National Seismic Hazard Mapping Program,[16] and the current United States Geological Survey (USGS) implementation of the UCERF-2 seismic source characterization.[17] Additionally, the SONGS 2010 PSHA was completed by using the 2008 Next Generation Attenuation[18] relationships. The seismic hazard evaluation was performed to an earthquake return period of 10,000 years or less, which supports the

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14 CPUC June 25, 2009 Letter to SCE; AB 1632 Report, pp. 9-10, 13.

15 "The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF-2)," 2007 Working Group on California Earthquake Probabilities, USGS Open File Report 2007-1437.

16 "Documentation for the 2008 update of the United State National Seismic Hazard Maps," United States Geological Survey (USGS), Open-File Report 2008-1128.

17 Appendix 1, "San Onofre Nuclear Generating Station, Seismic Hazard Assessment Program, 2010 Probabilistic Seismic Hazard Analysis Report."

18 Next Generation Attenuation, 2008, Earthquake Spectra, v. 24, no. 1, pp. 1-341.

seismic reliability report discussed below. The results from the SONGS 2010 PSHA are comparable to the SONGS 1995 PSHA, indicating that the assessment of SONGS seismic hazard risk has not changed.

3. Tsunami Hazard Analysis

SCE updated the SONGS tsunami hazard analysis. The elevation at the top of the SONGS 2 & 3 seawall is 30 feet mean lower low water (mllw) and at the North Industrial Area seawall is 28.2 feet mllw. Using the data provided in the "*Tsunami Inundation Map For Emergency Planning,*"[19] the new maximum tsunami height is approximately 22.9 feet mllw. During the preparation of the "*Tsunami Inundation Map For Emergency Planning,*" the North Industrial Area seawall was inadvertently excluded and the inundation map erroneously indicated the potential for flooding.[20] The North Industrial Area seawall protects the SONGS North Industrial Area from beach erosion, wave action, and storm and tsunami surges. The seawalls for SONGS 2 & 3 and the North Industrial Area will provide approximately 7.1 feet and 5.3 feet of margin, respectively, above the maximum tsunami, indicating that there is no potential tsunami impact to the SONGS site.

4. Evaluation of Lessons Learned from KK Nuclear Plant

SCE reviewed the following reports to assess the lessons learned from the KK nuclear plant following the 2007 Niigata-Chuetsu-Oki (NCO) earthquake:

- Institute of Nuclear Power Operations (INPO), Significant Event Notification: SEN 269, "*Earthquake at Kashiwazaki-Kariwa,*" October 24, 2007
- Electric Power Research Institute (EPRI), "*EPRI Independent Peer Review of the TEPCO*[21] *Seismic Walkdown and Evaluation of the*

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[19] "Tsunami inundation Map For Emergency Planning," 2009, prepared jointly by the State of California Office of Emergency Services, California Geologic Survey, the University of Southern California Tsunami Research Center, and the National Oceanic and Atmospheric Administration.

[20] Appendix 2, "Tsunami Hazard Evaluation."

[21] The Tokyo Electric Power Company, Inc. (TEPCO) is the owner and operator of the KK Nuclear Power Plant in Japan.

Kashiwazaki-Kariwa Nuclear Power Plants," Product ID: 1016317, January 2008

- International Atomic Energy Agency (IAEA), "*Preliminary Findings and Lessons Learned from the 16 July 2007 Earthquake at Kashiwazaki-Kariwa NPP*," Mission Reports Volumes 1 and 2, August 17, 2007

The six key lessons learned identified in these three independent reports are that nuclear plant operators should:

- Understand the site's seismic hazard
- Have an on-going seismic program
- Have procedures for earthquake response actions
- Have adequate fire protection measures
- Have provisions to minimize the unintended release of radioactive liquid to the environment
- Consider ground deformation at a plant site during design and construction

SCE has applied these six lessons learned to SONGS and determined the following:

- SCE properly determined the SONGS seismic hazard as part of the initial NRC licensing process. SCE continued to update SONGS seismic hazard assessment based on new and relevant seismic information.
- SCE has established an active on-going seismic program to assess the seismic hazard for the SONGS site. Under this program, new seismic data and new developments in seismic research relevant to SONGS are reviewed.
- SONGS operators have written procedures on the actions to be taken when earthquake ground motions occur at the site. These actions include determining the earthquake accelerations so that the appropriate activities can be performed to ensure plant safety.

- SONGS maintains an on-site, full-time, dedicated fire department with multiple alternative fire protection systems available to respond to fires.
- SCE assessed the potential for unmonitored releases of radioactive liquids to the environment at SONGS and identified possible radiological sources, potential areas where leaks could occur, early detection techniques, spill containment features, and mitigation measures. SONGS has taken actions to minimize the potential for an unintended release.[22]
- Much of the damage to the KK nuclear plant was caused by large ground deformations. The SONGS site will not have large ground deformations, due to its location within the San Mateo geological formation, which was studied and tested prior to constructing SONGS. Testing has demonstrated that the soil at SONGS is not prone to liquefaction or extensive settlement during a seismic event.

In summary, when applying the lessons to be learned from the KK nuclear plant earthquake experience to SONGS,[23] a review of SONGS design, processes and procedures indicate that SONGS is well prepared for a seismic event. SCE has properly understood the seismic hazard for SONGS, which is designed appropriately for earthquakes. SCE has and continues to review new seismic data and developments in seismic research for the purpose of assuring the safe and reliable operation of SONGS.

5. <u>Seismic Reliability Evaluation</u>

SCE completed a study to identify any important-to-reliability, non-safety-related SSCs that could be the cause of a prolonged outage due to a seismic event. The study[24] evaluated the non-safety-related SSCs that are required for power generation; these non-safety-related SSCs are considered important-to-reliability. Additionally, SCE

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[22] Section III.G provides additional information regarding ground water protection.

[23] Appendix 3, "Lessons Learned from Kashiwazaki-Kariwa Nuclear Power Plant."

[24] Appendix 4, "Seismic Reliability Study of San Onofre Generating Station Non-Safety-Related Structures, Systems, and Components."

evaluated the SONGS non-power block buildings that are needed to support power generation.

SCE determined that further evaluation of the offshore discharge conduits is required to assess the conduits' seismic capacity. All other important-to-reliability, non-safety-related SSCs would not be the cause of a prolonged outage following a seismic event. Two non-power block buildings were identified as important-to-reliability, and would not be the cause of a prolonged outage following a seismic event.

6. Additional Seismic Evaluations

The AB 1632 Report also made the following two recommendations regarding seismic hazards research: (1) develop an active seismic hazards research program; and (2) use three-dimensional seismic reflection mapping, other techniques, and a permanent GPS array for resolving seismic uncertainties for SONGS. As indicated in SCE's 2012 General Rate Case, SCE has established and is seeking funding for an on-going seismic program for SONGS.[25] Additionally, SCE has proposed three categories of planned future work: (1) re-processing and re-analyzing existing data using more modern digital and numerical computer processes; (2) supplementing existing geodetic and seismological networks; and (3) completing new 2-D and 3-D offshore and onshore geophysical survey programs as necessary.[26]

Another recommendation in the AB 1632 Report was to evaluate changes to seismic design standards and compliance with current building codes. SCE completed the evaluation and the results indicated that the SONGS 2 & 3 non-safety-related SSC designs are comparable to the current building codes and applicable seismic design standards.[27]

7. Conclusion

The seismic and tsunami recommendations that were directed toward SCE in the AB 1632 Report have been addressed in this section. The relevant conclusions are

[25] A.10-11-015, SCE-2, Volume 10, p. 43.

[26] A.10-11-015, SCE-2, Volume 10, p. 44.

[27] Appendix 5, "Building Codes and Seismic Design Standards."

provided above and are further described in the referenced appendices. Further analysis is required to assess the offshore discharge conduits' seismic capacity.

B. EMERGENCY PREPAREDNESS

1. Introduction

This section addresses the AB 1632 Report recommendation that SCE should reassess the adequacy of access roads and surrounding roadways for allowing: (1) emergency personnel to reach SCE's nuclear generating plant, and (2) local communities and non-essential plant workers to evacuate in the event of an emergency.[28]

2. Requirements/Regulatory Guidance Summary

As the operating agent for SONGS 2 & 3, SCE is required to meet or exceed the emergency planning regulations established for nuclear facilities by the NRC and the Federal Emergency Management Agency (FEMA). The NRC is the jurisdictional regulatory authority for the safe operation of all U.S. nuclear facilities, and in that role is responsible for the oversight of emergency preparedness activities. FEMA is responsible for the oversight of emergency preparedness activities of the offsite agencies that respond to certain emergencies at a nuclear facility.

The NRC requires each licensee to have approved, integrated emergency plans for inside and outside the nuclear facility's boundary (i.e., onsite and offsite).[29] As part of these requirements, SCE is required to conduct drills and exercises to evaluate all major portions of emergency response capabilities during a six-year drill cycle.[30] The NRC-approved emergency plan for SONGS meets these requirements.

Every two years, SCE conducts an exercise to assess the level of preparedness of local responders (e.g., police, firefighters, etc.) to react to a simulated emergency at SONGS, pursuant to FEMA policies and guidance concerning the exercise of state and local Radiological Emergency Preparedness plans and procedures. Participants in the exercise include SONGS employees, local agencies, other governmental agencies, and some members of the private sector.

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[28] CPUC June 25, 2009 Letter to SCE; AB 1632 Report, p. 16.

[29] NUREG-0654 FEMA-REP 1, Rev. 1, *Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants*.

[30] NUREG-0654 Part II.N and 10 CFR § 50.47 (b) (14).

In connection with the approved emergency plan, the NRC requires each licensee to address an Evacuation Time Estimate (ETE) study[31] for the site and surrounding areas. The ETE is used for pre-planning protective action recommendations.[32] The ETE addresses potential challenges to efficient evacuation, such as weather and earthquake damage, allowing mitigative measures to be pre-planned. SCE completed an ETE for SONGS in 2007,[33] in accordance with this guidance. The ETE assesses the time needed to evacuate the public[34] from a potential exposure pathway (Emergency Planning Zone or EPZ)[35] during a general emergency. The results provide both SCE and offsite agencies information to support protective action decisions, including whether evacuation or shelter in place is the appropriate response to the emergency.

3. Overview of Evacuation Plan

In the event of an emergency at SONGS, SCE's highest responsibility is safeguarding the surrounding communities and plant workers. To meet the responsibility in an emergency at SONGS and to evacuate the public and non-essential workers, SCE (1) has proven methods to inform workers, communities, and local agencies of emergency conditions; (2) actively partners with local, state, and federal agencies to coordinate evacuation activities; and (3) validates the ability to evacuate plant workers.

a) Overview of Evacuation Plan for the Public

SCE maintains a system of electronic sirens (Community Alert Siren System or CASS) strategically located in communities within the Emergency Planning Zone surrounding SONGS 2 & 3. Community officials for local jurisdictions are

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31 NUREG-CR-6863.

32 Protection Action Recommendation: recommendations made by plant personnel, based on plant conditions, to state and local government agencies on actions that could be taken to protect the population in the Emergency Planning Zone (EPZ) from exposure to radiation or radioactive materials. Based on the recommendation and independent assessment of other local factors, the state or local government agencies are responsible for making decisions on the actions necessary to protect the public and for relaying the decisions to the public.

33 Appendix 6, "San Onofre Nuclear Generating Station Evacuation Time Evaluation Final Report."

34 The public also includes non-essential SONGS 2 & 3 personnel once they leave the plant.

35 Emergency Planning Zone (EPZ): an area around a nuclear power plant that is defined as part of the pre-planned strategy for protective actions during an emergency.

responsible for activating the CASS in the event of a nuclear emergency requiring public action. Sounding the sirens will alert area residents to turn on a broadcast news station or radio for public safety information. Annually, a highly publicized siren test is conducted by the offsite agencies to familiarize the public with the distinctive sound of the sirens.[36]

Additionally, local community emergency responders have the ability to use AlertOC (Alert Orange County), which is a free, regional, county-wide mass notification system. AlertOC can send emergency voice messages from public safety officials to the home, cell, or business phone of nearby residents. Text messages also can be sent to email accounts, and receiving devices for the hearing impaired. AlertOC complements other emergency notification systems such as CASS, Emergency Alert System, or roving public address systems.

SCE also has an ongoing public outreach effort to educate local residents and businesses on the actions they should take in the event of an emergency, including the actions they should take when responding to the CASS. This outreach effort includes public meetings with local schools, communities, and residential groups; informational mailings to residents and businesses; and information booths at safety expos and other public venues.

Local jurisdictions' and SONGS' emergency plans provide for precautionary and planned actions, for example:

- Closure of California State Parks, as deemed appropriate by California State Parks personnel, prior to an announcement of a General Emergency.
- Relocation of students and faculty in the Capistrano Unified School District, as deemed appropriate by District personnel, prior to an announcement of a General Emergency.

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[36] In the event of an inadvertent siren actuation, a process has been developed and includes a range of responses based on the circumstances (e.g. length of siren activation, time of day, etc.). The offsite agencies will determine the most suitable method of notifying their communities of an inadvertent siren actuation.

- Closure of I-5 Northbound at SR-78 in Oceanside and I-5 Southbound at the 5/405 El Toro intersection by CHP in a General Emergency

An interjurisdictional planning committee (IPC) was established in 1982 to "promote nuclear power preparedness through agency coordination and integration of emergency plans."[37] To achieve this mission, the IPC collaborates and drills on emergency plans and procedures designed to protect the public health and safety during a declared emergency. The IPC includes community officials from the following local jurisdictions:[38]

- City of Dana Point
- City of San Clemente
- City of San Juan Capistrano
- Orange County
- San Diego County
- California State Parks
- Marine Corps Base Camp Pendleton
- Southern California Edison

IPC associate members (support jurisdictions) are:

- Capistrano Unified School District
- Oceanside Fire Department
- Orange County Fire Authority
- Mission Regional Medical Center
- California Highway Patrol
- California Emergency Management Agency
- Federal Emergency Management Agency
- Nuclear Regulatory Commission

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[37] http://www.nrc.gov/reading-rm/doc-collections/commission/slides/2006/20060502/rose-slides.pdf, p. 6.

[38] The IPC complies with the California Health & Safety Code § 114650(a).

b) Overview of Evacuation Plan for Non-Essential Workers

All SONGS employees are trained to respond to emergencies, and participate in periodic emergency preparedness drills. SONGS communication methods include public address (PA) announcements, sirens, beacons, and announcements at assembly areas. SONGS 2 & 3 emergency procedures call for the evacuation of non-essential personnel when the emergency classification level is "Site Area Emergency."[39] Site drills have confirmed SCE's ability to assemble and evacuate non-essential personnel during accident scenarios.

4. Overview of Plan for Plant Access for Essential Plant Workers

Essential members of the Emergency Response Organization (ERO) at SONGS are assigned a pager. In the event of a declared emergency, ERO pagers are activated, and personnel report to one of the Emergency Response Facilities on the plant site, or at staging areas, when I-5 has been closed. Communication arrangements have been made for ERO personnel to communicate with the plant and, if necessary, obtain a California Highway Patrol (CHP) escort to the plant.

5. Experience

a) Experience with Evacuation Plans for the Public

The biennial Radiological Emergency Preparedness exercise for SONGS was conducted in 2009. The exercise, held in accordance with FEMA policies and guidance, assessed the level of preparedness of local responders to react to a simulated emergency at SONGS. SONGS employees, local agencies, other governmental agencies, and private sector organizations who participated in the exercise, demonstrated knowledge of the emergency response plans and procedures, and the ability to execute those plans. There were no deficiencies identified during the course of the exercise.

SCE's emergency-response coordination with local agencies was also demonstrated during the week of October 2007, when several large brush fires

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[39] There are four emergency classification levels defined by the Emergency Plan. In order of increasing severity the classifications are: 1) Unusual Event, 2) Alert, 3) Site Area Emergency, and 4) General Emergency. These are described in an SCE publication entitled, "*A Guide to San Onofre Nuclear Generating Station for Visitors and Newcomers*," p. 6.

burned in Orange, Riverside, and San Diego counties. The event did not endanger the SONGS site, but the severity of the fires caused mandatory evacuations of many communities in southern California, forced the closure of the I-5 freeway used to access the plant, and required an evacuation of the SONGS Mesa facility. SONGS employees and the local agencies that were involved appropriately responded to this event, demonstrating effective coordination between SCE and local agencies.

b) Experience with Station Personnel Response

As stated above, SCE routinely trains on the assembly and evacuation of station personnel for an emergency at SONGS. Pursuant to 10 CFR § 50.47 (b) (10) and NUREG-0654 Part II.J, SCE is required to maintain provisions for the evacuation of non-essential personnel from the site in the event of a Site Area Emergency or General Emergency. Pursuant to 10 CFR § 50.47 (b) (14) and NUREG-0654 Part II.N, SCE is required to conduct drills and exercises to evaluate all major portions of emergency response capabilities during a six-year drill cycle. In accordance with these requirements, SCE tests the evacuation of non-essential personnel during a site evacuation drill. The last site evacuation drill was conducted on July 18, 2007. The results for the drill were successful. SCE also implemented improvements, which included: (1) the process for assembly and evacuation was enhanced to provide for evacuation at the Site Area Emergency level as soon as personnel in Assembly Areas have been provided necessary information regarding evacuation routes, safe area meeting locations, etc.; (2) a telecommunications bridge was established to allow for more efficient communication between the Assembly Areas and Administrative Leader relaying the directions from the Emergency Coordinator; and (3) additional training was conducted to ensure adequate Health Physics personnel and equipment resources are properly deployed to ensure proper radiological monitoring of all evacuated personnel.

In addition to training drills, the October 2007 fires in Orange, Riverside, and San Diego counties caused an emergency evacuation of the SONGS Mesa facility. The SONGS Mesa evacuation was successfully completed without incident. Additionally, offsite ERO personnel successfully exercised the escort arrangements with the CHP to gain access to the site during this event.

6. Modeling of Evacuations

As discussed above, NUREG-CR-6863 recommends that an ETE study should be updated as local conditions change. ETE modeling provides a tool for developing comprehensive evacuation planning studies, including estimating evacuation times, developing traffic management and control strategies, and identifying routes, traffic control points, and other elements of an evacuation plan.

The NRC recommends that ETE studies be performed when the possibility exists that ETE would change significantly.[40] The June 12, 2007 ETE study[41] was conducted using DYNASMART-P, a state-of-the-art dynamic route assignment model sponsored by the Federal Highway Administration and developed at the University of Maryland. This software package provides a blend of four-step regional models and corridor level micro-simulation models. This software dynamically models individual driver behavior in selecting available evacuation routes, and driving in gridlock conditions. Input data for this report includes:

- Geographic Information System (GIS) database of the study area
- Identification of resident and transient population within the study area
- Identification of existing institutions requiring special evacuation assistance, as well as known new institutions planned for construction
- Review of Emergency Response Plans for jurisdictions and agencies in the EPZ
- Inventory of existing highway facilities, including roadway facility type, number of lanes, operating speeds, and traffic controls
- Caltrans (California Department of Transportation) identified non-earthquake-retrofitted bridges, and locations for potential landslides in the area in the event of an earthquake
- Inventory of available demographic data, employment data, recreational facility usage and forecast usage

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40 NUREG-CR-6863, p. 26.

41 Appendix 6, "San Onofre Nuclear Generating Station Evacuation Time Evaluation Final Report."

The ETE models various scenarios to determine evacuation times as listed below:

- Summer weekday evacuation – Assumed the evacuation occurred during business hours with many residents working outside the EPZ, a significant number of non-resident workers in the EPZ, and a moderately heavy number of beach visitors.
- Summer weekend evacuation – Assumed the evacuation occurred during a summer weekend, with significant portions of the population consisting of non-resident workers in the EPZ, as well as recreational visitors. Assumed a large number of beach visitors (based on July 4th holiday) had to be evacuated in this scenario.
- Night Evacuation – Assumed the evacuation occurs during a night scenario in which the maximum number of residents, and the minimum number of non-residents were in the EPZ.

Other scenario variations considered were:

- Adverse weather – Assumed a slower evacuation rate out of the EPZ, than in non-adverse weather scenarios.
- Earthquake – Assumed the evacuation from the EPZ took place after an earthquake which resulted in landslides restricting available lanes of traffic along the ocean and adjacent cliffs, as well as failure of non-earthquake-retrofitted bridges that blocked egress by the population.

The ETE study states that ETE estimates range from 1.5 hours for the least populated areas under the most favorable of circumstances, to 18 hours for the most densely populated areas under earthquake conditions. It should be noted that evacuation is only part of an effective emergency plan, and shelter in place is at times a more appropriate option. The range of uncertainty for evacuation of the EPZ is plus or minus 2 hours.[42]

Annual reviews re-evaluate the key factors that impact the ETE. Most recently, for example, SCE evaluated population changes (increases in population,

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[42] Appendix 6, "San Onofre Nuclear Generating Station Evacuation Time Evaluation Final Report," p. E-2.

changes in age demographics, etc.) and roadway capacity (improvements, constraints, traffic flow, etc). The 2010 updated evaluation concluded that there have been no significant changes in the SONGS EPZ that would adversely affect the information contained in the June 12, 2007, ETE study.[43] The next ETE study will be conducted when the 2010 census information is released.

7. Conclusion

SCE periodically reassesses the access roads and surrounding roadways near SONGS and confirms that they are adequate for allowing (1) emergency personnel to reach SONGS, and (2) local communities and non-essential plant workers to evacuate when appropriate in the event of an emergency. SONGS' Emergency Preparedness Program is approved by the NRC and implemented pursuant to NRC and FEMA regulations. Based on the results of drills, overseen by the NRC and FEMA, as well as actual events that have caused local area evacuations, the emergency plans for SONGS have demonstrated their effectiveness.

[43] Appendix 7, "Annual Assessment of the San Onofre Nuclear Generating Station Evacuation Time Evaluation," dated August 23, 2010.

C. LOW LEVEL RADIOACTIVE WASTE

1. Introduction

This section addresses the following AB 1632 Report recommendations regarding Low Level Radioactive Waste (LLW):[44]

- During the upcoming CPUC proceeding on decommissioning costs, SCE should provide estimates of the amounts of LLW to be generated and ultimately disposed of during plant operation and decommissioning and the cost of this disposal based on current and projected market prices.
- As part of license renewal feasibility studies, SCE should assess the costs of disposing of LLW that will be generated during a 20-year license extension. The assessments should include the cost to dispose of LLW that would be generated from major capital projects that might be required over this period. SCE should also provide information on their plans for storage and disposal of LLW and spent fuel through plant decommissioning.

During the CPUC Nuclear Decommissioning Cost Triennial Proceeding (NDCTP), SCE updates its estimates of the volumes of LLW to be generated and disposed of during decommissioning and the cost of this disposal based on current and projected market prices. Most recently, SCE submitted an updated estimate on April 3, 2009.[45]

This section discusses the projected quantities, disposal options, and transportation and disposal costs for LLW generated at SONGS 2 & 3 during the remainder of the current licensed period, the period of extended operation, and the decommissioning period. The assumed volumes and costs for LLW from the SONGS Independent Spent Fuel Storage Installation (ISFSI) are included in the assumptions for the decommissioning period.

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[44] CPUC June 25, 2009 Letter to SCE; AB 1632 Report p. 28.

[45] Application (A.) 09-04-009, Nuclear Decommissioning Cost Triennial Proceeding.

a) Class A, Class B, and Class C LLW

10 CFR § 61.55 divides LLW into three different classifications: Class A, Class B, and Class C. Class A contains the lowest concentrations of radioactivity, and Class C contains the highest. Class A waste includes materials such as slightly contaminated tools or plant components. Class B and C waste includes materials such as primary system (i.e., reactor coolant system) filters and ion exchange resins.

b) Mixed LLW

Some waste generated during nuclear power operations contains both radioactive and hazardous waste constituents.[46] Such waste is known as mixed low-level radioactive waste (mixed waste). Examples of the hazardous constituents of mixed wastes include: (1) petroleum-based oils, (2) flammables and chlorofluorocarbons, and (3) solids (e.g., asbestos, lead, and electrical waste (e-waste) materials).

2. Onsite Interim Storage, Offsite Disposal, and Disposal Costs of SONGS 2 & 3 LLW

This section will discuss the projected quantities, disposal plans, and disposal costs for Class A, B, and C LLW, and mixed waste, generated at SONGS 2 & 3 during the remainder of the current licensed period, the period of extended operation, and the decommissioning period.

The licensed LLW disposal facility operated by EnergySolutions at Clive, Utah, is expected to be available to accept Class A waste from SONGS 2 & 3 throughout the remainder of the current SONGS 2 & 3 licensed period, the 20-year period of extended operation, and the decommissioning period. The EnergySolutions disposal facility at Barnwell, South Carolina, was available to accept Class A, Class B, and Class C waste from SONGS 2 & 3 until June 30, 2008. As of July 1, 2008, that facility stopped accepting LLW from waste generators in California and all other states outside the Atlantic Coast LLW Compact, as mandated by South Carolina state law.[47] The nuclear industry is working to license new disposal facilities, and is working with the NRC to

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[46] Hazardous wastes are defined in Subtitle C of the Resource Conservation and Recovery Act (RCRA). Reference http://www.epa.gov/rpdweb00/mixed-waste/guidance-identification-llmw.html.

[47] S. C. Code Ann. § 48-46, Atlantic Interstate Low-Level Radioactive Waste Compact Implementation Act.

develop alternative disposal methods for these types of materials. Current licensed waste disposal companies are also looking to expand their licenses to receive Class B and Class C waste. SCE will ship Class B and Class C waste when a disposal facility becomes available. Until such time, SCE has sufficient on-site interim storage capacity to accommodate all Class B and Class C waste generated during the current licensed period and the period of extended operation. Table III-1 below provides the disposal rates published in a recent industry study to project the cost of LLW disposal:[48]

Table III-1
LLW Disposal Rates from 2008 NEWEX Study
(2011 $, 100% Level)

Bulk Class A LLW[49]	$74.83 per cubic foot
General Class A LLW[50]	$307.02 per cubic foot
Class B and C LLW	$3,565.65 per cubic foot

Mixed waste must be disposed of separately from LLW. Mixed waste with different hazardous constituents is subject to different disposal requirements.[51] Licensed disposal facilities are currently available for each type of mixed waste, and are projected to be available throughout the remainder of the current licensed period, the period of extended operation, and the decommissioning period.[52]

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[48] Reference "Establishing an Appropriate Disposal Rate for Low-level Radioactive Waste During Decommissioning," dated July 2008, by Robert Snyder, NEWEX. SCE assumes these LLW disposal rates will escalate by approximately 7 percent per year.

[49] "Bulk" Class A LLW includes materials such as crushed concrete rubble and scrap metal.

[50] "General" Class A LLW includes materials such as containerized waste, high density or oversized packages, and large components (e.g., steam generators).

[51] Each mixed waste disposal or treatment facility must possess not only a license from the NRC or NRC Agreement state, but also a permit from the EPA or EPA Authorized state.

[52] All mixed waste generated to-date at SONGS have contained Class A radioactivity concentrations, for which disposal facilities are currently available. Licensed disposal facilities are not currently available for mixed wastes that contain Class B or Class C radioactivity levels. SCE does not anticipate generating any mixed waste Class B or Class C mixed waste during the remainder of the current licensed period, the period of extended operation, or decommissioning.

a) <u>Remainder of Current Licensed Period</u>

Based on historical volumes, SCE projects that SONGS 2 & 3 will dispose of 7,500 cubic feet of Class A waste, on average, in each remaining year of the current licensed period (through 2022).[53] SCE also projects that it will dispose of an additional 27,000 cubic feet of Class A waste in 2011-2012 from the steam generator replacement project. In addition, SCE projects that 5,000 cubic feet of Class A waste from the SONGS 2 & 3 reactor vessel head replacement project will require disposal in 2012-2013. If SONGS 2 & 3 is permanently shut down at the end of the current licensed period, disposal costs for Class A LLW will be approximately $14.8 million (2011 $, 100% level) during the current licensed period.[54]

SCE projects that SONGS 2 & 3 will generate, on average, 100 cubic feet of Class B and Class C waste from routine plant operations in each remaining year in the current licensed period (through 2022).[55] For purposes of this report, SCE assumes that Class B and Class C waste will remain in onsite interim storage until decommissioning. Therefore, SCE has included the disposal costs for all Class B and Class C waste projected to be generated during the remaining years of the current licensed period with the LLW disposal costs projected during the decommissioning period, discussed in section (c) below.

The volumes and hazardous constituents of mixed waste generated at SONGS 2 & 3 vary from year to year. SCE generates, on average, 550 cubic feet of mixed waste per year, at an annual disposal cost of approximately $340,000 (2011 $, 100% level). SCE projects that it will continue to generate similar mixed waste volumes and incur similar mixed waste disposal costs throughout the remaining years of the

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[53] Projections of annual Class A, Class B, and Class C LLW volumes from routine nuclear power operations are based roughly on the corresponding quantities of materials shipped to licensed LLW disposal facilities recorded during the 2001-2009 period, as reported to the Southwestern Low-level Radioactive Waste Compact Commission.

[54] For estimating purposes, SCE assumes that 80% of Class A LLW will be Bulk Class A material, and 20% will be General Class A material.

[55] Projections of annual Class A, Class B, and Class C LLW volumes from routine nuclear power operations are based roughly on the corresponding quantities of materials shipped to licensed LLW disposal facilities recorded during the 2001-2009 period, as reported to the Southwestern Low-level Radioactive Waste Compact Commission.

current licensed period. The projected cost for mixed waste disposal during the remainder of the current licensed period is $4.1 million (2011 $, 100% level).

b) Period of Extended Operations

SCE projects that SONGS 2 & 3 will dispose of 7,500 cubic feet of Class A LLW, on average, in each year during the 20-year period of extended operation (2023-2042).[56] During the 20-year period of extended operation, disposal costs for Class A waste will be approximately $18.2 million (2011 $, 100% level).

In addition, SCE projects that it will generate, but not dispose of, 100 cubic feet of Class B and Class C LLW in each year during this extended period.[57] For purposes of this report, SCE assumes that Class B and Class C waste will remain on-site in interim storage until decommissioning. At this time, SCE has not identified any one-time projects that would require disposal of additional quantities of Class A, Class B, or Class C waste during the period of extended operation. SCE has included the disposal costs for all Class B and Class C waste generated throughout the period of extended operation with the LLW disposal costs projected during the decommissioning period, discussed in section (c) below.

SCE generates, on average, 550 cubic feet of mixed waste, at an annual disposal cost of approximately $340,000 (2011 $, 100% level). SCE projects that it will continue to generate similar mixed waste volumes and incur similar mixed waste disposal costs throughout the period of extended operation. The projected cost for mixed waste disposal during the period of extended operation is $6.8 million (2011 $, 100% level).

c) Decommissioning Period

If SONGS 2 & 3 commences decommissioning in 2023, SCE projects that the decommissioning of SONGS 2 & 3 would require disposal of approximately 1.5 million cubic feet of Class A waste; approximately 6,100 cubic feet of

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[56] *Id.*

[57] *Id.*

Class B waste; and approximately 1,400 cubic feet of Class C waste.[58] These quantities include all Class B and Class C waste that is projected to be generated during the current licensed period. The total LLW disposal cost during the decommissioning period is projected to be $208.6 million (2011 $, 100% level).

Alternatively, if SONGS 2 & 3 commences decommissioning in 2043, SCE projects that the decommissioning of SONGS 2 & 3 would require disposal of approximately 1.5 million cubic feet of Class A waste, 7,300 cubic feet of Class B waste, and 2,200 cubic feet of Class C waste.[59] These quantities include all Class B and Class C waste that is projected to be generated during both the remainder of the current licensed period and the period of extended operation.[60] The total LLW disposal cost during the decommissioning period is projected to be $215.8 million (2011 $, 100% level).

SCE projects that it will generate approximately 13,000 cubic feet of mixed waste annually during decommissioning. The projected cost of disposal for mixed waste during decommissioning is $14.1 million (2011 $, 100% level).[61] SCE projects that it will generate the same amount of mixed waste during decommissioning, regardless of whether SONGS 2 & 3 is permanently shut down at the end of the current licensed period or after the period of extended operation.

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[58] Projected quantities of Class B and Class C waste include volumes generated during the remaining years of the current operating licensed period plus projected volumes contained in San Onofre Nuclear Generating Station Units 2 and 3 Decommissioning Cost Estimate, prepared for Southern California Edison Company by ABZ, Incorporated, February 2009, Unit 2 Volume, Appendix A, p. 3, and Unit 3 Volume, Appendix A, p. 3.

[59] Projected quantities of Class B and Class C waste include volumes generated during the remaining years of the current operating licensed period and the period of extended operation, and the projected volumes contained in "San Onofre Nuclear Generating Station Units 2 and 3 Decommissioning Cost Estimate," prepared for Southern California Edison Company by ABZ, Incorporated, February 2009, Unit 2 Volume, Appendix A, p. 3, and Unit 3 Volume, Appendix A, p. 3.

[60] Because SCE has not identified any one-time projects that would require disposal of additional quantities of Class A waste during the period of extended operation, the projected volumes of Class A LLW that will require disposal during decommissioning remain the same whether decommissioning occurs at the end of the current operating license expires or after the period of extended operation.

[61] "San Onofre Nuclear Generating Station Units 2 and 3 Decommissioning Cost Estimate," prepared for Southern California Edison Company by ABZ, Incorporated, February 2009, Unit 2 Volume, Appendix E, p. 31.

3. Transportation of LLW to Licensed Disposal Facilities

Transportation of Class A waste from SONGS 2 & 3 to the licensed disposal facility at Clive, Utah, during the current licensed period and the period of extended operation, are projected to be 99% by truck and 1% by rail. Transportation costs are projected to be $12.23 (2011 $, 100% level) per cubic foot for truck shipments, and $6.11 (2011 $, 100% level) per cubic foot for rail shipments. Truck shipments will be used predominantly during plant operations due to the relatively small volumes of materials expected to be shipped, except for large, heavy shipments for which rail shipment is warranted. During decommissioning, however, shipments of Class A waste are projected to be 90% by rail and 10% by truck. This is because the shipping volumes will be much greater during decommissioning. Shipments of Class B and Class C waste are assumed to be by truck at a projected cost of $489.06 (2011 $, 100% level) per cubic foot. LLW transportation costs are projected to be $1.5 million (2011 $, 100% level) during the remaining years of the current licensed period and $1.8 million (2011 $, 100% level) during the period of extended operation. LLW transportation costs during decommissioning are projected to be approximately $13.7 million (2011 $, 100% level) if decommissioning commences at the end of the current licensed period and approximately $14.7 million (2011 $, 100% level) if decommissioning commences after the period of extended operation.

Each type of mixed waste is shipped to a different disposal facility. Transportation costs for mixed wastes to each disposal facility are approximately $10,000 per shipment (2011 $, 100% level), regardless of the number of container in the shipment. SCE projects that it will make one shipment of each mixed waste type per year during the remainder of the current licensed period and during the period of extended operations. This would result in mixed waste transportation costs of $360,000 (2011 $, 100% level) throughout the remainder of the current licensed period and $600,000 (2011 $, 100% level) throughout the period of extended operation. SCE projects that it will make, on average, six mixed waste shipments per year during the decommissioning period. The cost to transport all mixed waste generated during decommissioning will be approximately $900,000 (2011 $, 100% level).

4. Conclusion

SONGS 2 & 3 has adequate plans for storage and disposal of LLW and has estimated the costs for LLW disposal as provided in Table III-2 below:

Table III-2
SONGS 2 & 3 LLW and Mixed Waste Disposal and Transportation Costs (2011 $ in Millions, 100% Level)

	Class A LLW Disposal	Class B & C LLW Disposal	LLW Transportation	Mixed Waste Disposal	Mixed Waste Transportation
Remaining Licensed Period	$14.8	N/A	$1.5	$4.1	$0.4
Period of Extended Operations	$18.2	N/A	$1.8	$6.8	$0.6
Decommissioning (begin in 2023)	$181.9	$26.7	$13.7	$14.1	$0.9
Decommissioning (begin in 2043)	$181.9	$33.9	$14.7	$14.1	$0.9

D. USED FUEL MANAGEMENT

1. Introduction

This section describes SCE's plan for the safe and secure storage of used fuel.[62]

2. Used Fuel Management Plan

SCE complies with NRC requirements for used fuel storage. SCE will continue to adhere to its current used fuel management plan in which used fuel for SONGS 2 & 3 is stored in used fuel pools or dry cask storage containers. Both configurations are safe and have measures in place to protect the public. SCE transfers used fuel from SONGS 2 & 3 used fuel pools to dry cask storage (otherwise known as the Independent Spent Fuel Storage Installation or ISFSI) as necessary to maintain full core offload capability, in accordance with NRC requirements.

SCE intends to periodically increase the amount of dry cask storage containers to accommodate (1) maintaining full core offload capability within the used fuel pool during operations, and (2) storing all used fuel in the ISFSI approximately 5 to 12 years after SONGS 2 & 3 is permanently shut down. SCE plans to continue safely storing used fuel at SONGS pursuant to this plan until the Department of Energy (DOE) fulfills its contractual obligations to remove all used fuel at SONGS for permanent disposition.

This plan is consistent with the NRC's position on used fuel storage, as outlined in the recently approved Waste Confidence Decision.[63] The NRC issued a revision to 10 CFR § 51.23, which specifies that used fuel can be safely stored for at least 60 years beyond the licensed life of a nuclear power plant including license renewal.[64] SCE plans to safely store its used fuel onsite in the ISFSI and in its used fuel storage pools, as necessary, until the DOE fulfils its contractual obligations to remove the used fuel from the site. The technology exists to evaluate, refurbish, and repair or replace

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[62] CPUC June 25, 2009 Letter to SCE; AB 1632 Report, p. 34.

[63] SECY-09-0090 – Final Update of the Commission's Waste Confidence Decision.

[64] "Consideration of Environmental Impacts of Temporary Storage of Spent Fuel After Cessation of Reactor Operation; Waste Confidence Decision Update; Final Rules," 75 Fed. Reg. 81,032-81,706 (Dec. 23, 2010) (to be codified at 10 CFR pt. 51).

used fuel dry cask storage system components, for as long as it is necessary to extend the life of the used fuel dry cask storage facility.

3. Used Fuel Storage Costs

The capital costs associated with used fuel storage are addressed in SCE's 2012 General Rate Case (GRC).[65] The costs associated with SONGS used fuel storage are also components of the costs included in SCE's cost-effectiveness analysis that SCE will submit in a separate license renewal funding application to the CPUC. Cost estimates for decommissioning the ISFSI have been included in the NDCTP. The incremental costs for decommissioning the dry cask storage modules due to an additional 20 years of operation if SONGS 2 & 3 operating licenses are renewed, will be included in a future NDCTP proceeding, as appropriate. These additional costs have a negligible impact on the cost-effectiveness analysis that will be included with SCE's license renewal funding application.

In addition to the costs identified above, SCE customers contribute 1 mil per kWh for electricity produced from nuclear fuel to the federal government for the Nuclear Waste Fund to pay for all costs incurred by DOE in fulfilling its contractual obligations to remove and permanently disposition all used fuel from SONGS.

4. Used Fuel Storage Systems

a) Used Fuel Pool

The NRC has approved the use of engineered pools to store used fuel. These pools provide cooling, prevent criticality, and protect the fuel assemblies from excess mechanical or thermal loading. Used fuel is stored underwater in the pools in storage racks. Used fuel assemblies are maintained in a safe configuration by several design aspects of the used fuel storage racks including: (1) the pattern of the fuel assemblies in the racks, and (2) the design of the racks which limit fuel assembly interaction. Design of the used fuel pools ensures adequate convective cooling for the removal of decay heat. The used fuel pools are located in a secured area at SONGS 2 & 3, with one pool for each unit. Cooling and system integrity monitoring and maintenance are performed as part of routine operation and maintenance programs.

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[65] A.10-11-015, SCE-02, Volume 2.

As indicated above, the NRC requires that sufficient space in each used fuel pool be available to allow off-loading of a full core of each reactor. SCE adheres to this requirement.

b) Independent Spent Fuel Storage Installation

The NRC has approved the use of dry cask storage to store used fuel once it has cooled to acceptable levels in a used fuel pool. SONGS 2 & 3 used fuel requires 5 to 12 years of cooling in pools before it can be transferred to dry cask storage. Transfers from SONGS 2 & 3 used fuel pools to dry cask storage in the ISFSI are scheduled as necessary to maintain the capability to offload a full core of used fuel.

The ISFSI is located in a secured area at SONGS, dedicated to the dry cask storage of SONGS used fuel. The ISFSI (the dry cask storage system) consists of reinforced concrete modules, in which the sealed steel canisters containing used fuel are stored. The size of the ISFSI is expanded as necessary to accommodate used fuel from SONGS 2 & 3 operations. There is sufficient space to store in the ISFSI, all used fuel generated from SONGS 2 & 3 operations, through the period of extended operation if SONGS 2 & 3 operating licenses are renewed, until the DOE removes the used fuel from the site.

5. Conclusion

SCE continues to follow its used fuel management plan, transferring used fuel from SONGS 2 & 3 used fuel pools to ISFSI dry cask storage as needed to maintain the full core offload capability required by the NRC. SCE's used fuel management plan provides safe and secure storage of used fuel, until the DOE meets its acknowledged obligations to remove the used fuel from the site.

E. ECONOMIC IMPACT

1. Introduction

This section addresses the AB 1632 Report recommendation that SCE provide an economic impact evaluation regarding SONGS 2 & 3, and compare that impact with the alternate uses of the SONGS site.[66] SCE leases land for SONGS 2 & 3 from the Department of the Navy under long term agreements that specify SCE's use of the land. Future alternative use of the land would be at the discretion of the Department of the Navy. At this time, SCE has no information about what alternate uses the Department of the Navy might consider.

2. Methodology

SCE retained IHS Global Insight to study the economic impacts of SONGS 2 & 3. IHS Global Insight is a leading economic forecasting and consulting company.[67] IHS Global Insight used the IMPLAN input/output (I/O) model to estimate the total economic impacts of SONGS 2 & 3 on the California economy. The IMPLAN model computes a set of multipliers that produce estimates of the total regional increases in output,[68] value added,[69] employment, and income produced by direct spending. The IMPLAN model uses inter-industry purchasing relationships to derive sector-specific multipliers that are unique to the regional economy being analyzed (California). The sizes of the multipliers are determined by the production functions in the affected final demand sectors, or by the number and types of industries that supply inputs to the directly affected sectors. The multipliers are used to derive indirect[70] and induced[71] effects, which

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[66] CPUC June 25, 2009 Letter to SCE; AB 1632 Report, p. 25.

[67] Both the Commission and SCE have used IHS Global Insight's macroeconomic projections for over 3 decades.

[68] Output - The value of production by industry for a given time period.

[69] Value Added - Payments made by industry to workers, interest, profits, and indirect business taxes.

[70] Indirect effects result from direct suppliers purchasing additional inputs from other regional suppliers, such as a concrete contractor purchasing sand and gravel from a local quarry.

[71] Induced effects result from the increase in local spending of disposable income by the newly hired workers. For example, an induced effect may be a newly hired contractor spending their earnings at local restaurant, gas station or grocery store.

are then added to the direct effects to obtain the total change in regional economic activity.

3. Results

IHS Global Insight prepared a study to assess the economic impact, over a 5-year period (2010 - 2014), using SONGS 2 & 3 expenditure estimates provided by SCE.[72] The study first discusses the wage, employment, and expenditure estimates used in the study. Next, the study provides estimates of the indirect and induced effects on other economic sectors in California. The results of the study provide a macroeconomic estimate of wages, total output, taxes, and value added activity generated in the California economy due to the direct, indirect, and induced impacts of SONGS 2 & 3.

Specifically, the operation of SONGS 2 & 3 affects a large number of sectors within the California economy. The study indicates that the operation of SONGS 2 & 3 supports about 9,400 jobs and impacts the California economy by more than $3.3 billion per year. The type of employment at SONGS 2 & 3 also has significant impacts. In California, average annual wages in 2010 totaled $56,000 and value added per employee is measured at about $135,000. In comparison, SONGS 2 & 3 average annual wages in 2010 were $84,000 and the value added per employee was over $243,000 per year, which were both substantially more than the state average.

Employment and economic impacts were as follows:

Employment Impacts

- 3,751 jobs,[73] on average, are directly supported per year.
- 9,451 jobs, on average, are directly and indirectly supported per year.
- The value added per employee is $243,000 per year.

[72] Appendix 8, "Economic Impacts of the San Onofre Nuclear Generating Station on the California Economy."

[73] Individuals counted in "direct employment" include SCE employees, contractors, and services employees.

Economic Impacts

- SONGS 2 & 3 total impact on the California economy on average is over $3.3 billion annually or $16.5 billion over the 5-year study period.
- State Tax Revenue is estimated to be $246 million annually or $1.2 billion over the 5-year study period.
- During the study period, each dollar spent on SONGS 2 & 3 generates a total of $4.30 in output in the California economy.
- During the study period, each dollar spent on SONGS 2 & 3 generates a total of $3.00 in value added in the California economy.
- During the study period, each dollar spent on SONGS 2 & 3 produces $1.35 of labor earnings.

4. Conclusion

As the IHS Global Insight study demonstrates, operations of SONGS 2 & 3 will provide broad economic benefits to the California economy.

F. NUCLEAR SAFETY CULTURE

1. Introduction

This section addresses the AB 1632 Report recommendation that SCE report on its progress in addressing nuclear safety culture issues at SONGS,[74] and includes a summary of the NRC's evaluation of these efforts and of overall performance at SONGS.[75] In particular, this section outlines SCE's:

- Overall commitment to a strong nuclear safety culture;
- Actions to strengthen the nuclear safety culture;
- Actions to preserve and improve the environment in which all personnel are encouraged and able to raise concerns by multiple pathways; and
- Monitoring and progress in achieving a strong plant nuclear safety culture.

2. SCE's Commitment to a Strong Nuclear Safety Culture

Nuclear safety culture refers to an organization's values and behaviors – modeled by its leaders and internalized by its members – that make nuclear safety the overriding priority for the organization. In an organization with a strong nuclear safety culture, personnel feel personally responsible for nuclear safety and act in ways that demonstrate their commitment to keeping nuclear safety the highest priority.

At SONGS, a strong nuclear safety culture is the foundational principle, ensuring that safety is always the top priority. SCE is committed to cultivating an open, collaborative culture, where:

- Everyone is personally responsible for nuclear safety;
- Leaders demonstrate commitment to safety;
- Trust permeates the organization;
- Decision-making reflects safety first;
- Nuclear technology is recognized as special and unique;

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[74] CPUC June 25, 2009 Letter to SCE; AB 1632 Report, p. 19.

[75] CPUC June 25, 2009 Letter to SCE.

- A questioning attitude is cultivated;
- Organizational learning is embraced;
- Nuclear safety undergoes constant examination; and
- Leadership establishes and maintains a healthy safety conscious work environment where individuals are free to raise concerns without fear of retaliation.

SCE is committed to conducting business every day in a manner consistent with these standards and principles. Site management consistently and clearly communicates nuclear safety messages, including that (1) safety is the first priority; (2) site personnel are expected to identify and report potential safety concerns; (3) site personnel must comply with regulatory requirements and SONGS procedures and programs, and stop when uncertain on how to implement requirements; and (4) retaliation against those who raise safety concerns is not permitted and will not be tolerated.

SCE is responsible day-to-day for ensuring that SONGS 2 & 3 is operated safely. In addition, the NRC has increasingly focused its oversight on nuclear safety culture in the nuclear power industry. The NRC continues to strengthen its rules, update its guidance, and enhance its inspection and enforcement programs to meet the agency's mission to ensure public health and safety. The NRC's evaluation and regulation of nuclear safety culture[76] provides further assurance that safety is always the top priority at SONGS.

3. Nuclear Safety Culture Action Plan

To preserve and strengthen the nuclear safety culture at SONGS, SCE completed the following actions as part of SONGS Nuclear Safety Culture Action Plan:[77]

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[76] NRC Inspection Manual Chapter 0310, Components Within The Cross-Cutting Areas, describes the components of nuclear safety culture. The safety culture components are described as the human performance, problem identification and resolution, and safety conscious work environment cross-cutting area components, and other components (accountability, continuous learning environment, organizational change management, and safety policies). The cross-cutting area components are evaluated during the conduct of both baseline and supplemental inspection programs, while the other components are evaluated during the conduct of the supplemental inspection program.

[77] SCE letter to the NRC, dated October 29, 2009, regarding the independent safety culture assessment results and action plans.

- Developed mechanisms to monitor nuclear safety culture progress and effectiveness, including designating a project manager to track progress;
- Strengthened on-going communications to site personnel to improve understanding of nuclear safety culture and Safety Conscious Work Environment;
- Developed and continue to align station personnel to the SONGS Excellence model, which includes overall site and nuclear safety culture standards;
- Conducted leadership seminars for station managers and supervisors to improve understanding and alignment around nuclear safety; and
- Established and is implementing a Leadership Academy to strengthen management alignment and demonstration of their role in enhancing nuclear safety culture.

4. SCE's Response to NRC Letter Regarding Work Environment Issues at SONGS

SCE identified actions to improve the SONGS Safety Conscious Work Environment (SCWE) – an environment in which everyone is encouraged to raise concerns, and those concerns are addressed, without fear of retaliation. SCWE is a subset of nuclear safety culture.

In March 2010, the NRC issued a letter to SCE identifying a potential chilling effect regarding work environment issues. Although surveys and interviews indicated that most (95% or more) site personnel felt comfortable raising safety concerns, NRC inspection results and SCE's own reviews indicated there were areas for improvement that require action to ensure a strong SCWE among all work groups at SONGS. SCE leadership is committed to fostering an environment in which all personnel are encouraged and able to raise concerns using multiple paths. To ensure an approach that is consistent with industry best practices for resolving SCWE issues, SCE adopted the following "Four Pillar" model as the framework for development of actions to strengthen the SCWE at SONGS:

- **Pillar 1** – Employees Raise Concerns Without Fear of Retaliation
- **Pillar 2** – Effective Normal Problem Resolution Processes
- **Pillar 3** – Effective Alternate Resolution Processes
- **Pillar 4** – Effective Methods to Detect and Prevent Retaliation

The Four Pillar model, supported by organizational structures and formal processes, is now the basis for SCWE improvement actions at SONGS. Action[78] areas included:

- **Communications –** SCE continues to provide numerous site-wide communications to reinforce SCE's SCWE expectations and policies, and to encourage workers to raise concerns to their supervisors, by writing a Nuclear Notification,[79] by contacting the Employee Concerns Program or by informing the NRC. An important part of this effort includes senior site management meeting with smaller groups of employees throughout the site to hear personnel's issues and concerns;
- **Training** – SCE has provided training to managers and supervisors on SCWE principles and behaviors to ensure that their behavior encourages workers to raise concerns without the fear of retaliation; SCE has provided training to SONGS employees and contractors on SCWE policies and principles, and avenues to raise concerns, including via management, through the Corrective Action Program, through alternate processes such as the Employee Concerns Program and to the NRC without fear of retaliation;
- **Employee Concerns Program (ECP)** – SCE made this program more accessible and responsive to SONGS employees and

[78] SCE letter to the NRC, dated March 31, 2010, regarding actions associated with work environment issues.

[79] A Nuclear Notification is a document that captures a problem or concern and allows for the formal evaluation and resolution of the problem.

contractors, and increased face-to-face contact between Employee Concerns Program personnel and members of the workforce.

- **Corrective Action Program (CAP)** – SCE made the CAP – the program used to identify and track resolution of issues at SONGS – easily accessible to SONGS employees and contractors for reporting concerns, and ensured that concerns can be reported anonymously, and that personnel readily obtain feedback on how their concerns were addressed.
- **Management Engagement and Oversight**—SCE improved the processes for monitoring, management engagement and taking prompt action to address SCWE issues as they emerge. This includes additional surveys, meeting with groups of employees, and the Employee Concerns Program personnel contacting workers to facilitate identification and prompt resolution of SCWE issues.

5. <u>SCE's Nuclear Safety Culture Monitoring and Progress</u>

SCE initiated monitoring processes to track the progress and effectiveness of actions associated with strengthening SONGS nuclear safety culture, including SCWE. These processes include:

- Monthly review of performance metrics for nuclear safety culture and SCWE;
- Quarterly review for effectiveness of the nuclear safety culture and SCWE improvement actions by an Effectiveness Review Challenge Board; during reviews, this board identifies any "check and adjust" actions deemed necessary to meet improvement goals; and
- Conducting follow-up effectiveness reviews through periodic assessments and surveys.

An effectiveness review was completed in June 2010 by a team of five individuals independent of SCE with experience in assessing and improving SCWE. This team interviewed over 400 personnel, with ninety-two percent being non-management personnel. Additionally, another effectiveness review was completed in August where over 1200 employees were surveyed regarding several SCWE areas including their willingness to raise concerns. The conclusions from these effectiveness reviews[80] were:

- SONGS personnel were willing to raise safety, compliance and quality issues, and were encouraged to do so by their management. Additional work is needed to ensure that individuals feel comfortable challenging what they consider a non-conservative decision, and to ensure their understanding that the SONGS culture supports raising nuclear safety and quality concerns. The continuation of the senior site management meetings with smaller groups of SONGS personnel and the subsequently completed management, supervision and employee training is expected to improve the willingness of SONGS personnel to challenge decisions and improve their understanding of and compliance with SCE's expectation for SONGS personnel to raise nuclear safety and quality concerns.
- SONGS has improved accessibility of the CAP, and personnel agreed that SONGS management at all levels reinforces the use of the CAP and the Nuclear Notification process.
- Virtually every person interviewed exhibited a general awareness of the alternative avenues for raising concerns. An overwhelming majority of those interviewed indicated no fear of retaliation if they or someone they knew raised a safety concern to the NRC. Interviewees were aware of recent programmatic changes to the ECP. Based on the survey results, additional work is needed to improve workers' confidence in the results of the ECP investigations and findings. The implementation of the enhanced Employee Concerns Program is expected to improve worker's confidence in ECP investigations and findings.

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[80] SCE letter to NRC, dated August 31, 2010, regarding status of action associated with work environment issues.

- Personnel were aware that any type of harassment, intimidation, retaliation or discrimination against anyone for raising concerns is expressly prohibited. SCE has reinforced this standard through various ongoing communications and training regarding SCWE and related issues.

Based on the effectiveness reviews, performance measures, and other survey tools, actions to strengthen the nuclear safety culture, including SCWE, are showing progress. SCE recognizes that additional improvement is needed and continues to adjust its programs as necessary to achieve a strong nuclear safety culture.

The NRC continues to monitor SCE's nuclear safety culture efforts and overall plant performance through the NRC's Reactor Oversight Process[81] (ROP). When implementing the ROP, the NRC conducts inspections and may identify findings. During 2009 and 2010, the NRC's findings were of very low safety significance. In their 2010 annual assessment letter, the NRC continued to affirm that SONGS has been operated in a manner that preserved public health and safety and fully met all cornerstone[82] objectives. In December 2010, the NRC informed SCE that the White Finding[83] is closed and that the performance at SONGS 2 had improved, allowing SONGS 2 to be in the Licensee Response Column (Column 1) of the ROP Action Matrix, improved from the Regulatory Response Column (Column 2).[84] Additionally, in their December Inspection of

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81 The Reactor Oversight Process (ROP) provides a framework for the NRC to monitor performance in three broad areas -- reactor safety; radiation safety for both plant workers and the public during routine operations; and protection of the plant against sabotage or other security threats. The ROP also features three "cross-cutting" elements, so named because they affect and are therefore part of each of the cornerstones: human performance, problem identification and resolution, and safety-conscious work environment.

82 The seven cornerstones are: initiating events, mitigating systems, barrier integrity, emergency preparedness, public radiation safety, occupational radiation safety, and physical protection. Satisfactory licensee performance in the cornerstones provides reasonable assurance of safe facility operation and that the NRC's safety mission is being accomplished. Each cornerstone contains inspection procedures and performance indicators to ensure that their objectives are being met.

83 Reference NRC Inspection Report Inspection Report 2009003 in Section 4OA2.3 for information related to the White Finding issued on Dec 11, 2008, for the "Failure to Establish Appropriate Instructions."

84 Reference NRC Letter to SCE, December 22, 2010, NRC Inspection Procedure 95001 Supplemental Inspection Report.

the substantive cross cutting issues, the NRC concluded there was measurable progress toward closing two of the CAP cross cutting issues. SCE concurs with this conclusion and continues take actions to resolve remaining open NRC substantive cross-cutting issues and to achieve a stronger nuclear safety culture at SONGS.

6. Conclusion

SCE is committed to preserving and improving a strong nuclear safety culture at SONGS. SCE is committed to ensuring an atmosphere exists that encourages workers to raise nuclear safety concerns. SCE will not tolerate retaliation against workers who identify nuclear safety or other concerns. SCE has taken actions to improve the nuclear safety culture at SONGS. SCE will continue to identify, through systematic reviews, actions to strengthen the SONGS nuclear safety culture.

G. GROUND WATER PROTECTION

1. Introduction

This section addresses the AB 1632 Report recommendation that Electric Power Research Institute's (EPRI) ground water protection guidelines should be followed to prevent inadvertent releases of tritium due to degraded material or operational failures.[85]

2. Requirements/Regulations Summary

Nuclear power plant licensees are required to control releases of radioactive liquids and airborne materials from their facilities to ensure that they are below limits set forth in 10 CFR §§ 20 and 50, and to operate the facility in a manner that adequately protects public health, safety, and the environment. Regulatory requirements for the control of radioactive effluents include sampling, analysis, monitoring and controlling releases, and assessing and reporting the potential impacts to the public. In addition, licensees are required by the NRC to establish a radiological environmental monitoring program to assess the long-term impacts due to plant operation and to report the results of the monitoring program. The EPA also established in 40 CFR § 190 a nuclear power plant standard on environmental radiation protection.

In November 2005, the Nuclear Energy Institute (NEI) sponsored the development of a nuclear industry-wide voluntary Ground Water Protection Initiative (GPI). The GPI was formally approved in May 2006 by the chief nuclear operating officers of each operating utility, and each utility was expected to implement the GPI no later than July 31, 2006. The GPI is designed to improve nuclear power plant licensees' management[86] of unintentional releases of radioactive substances to ground water and to enhance communications with stakeholders about those instances of unintentional releases. None of the instances of unintentional releases of radioactive substances to ground water that have been identified at operating and decommissioning nuclear power plants have posed any risk to public health and safety. The industry guidance contained

[85] AB 1632 Report, p. 19.

[86] "Management" as used for ground water protection in NEI 07-07 refers to establishing measures to assure timely detection of unintended releases and taking actions to prevent the migration of licensed radioactive material from an unintended release off-site.

in NEI 07-07 was published in August 2007.[87] NEI 07-07 provides the industry's policy position on ground water protection. In January 2008, EPRI published a companion set of guidelines, "Groundwater Protection Guidelines for Nuclear Power Plants," for establishing a ground water protection program to implement NEI 07-07.[88]

In March 2006, the NRC convened a Liquid Radioactive Release Lessons Learned Task Force to review industry events and any associated public health impacts, industry actions, applicable NRC's regulatory and inspection requirements, and communications with external stakeholders. The NRC task force's final report[89] was issued on September 1, 2006 and provided a number of recommendations, including among other things, recommendations to: (1) augment the existing regulatory framework, (2) review design and maintenance requirements for components that contain radioactive fluids but are not safety-related, and (3) perform additional reviews of guidance and regulations for decommissioning and license renewal. With regard to the public health impacts resulting from unintended radioactive liquid discharges to the environment, the report concluded:[90]

> The most significant conclusion of the task force regarded public health impacts. Although there have been a number of industry events where radioactive liquid was released to the environment in an unplanned and unmonitored fashion, based on the data available, the task force did not identify any instances where the health of the public was impacted.

In March 2010, the NRC established a Groundwater Contamination Task Force to evaluate the completeness of the NRC's actions and responses to recent incidents of unintended releases of radioactive substances to ground water and soils. The task force also reassessed the NRC's regulatory framework for ground water

87 NEI 07-07 "Industry Ground Water Protection Initiative – Final Guidance Document."

88 "Groundwater Protection Guidelines for Nuclear Power Plants" Report 1016099, EPRI, issued January 2008.

89 "Liquid Radioactive Release Lessons Learned Task Force Final Report," U.S. NRC, issued September 1, 2006.

90 *Id.*

protection, health impacts resulting from the unintended releases, communications with stakeholders, and international perspectives. The task force issued a final report in June 2010 that reiterated the NRC's previous statements that the leaks/spills to date have not posed a hazard to human health.[91] The senior NRC management team is reviewing the final report and will provide recommendations to the NRC as appropriate. Other information on the NRC's oversight on this issue may be found on the NRC's website.[92]

NEI 07-07 establishes the industry's commitment to go beyond the regulatory requirements that are imposed by the NRC. SCE was an active participant in the development of both the industry GPI and the EPRI ground water guidelines and continues to take a leadership role in the industry effort. SCE has a comprehensive program and procedures in place for the implementation of the GPI that are consistent with the EPRI ground water protection guidelines.

3. Overview of SCE's Implementation of the Industry GPI

In the four years since the initial implementation of the industry GPI, SCE has taken actions to meet each of the objectives and acceptance criteria outlined in NEI 07-07. These actions include:

- Completed studies under the direction of a professional geologist to update the characterization of the site hydrology and to develop a site conceptual model to describe the flow of ground water beneath the site.
- Evaluated structures, systems, and components and work practices to assess the potential for equipment failure or human performance to result in an unintended leak or spill of radioactive fluids to the environment.
- Installed on-site ground water monitoring wells to provide timely detection of unintentional releases to ground water. These wells are sampled routinely and the sample results are provided in the Annual

[91] "Groundwater Task Force Final Report" U.S. NRC, issued June 2010.

[92] http://www.nrc.gov/reactors/operating/ops-experience/grndwtr-contam-tritium.html
http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/buried-pipes-fs.html
http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-radiation-fs.html

Effluent Radioactive Release Report to the NRC. These annual reports are available to the public and are posted on the NRC's website.

- In support of the objective to improve transparency, developed procedures for voluntary communication and reporting to ensure that stakeholders would be contacted in the event of a spill or leak to ground water that meets the thresholds for communication identified in NEI 07-07. The thresholds for contacting designated stakeholders are well below any events that would require reporting to the NRC or to any other agency. SCE discussed the Industry Initiative with designated stakeholders prior to the initial implementation date in August 2006 and provides annual updates on both industry and SONGS-specific efforts on this issue.

SCE's implementation of the GPI was assessed by industry peers and by a team sponsored by NEI. The assessments determined that SCE met the criteria in NEI 07-07 and the EPRI ground water protection guidelines. The NRC has also assessed SCE's performance to meet the industry GPI and found that SCE met all of the objectives for a ground water protection program.

4. Conclusion

The nuclear power industry has identified instances of unintended releases of radioactive substances to ground water. However, none of those instances has threatened public health and safety or compromised environmental protection. SCE has and continues to implement the objectives of the industry GPI and the EPRI ground water protection guidelines at SONGS 2 & 3.

H. WORKER TRAINING AND RECRUITMENT

1. Introduction

This section addresses the AB 1632 Report recommendations that (1) the CPUC continue to recognize the importance of SCE's plant worker training and recruiting programs for SONGS 2 & 3, and approve adequate funding for such programs; and (2) the CPUC should assess the adequacy and success of SCE's training and recruiting programs for replacing retiring plant workers and ensuring that knowledge held by the retiring workers and the commitment to maintaining a strong safety culture are instilled in the new workers.[93] This section describes the programs and activities that demonstrate SCE's commitment to and ability for maintaining a highly skilled and knowledgeable workforce at SONGS 2 & 3.

2. Recruitment Programs

SCE competes with other nuclear utilities, other industries, vendors, and regulatory agencies such as the NRC to attract a qualified nuclear workforce. SCE needs to continue to build for the future by recruiting and training nuclear workers in advance of the anticipated retirement of workers in critical positions at SONGS 2 & 3. In addition, to meet the competitive challenge for recruiting qualified nuclear workers in important and difficult-to-fill positions, SCE must continue its strategy to utilize enhanced recruitment tools necessary to successfully recruit a qualified nuclear workforce.

In 2003, SCE initiated efforts to recruit new workers in advance of the anticipated retirement of workers in critical positions at SONGS 2 & 3. SCE requested funding in its 2006 GRC for these efforts.[94] Emphasis was placed on filling positions in which new qualified workers were in short supply or required a longer period of time for training, such as instrumentation and control (I&C) technicians, test technicians, nuclear electricians, boiler and condenser (B&C) mechanics, machinists, chemical technicians, health physics technicians, and engineers. The training duration for these types of critical positions at SONGS 2 & 3 range from one year for B&C mechanics and machinists, two

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[93] AB 1632 Report, p. 19.

[94] Decision (D.) 06-05-016.

years for nuclear electricians and engineers, and three years for I&C technicians, health physics technicians, test technicians, and chemical technicians.

SCE's 2009 GRC requested funding to enhance existing recruitment tools and expand its investment in the development of staffing pipelines for important and difficult-to-fill nuclear positions.[95] SCE established a number of educational partnerships with local area community colleges and high schools to expand the pipeline of nuclear qualified workers in important skill areas. As an example, SCE collaborated with Mira Costa College, a San Diego County-based community college, to develop a certificate program in Nuclear Technology that provided the technical skills required to qualify for entry-level positions in radiation protection and nuclear plant operations. The program was successful and has expanded into an official two-year Associates Degree program in Energy Technology that will provide future highly qualified and motivated entry-level workers. This pipeline program enhances the existing pipeline. Program graduates will have an accredited college associate's degree in technology based upon an industry-recognized uniform curriculum. Between the first and second years of the program, students will spend 12 weeks at SONGS 2 & 3 working and rotating through four departments: maintenance, operations, chemistry, and health physics. This program benefits both SONGS 2 & 3 and the local communities. Mira Costa College is providing qualified entry-level candidates to support SCE's ability to maintain skilled nuclear workforce candidates and ensure continued reliable nuclear plant operations at SONGS 2 & 3.

In addition to establishing educational partnerships to attract and retain highly skilled and knowledgeable employees at SONGS 2 & 3, SCE uses supplemental tools in its recruitment processes, including offering sign-on bonuses, relocation benefits, enhanced housing allowances, and student loan repayment plans, as warranted. SCE also continues to meet the demand for nuclear workers through the use of contingent workers.

SCE's 2012 GRC continues to request funding for recruiting new workers in advance of the anticipated retirement of workers in critical positions at SONGS 2 & 3,

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[95] Decision (D.) 09-03-035.

including funding for supplemental recruitment tools and maintaining educational partnerships with local schools.

In summary, SCE continues to meet the demand for nuclear workers through the successful implementation of recruitment programs and the use of contingent workers.

3. Training Programs

To maintain high standards for the training and qualification of nuclear plant workers, the industry established a training program accreditation process that is endorsed by the NRC. The training program ensures that personnel, who operate the plant, maintain plant systems, conduct radiological protection activities, maintain plant chemistry, and perform engineering duties, are initially provided with and subsequently maintain, through continuing training programs, the skills and knowledge to perform their job. SONGS 2 & 3 training programs were initially accredited through this process and are reviewed for re-accreditation on a four-year basis.

The objectives and criteria for training program accreditation in the nuclear power industry provide the framework for the application of a systematic approach to training (SAT), which ensures the workers have the necessary knowledge, skills and abilities to do their job. Experience and insights gained in the industry are fed back into SONGS 2 & 3 training programs through the use of the SAT process. This feedback loop for capturing industry-wide operating experience ensures that future generations of SONGS 2 & 3 workers will learn from the past and current workforce.

Beyond the accredited programs, general employee training and training targeted for management and supervision is provided to enhance knowledge, skills and further learning through understanding lessons learned from operating experience.

Training is critical to SONGS 2 & 3 success and is used as a strategic tool to provide highly skilled and knowledgeable personnel to ensure safe and reliable operations. Training accreditation by the National Nuclear Accrediting Board shows that SONGS 2 & 3 owns its training and is meeting industry standards for providing nuclear employees who safely operate and maintain SONGS 2 & 3. General employee training ensures employees have the knowledge and the skills to independently perform their job assignments.

4. Safety Culture Training

Nuclear safety is the top priority at SONGS. Nuclear safety culture refers to an organization's values and behaviors – modeled by its leaders and internalized by its members – that make nuclear safety the overriding priority for the organization.

SCE uses many methods to instill a strong nuclear safety culture in its new employees. These various methods include a variety of training modules that address nuclear safety culture. These training modules include: 1) new employee orientation whose objectives include commitment to Nuclear Safety, Safety Conscious Work Environment (SCWE), and the Employee Safety Concerns program; 2) basic training for supervisors on SCWE and Nuclear Safety Concerns whose objectives include establishing and maintaining a SCWE and guidance on what to do when a worker raises a safety concern. The program requires new supervisors receive this training within their first year of supervising. Nuclear Safety Culture is also included in General Employee Training (GET) for all personnel having unescorted protected area access.

5. Conclusion

SCE is meeting the competitive challenge for hiring and training qualified nuclear workers in important and difficult-to-fill skill areas by continuing its: 1) recruitment programs for replacement of retiring workers for critical SONGS 2 & 3 positions and through the use of contingent workers; 2) training programs for employees; and 3) ensuring knowledge and strong safety culture are instilled in new SONGS 2 & 3 workers.

I. ALTERNATIVE GENERATION

This section addresses the AB 1632 Report recommendation that as a part of license renewal studies for SONGS 2 & 3, the CPUC should require detailed studies of alternative power generation options to quantify the reliability, economic, and environmental impacts of replacement options.[96]

SCE plans to submit a request to the CPUC for funding the processing of a license renewal application at the NRC. The CPUC filing, expected in early 2011, will include a cost-effectiveness analysis of alternative power generation that will allow the CPUC to determine that the extended operation of SONGS 2 & 3 would be beneficial for SCE's customers and the state.

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[96] CPUC June 25, 2009 Letter to SCE; AB 1632 Report, p. 31.

J. ONCE THROUGH COOLING

1. Introduction

This section addresses the AB 1632 Report recommendation that the California Independent System Operator (CAISO) address the Stakeholder Study of Aging Power Plants and Once-Through Cooling Mitigation as quickly as feasible and that the review determine the extent supplemental studies are needed.[97] SCE's review of the once through cooling (OTC) policy, as it relates to SONGS 2 & 3 and its environmental mitigation status, is included below.

On May 4, 2010 the State Water Resources Control Board (SWRCB) adopted a policy[98] on the use of coastal and estuarine waters for power plant cooling. The policy, which became effective October 1, 2010, includes a schedule for implementation, including milestones for thermal fossil plants using OTC technology to retrofit using alternative cooling technologies, such as cooling towers, or to shut down no later than the end of 2020.

The OTC policy also established separate requirements for the state's nuclear-fueled power plants, such as SONGS 2 & 3, because of these plants' positive environmental benefits and importance to the reliability of the electric grid. The requirements include: (1) installing large organism exclusion devices around the SONGS 2 & 3 intake structures within one year after the effective date of the policy (i.e., by October 1, 2011); (2) conducting and providing to the SWRCB within three years after the effective date of the policy (i.e., by October 1, 2013) a special study of alternatives for SONGS 2 & 3 to meet the policy's objectives, including costs for the alternatives;[99] and (3) achieving full compliance with the policy by implementing alternative cooling technologies such as a closed cycle cooling system (i.e., cooling towers) at SONGS 2 & 3 or shut down by December 31, 2022.

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[97] AB 1632 Report, p. 24.

[98] Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling (Policy), Resolution No. 2010-0020; adopted by SWRCB May 4, 2010; effective October 1, 2010.

[99] The special study to assess alternatives for nuclear-fueled power plants must be conducted by an independent third party under the oversight of a Review Committee; reference Policy, § 3(D).

The relevance of the OTC policy requirements to SONGS 2 & 3 is discussed below.

2. SCE Has Fully Mitigated For the Impact of SONGS 2 & 3 on the Marine Environment[100]

SONGS 2 & 3 employs state-of-the-art engineering and operational measures to minimize impingement and entrainment of marine organisms. These include velocity caps on the mid-water depth offshore intakes,[101] an in-plant fish handling system (diversionary louvers, rescue elevators, and return lines), and customized outfall heat treatment procedures to maximize fish handling system effectiveness.

In addition to the design engineering and operational measures described above, SCE has performed mitigation measures that include: (1) restoring wetlands in San Dieguito; (2) constructing the largest artificial giant kelp reef in California, the 174-acre Wheeler North Reef; (3) funding the Hubbs white sea bass hatchery in Carlsbad; and (4) funding ongoing independent monitoring of the mitigation measures.

Independent verification monitoring of SCE's environmental mitigation efforts show substantial enhancement of habitat resources, even before the mitigation projects are physically complete. For example, the San Dieguito wetlands project created over 160 acres of new wetlands (including 100 acres of tidal salt marsh land) and restored tidal flows, natural habitats, and vegetation to a former wetland area, resulting in measurable increases of fish and wildlife in the project area.[102] Additionally, the Wheeler North Reef is a significant new marine kelp habitat on the southern California coast that produces and nourishes as many as 50 varieties of fish and invertebrates and the 174-acre kelp forest ecosystem that supports them.

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[100] Appendix 9, Letter from Peter Douglas, Executive Director, California Coastal Commission, dated February 4, 2010.

[101] Mid-water location of the intakes is a design feature intended to minimize fish entrainment.

[102] UCSB SONGS Mitigation Monitoring website: http://marinemitigation.msi.ucsb.edu/.

3. **SCE Will Install Large Marine Organism Exclusion Devices at SONGS 2 & 3 If Feasible**

The requirement for SONGS 2 & 3 to install large marine organism exclusion barriers around the circulating water intake velocity caps within one year after the effective date of the policy is not achievable. Such a barrier requires time to design and requires a detailed review to ensure that conditions of the NRC operating license will continue to be satisfied. If an exclusion device is determined to be feasible, a considerable amount of time would be required to install the modifications while the units are off-line. SCE is currently identifying options for meeting this policy requirement, and is working with the SWRCB regarding this policy.

4. **Cooling Towers Are Not Feasible**

The SWRCB OTC policy requires plants utilizing OTC to reduce their intake of cooling water by installing closed-cycle wet cooling systems or by reducing intake to a comparable level by alternative means. Installing a closed-cycle wet cooling system (i.e., cooling towers or the equivalent) has been evaluated and is not feasible at SONGS 2 & 3. A retrofit with a closed-cycle cooling system at SONGS 2 & 3 would face unparalleled engineering challenges, insuperable permitting obstacles, and adverse environmental impacts likely greater than those associated with OTC.

5. **Possible Exceptions to the SWRCB OTC Policy**

The OTC policy requires completion of special studies conducted by an independent third party within three years of the effective date of the policy. These studies are to assess alternatives for the nuclear-fueled power plants to meet OTC policy requirements. Pursuant to the policy, the SWRCB must consider the study results in evaluating whether to modify the compliance requirements for nuclear-fueled power plants. The SWRCB staff is in the initial phases of selecting the contractor for the nuclear plant special studies and appointing the oversight committee.

The date for SONGS 2 & 3 to comply with the OTC policy is December 31, 2022, but this date could be adjusted by the SWRCB based on written notification from the CAISO that the plant is needed to maintain reliability of the electric system; however, SONGS 2 & 3 cannot operate beyond 2022 unless the NRC grants license renewal.

6. <u>Conclusion</u>

Consistent with the directives of the California Coastal Commission (CCC), SCE has fully mitigated for the impact of SONGS 2 & 3 on the marine environment. Cooling towers are not feasible at SONGS 2 & 3 and an alternative means of compliance will be required to allow SONGS 2 & 3 to enter a period of extended operation; however, SONGS 2 & 3 cannot operate beyond 2022, even if the CAISO determines it would be necessary, unless NRC license renewal had been obtained.

K. ADEQUACY OF MAINTENANCE PROGRAMS

1. Introduction

This section addresses the AB 1632 Report recommendation that, to help ensure plant reliability, SCE should address the adequacy of maintenance programs at SONGS 2 & 3.[103] This section describes SCE's maintenance programs and results for assuring that SONGS 2 & 3 structures, systems, and components (SSCs) support reliable operations. Specifically, this section focuses on non-safety-related SSCs that are important to plant reliability.

2. Standards

There are a number of entities that provide initiatives, standards, and methodologies for maintaining plant SSCs, including but not limited to:

- Nuclear Regulatory Commission (NRC) – a federal agency whose requirements are provided in the CFR. SCE is required to adhere to CFRs that are applicable to operation of a nuclear power plant. In addition, SCE must meet maintenance-related technical specifications mandated by the NRC in the operating licenses for SONGS 2 & 3. An example of a program required by the CFR is SCE's Maintenance Rule Program. This program monitors, trends, and assesses performance of plant SSCs in accordance with 10 CFR 50.65.[104] Given the link between effective maintenance and SSC reliability, the program seeks to reduce the number of challenges to safety systems by improving operability, availability, and reliability of SSCs, including the reliability of non-safety-related SSCs.
- Electric Power Research Institute (EPRI) – an organization that includes scientists, engineers, and experts in the energy industry to help address challenges in reliability, efficiency, health, safety, and

[103] AB 1632 Report, p. 34.

[104] 10 CFR § 50.65, Requirements For Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.

the environment. SCE utilizes EPRI guidelines to establish standardized inspection and acceptance criteria for various plant programs at SONGS 2 & 3, such as SCE's program for maintaining the plant's water chemistry.

- American Society of Mechanical Engineers (ASME) – an organization that developed the Boiler and Pressure Vessel Code that establishes rules of safety governing the design, fabrication, and inspection of nuclear power plant SSCs, such as feedwater heaters.
- Institute of Electrical and Electronic Engineers (IEEE) – an organization for the advancement of technology related to electricity. IEEE develops industry standards that help define the performance and reliability criteria of electrical systems and components in a broad range of disciplines, such as for differential relays in the 220kV switchyard at SONGS 2 & 3.

3. Approach to Maintenance of Non-Safety-Related SSCs Important to Plant Reliability

Maintenance is performed on non-safety-related plant SSCs for a variety of reasons, including to address normal wear and tear and aging degradation, or component obsolescence. Plant SSCs experiencing normal wear and tear[105] and/or aging degradation[106] are identified and corrected through periodic maintenance that includes monitoring and testing to ensure they are in good working order, are replaced as appropriate, and demonstrate component reliability.

Maintenance is performed on active and passive components. Because active components have moving parts or continuously operate, degradation is more readily observed. Operators monitor the plant's operating components through routine rounds where data is collected and assessed. Maintenance and engineering personnel also monitor components for changes in performance or condition, when components are

[105] An example of normal wear and tear degradation is oil or bearings in a pump that need periodic changing due to use.

[106] An example of aging degradation is external corrosion of piping components over time due to salt air exposure.

in-service or taken out of service for inspections. Because passive components do not have moving parts and may be used intermittently, degradation is identified through inspections.

SCE manages both active and passive components (mechanical, structural, and electrical) through the following types of maintenance activities:

- periodic, predictive, and planned maintenance
- corrective maintenance
- performance monitoring
- periodic testing and inspection

Several existing programs at SONGS 2 & 3 have been implemented to address the types of maintenance described above. These programs ensure that plant SSCs support reliable operation.

a) Equipment Reliability Program

SCE has an Equipment Reliability Program (ERP) that integrates a broad range of activities into one program. In this program, personnel evaluate plant SSCs; develop and implement long-term health plans; monitor performance and conditions; and make continuous adjustments to preventive maintenance tasks and frequencies based on SSC operating experience.

The Life Cycle Management Program (a sub-program of the ERP) develops long-term health plans by assessing SSC performance trends; component age; obsolescence and reliability concerns; industry operating experience; and periodic and predictive maintenance history.

Examples of non-safety-related SSCs covered under the ERP to maintain plant reliability include:

- Main Feedwater Pumps and Turbines – refurbishments and routine maintenance were completed in accordance with vendor recommendations.
- Generator Stator Water System – the system was modified to improve the corrosion product removal process.
- Generator Seal Oil System – design changes were implemented to prevent continued corrosion from salt air.

- Main Transformers – performed maintenance to correct corroded oil lines that were discovered during routine transformer inspection.
- Feedwater Piping – sections of piping were replaced due to corrosion identified by the Flow Accelerated Corrosion Program that is established at SONGS 2 & 3.

b) Work Management Program

SCE established the Work Management Program to provide timely identification, selection, planning, coordination, prioritization, and execution of work necessary to maximize the availability and reliability of plant SSCs. Personnel implementing this program are able to manage the risk associated with conducting work, identify the impact of work to the plant, and protect the station from unanticipated transients due to the conduct of work. The Work Management Program maximizes the efficiency and effectiveness of plant personnel and material resources by prioritizing work, and coordinating all aspects of work performed on SSCs. All work performed at SONGS 2 & 3 is done under this program.

c) Support of Maintenance Programs

To support the effective implementation of the maintenance programs at SONGS 2 & 3, SCE also employs a variety of underlying programs, including for example:

- Shelf Life Program – uses industry guidelines and manufacturer recommendations to establish controls to maintain parts and equipment in storage that may be subject to deterioration.
- Procedures Control Program – ensures proper identification, development, approval, and revision of procedures used to maintain plant equipment at SONGS 2 & 3.
- Training Programs [107] – a structured training process that ensures plant personnel are provided with the skills and knowledge necessary to perform their jobs.

[107] Section H, Worker Training and Recruitment.

4. Conclusion

SCE's implementation of the programs described above meets the nuclear industry maintenance standards and has resulted in reliable service for customers. As a recent example, in 2010, SONGS 3 surpassed a plant record when it reached 660 days of continuous operation. The maintenance programs provide a solid basis for reliable plant operations through a possible period of extended operation.

IV.

CONCLUSION

SONGS 2 & 3 is operated in a safe and reliable manner, in accordance with federal, state, and local regulatory requirements, and provides the needed electricity to meet customers demands. Rated at 1,070 megawatts (MW) and 1,080 MW, respectively for each unit, SONGS 2 & 3 generates enough electricity to serve 1.4 million average southern California homes every day. In addition, SONGS 2 & 3 generates clean, low-carbon electricity, in support of the state's environmental and greenhouse gas (GHG) policy objectives. Further, due to the location of SONGS 2 & 3 between two major metropolitan areas in San Diego, Los Angeles, Orange, and other counties in southern California, SONGS 2 & 3 is integral to adequately maintaining the reliability of the electric grid in southern California.

As discussed above, SCE's evaluations demonstrate that SONGS can continue to provide reliable operation through a period of extended operation, if the NRC grants license renewal for SONGS 2 & 3.

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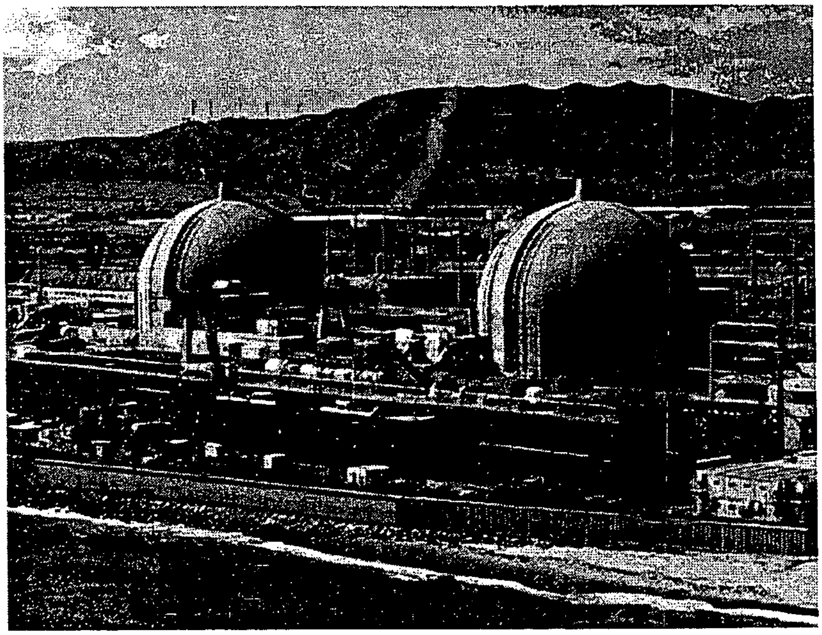
Southern California Edison's Evaluation of California Energy Commission AB 1632 Report Recommendations Appendices 1 through 9



February 2011

Appendix 1

San Onofre Nuclear Generating Station 2010 Probabilistic Seismic Hazard Analysis Report

SAN ONOFRE NUCLEAR GENERATING STATION
SEISMIC HAZARD ASSESSMENT PROGRAM
2010 PROBABILISTIC SEISMIC HAZARD ANALYSIS REPORT

Prepared for
Southern California Edison

December 2010

GeoPentech
Geotechnical & Geoscience Consultants

PROBABILISTIC SEISMIC HAZARD ANALYSIS OUTLINE

1.0 INTRODUCTION

1.1 Purpose

A seismic hazard analysis update was performed for the San Onofre Nuclear Generating Station (SONGS) to evaluate if the most recent or current available seismic, geologic, and ground motion information in the vicinity of SONGS has affected the seismic hazard at SONGS. The analysis specifically included the Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2) by the 2007 Working Group on California Earthquake Probabilities (WGCEP, 2008), which is the joint product of the Southern California Earthquake Center (SCEC), the California Geological Survey (CGS) and the United States Geological Survey (USGS).

1.2 Site Information

SONGS is located on the west coast of southern California in San Diego County, approximately 80 kilometers (km) northwest of the City of San Diego and 97 km southeast of Los Angeles, as seen in the map on Figure 1-1. The plant is located entirely within the Camp Pendleton Marine Corps Base (Base) near the northwest end of the Base's shoreline. Figure 1-1 also shows the general configuration of SONGS. The plant is currently operating Units 2 and 3, which, as seen on Figure 1-1, occupy about 21 hectare (ha) of the approximately 34 ha facility. The power block for both Units 2 and 3, and the station's switchyard cover about 11 ha with the remaining 10 ha providing parking, access areas, and other miscellaneous facilities.

Approximately 6 ha of SONGS, northwest of Unit 2, were previously occupied by Unit 1; the last of Unit 1 facilities was removed in 2008. This area is now called the "North Industrial Area," as shown on Figure 1-1.

1.3 Approach

This evaluation of the seismic hazard at SONGS utilizes a probabilistic seismic hazard analysis (PSHA) approach. The PSHA was used on the plant's established ground motion criteria to evaluate the implications of alternative active fault models based on the most recent or current seismic, geologic, and ground motion information in the vicinity of SONGS.

The analysis uses UCERF 2 (WGCEP, 2008), the National Seismic Hazards Mapping Program (NSHMP) (USGS, 2008), the current USGS implementation of UCERF 2 seismic source characterization (USGS, 2009, personal communication [PC]), and more recently available information regarding both the regional faults and the Newport-Inglewood/Rose Canyon (NI/RC) Fault Zone. The current USGS seismic source characterization roughly corresponds to the initial seismic source characterization used in the plant's licensing and in its two follow-on PSHAs (SCE, 1995 and 2001). These earlier seismic source characterizations and that used by the USGS (2008) lead to the conclusion that the active, right-lateral, strike-slip NI/RI Fault Zone is the largest contributor to the seismic hazard at SONGS.

A postulated active, regional low-angle thrust fault (the Oceanside Blind Thrust [OBT]) was proposed to extend beneath the coastline under SONGS and from offshore of Dana Point to the U.S./Mexican border by Rivero et al. (2000), Rivero (2004), Rivero and Shaw (2005), and Rivero and Shaw (2010, in press). The implication of this hypothesized OBT on SONGS' seismic hazard was first evaluated as part of the

SCE (2001) study through a PSHA approach using published and unpublished information available in 2001.

For this updated 2010 PSHA for SONGS, both a strike-slip end-member model, which includes the NI/RC Fault Zone source, and a blind thrust end-member model, which includes the OBT Fault source, were incorporated to reflect current alternative interpretations of the seismic source characteristics of active faults in the Inner Continental Borderland (ICB) near SONGS. For incorporation into this 2010 PSHA, a relative contribution, or relative weight, was assigned to each of these end-member models based on an assessment of the technical community's consensus on interpretation of data available in relevant publications and ongoing research.

The Next Generation Attenuation (NGA) relationships (NGA, 2008) were used in performing this PSHA. This seismic hazard evaluation was limited to annual frequencies of exceedance greater than 10^{-4}. A 10^{-4} annual frequency of exceedance is equivalent to a return period (RP) of 10,000 years. At annual frequencies of exceedance lower than 10^{-4}, some issues are to be addressed that potentially could affect the calculated seismic hazard results. These issues consist of those associated with dispersions, such as epistemic and aleatory uncertainties in seismic source characterization and ground motion characterization models including the ground motion predictive equation (GMPE) epistemic uncertainty, and those associated with nonlinear behavior of soils at the site. These issues will be addressed as part of the SONGS ongoing seismic hazard program.

In presenting the results of this SONGS seismic hazards analysis, this report is organized into six sections and two appendices.

Section 1 is this introductory section.

Section 2 describes the seismic source characterization used in this PSHA.

Section 3 presents a more detailed discussion of the methodology used in conducting the PSHA and the results of the PSHA.

Section 4 provides our conclusions regarding the SONGS seismic hazards assessment.

Section 5 lists the relevant references.

Section 6 provides a glossary.

The two appendices are:

A. Seismic Source Characteristics, which provides a detailed summary of the currently available information regarding these seismic source characteristics including references and abstracts of the key sources of information (Attachment A-1).

B. PSHA – Selected Issues, which provides a detailed summary of the methodology used and key issues with this current PSHA.

1.4 Acknowledgements

The overall project was sponsored by Southern California Edison (SCE). GeoPentech's effort was managed by Mr. John Barneich with the seismic source characterization work led by Mr. S. Thomas Freeman and the PSHA evaluation by Dr. Yoshi Moriwaki. Other GeoPentech team members were geoscientists Mr. Steven Duke (seismic source characterization support); Ms. Phuong Chau and Ms. Alexandra Sarmiento (geologic support); and engineers Dr. Phalkun Tan (PSHA) and Mr. Andrew Dinsick (logic tree development). Geoscientists Dr. Philip Hogan and Mr. Steven Varnell of Fugro West provided input on offshore fault characteristics from evaluations of available geophysical marine seismic surveys and other relevant sources of information. Ms. Kathryn Hanson of AMEC Geomatrix provided input, guidance, and reviews to the seismic source characterization effort, and Dr. Robert Youngs, also from AMEC Geomatrix, provided early input to the PSHA evaluation.

Mr. Freeman, Dr. Hogan, and Ms. Hanson served as a seismic source characterization integrator team in compiling the seismic source characterization models for the offshore area and ultimately developed the relative weights for these models that were used in this PSHA.

Several consultants were involved in the project, including Dr. John Shaw and Dr. Andreas Plesch of the Department of Earth and Planetary Sciences, Harvard University, who provided helpful input and reviews on the characteristics of the blind thrust fault models. Dr. Thomas Rockwell of San Diego State University contributed fault characterization input for the strike-slip fault model and provided helpful reviews. Dr. Peter Shearer and Dr. Neil Driscoll of the University of California at San Diego Scripps Institute, Dr. Lisa Grant of University of California at Irvine, and Dr. Roy Shlemon also provided timely input, guidance, and reviews on the source characterization effort.

Dr. Holly Ryan and Dr. Dan Ponti from the USGS are acknowledged for meeting with the seismic source characterization technical integrator team and sharing pre-publication data and information on the offshore faults and the onshore NI Fault, respectively, as well as providing helpful review comments.

Lastly, acknowledgement is given to the members of the Seismic Technical Advisory Board (STAB) for their comments and recommendations on the methods and presentation of this report: Dr. Clarence Allen, California Institute of Technology emeritus; Dr. Kevin Coppersmith, Coppersmith Consulting; Dr. Jan Rietman, consultant; Mr. Lloyd Cluff, consultant; Dr. Steven Day, San Diego State University; Dr. I.M. Idriss, consultant; and Dr. Norman Abrahamson, consultant.

GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	SITE LOCATION MAP AND APPROXIMATE STATION LAYOUT	FIGURE 1-1

2.0 SEISMIC SOURCE CHARACTERIZATION

Two variations have been proposed on the tectonic model explaining the crustal deformation currently occurring in the ICB offshore adjacent to SONGS.

One variation of the model, which has substantial support in the technical community (e.g., Moore, 1972; Fischer and Mills, 1991; Legg, 1991; Wright, 1991), assumes that active high-angle, right-lateral strike-slip faults, similar to what is observed on land, extend to seismogenic depth and are the primary source of large offshore earthquakes that might affect the plant. Figures 2-1a through 2c show the mapped surface traces of the active, right-lateral strike-slip faults and recorded earthquakes in the region surrounding SONGS. The closest of these right-lateral strike-slip faults to SONGS is the NI/RC Fault Zone, located 8 km offshore.

In this right-lateral strike-slip model, nearby shallow-dipping, active and non-active, normal, oblique, reverse, and thrust faults are subsidiary to the high-angle strike-slip fault (i.e., the NI/RC Fault Zone). The UCERF 2 (WGCEP, 2008) seismic source characterization model and the seismic source characterization model used in the 2008 National Seismic Hazard Mapping Program (USGS, 2008) and the current implementation of UCERF 2 by the USGS (2009, PC) are based on this strike-slip model. For this PSHA, a logic tree for the NI/RC Fault Zone was developed based on WGCEP (2008) and USGS (2008 and 2009, PC).

A brief overview of the seismic characteristics of the strike-slip dominated tectonic model used in this 2010 PSHA is provided in the following Section 2.1 with particular emphasis on the NI/RC Fault Zone, which is the closest fault source to SONGS. In addition, Dr. Tom Rockwell provides a more thorough discussion of the current understanding of the seismic characteristics of the NI/RC Fault Zone in Appendix A, Attachment A-2.

The other variation of the tectonic model was proposed by Rivero et al. (2000) in which regional blind thrust faults (reactivated Miocene detachment surfaces) also represent regional-scale active faults. These regionally extensive blind thrusts are inferred to interact at depth with high angle, strike-slip or oblique-slip faults, such as the NI/RC Fault Zone, yielding segmented fault geometries. This alternative model was further developed and described by Rivero (2004), Rivero and Shaw (2005), and Rivero and Shaw (2010, in press). Figure 2-2 provides a copy of the Community Fault Model (CFM) developed by Plesch et al. (2007), which illustrates the blind thrust faults included in this variation of the tectonic model. These postulated blind thrust fault sources were described in UCERF 2 (WGCEP, 2008) as being considered for future deformation model development, but they are not included in the current USGS source characterization model (USGS, 2009, PC).

Section 2.2 presents a brief overview of the seismic characteristics of the blind thrust variation to the tectonic model, in particular the OBT, the closest inferred blind thrust to SONGS. For this PSHA, Dr. Shaw and Dr. Plesch (2010, Appendix A, Attachment A-3) developed logic trees and segmentation models to assign seismic source characterization parameters for fault sources based on the blind thrust variations of the tectonic model as outlined by Rivero et al. (2000), Rivero (2004), Rivero and Shaw (2005), and Rivero and Shaw (2010, in press).

There are significant differences in the characterization of fault sources in the vicinity of SONGS based on these two variations of the tectonic model. As such, the alternative seismic source characterizations that stem from these two models are considered end-member assessments, referred to as: (1) the strike-slip end-member seismic source characterization model and (2) the blind thrust end-member seismic source characterization model. Based on recent and ongoing interpretations of offshore and nearby onshore seismic and geologic data, other researchers (e.g., Grant et al., 2002; Grant and Rockwell, 2002; Grant and Shearer, 2004) have suggested modifications to the blind thrust model presented by Rivero et al. (2000) and Rivero (2004). The results of more recent studies (e.g., Ponti and Ehman, 2009; Ryan et al., 2009; Sorlien et al., 2009a; Conrad et al., 2010; Rockwell, 2010; and Rentz, 2010), which were not available or had not undergone sufficient peer-review at the time of preparing UCERF 2 (WGCEP, 2008), were incorporated in this study.

The seismic sources included in the PSHA for this current study are outlined in the following sections:

Section 2.1 provides an updated description of the NI/RC Fault Zone and its seismic source characterization parameters as part of the strike-slip end-member model.

Section 2.2 provides a summary of the seismic characterization parameters for alternative fault sources based on the blind thrust end-member seismic source characterization model.

Section 2.3 presents the time-independent seismic source characteristics of the more distant regional faults that were used in USGS (2009, PC) source characterization. These more distant faults in the region are included in both of the end-member models.

Section 2.4 provides discussions regarding the weights assigned to the two alternative end-member seismic source characterization models for incorporation in the PSHA based on information from previous studies and using more recent published and unpublished studies by other researchers in the technical community.

Summaries of the key publications and results and observations from past, recently completed, and ongoing research in the California Continental Borderland offshore SONGS that were used in this evaluation are provided in Attachment A-1 of Appendix A.

2.1 Strike-slip Seismic Source Characterization Model

In the strike-slip end-member seismic source characterization model used in this 2010 PSHA, the offshore portion of the high-angle, right-lateral NI/RC Fault Zone is the closest fault source to SONGS. The onshore NI/RC Fault Zone, including its numerous oil fields, has been extensively studied (Moody and Hill, 1956; Wilcox et al., 1973; Harding, 1973; and Yeats, 1973). These authors concluded that the subsidiary faulting is mechanically consistent with, and causally related to, dominant strike-slip faulting, and, parenthetically, the evidence is sufficiently strong that NI/RC Fault Zone has been sometimes cited as one of the classic examples of this so-called wrench tectonics mode of deformation. This theory explains and is compatible with the presence of shorter, shallower dipping, normal, and thrust subsidiary faults in a system dominated by a high-angle, through-going primary strike-slip fault.

During the 1970s, SCE, with the assistance of firms such as Fugro West, Western Geophysical, Woodward-Clyde Consultants, and other independent consultants, completed rigorous onshore and offshore investigations to evaluate the seismic source characteristics of the NI/RC Fault Zone. The conclusion from this work was that the faulting offshore of San Diego County is a continuation of the strike-slip dominated wrench faulting tectonics reflected in the northern onshore portion of the NI/RC

Fault Zone in the Los Angeles Basin. The characterization of the NI/RC Fault Zone as a strike-slip fault was the basis of deterministic ground motion analyses completed for the licensing of SONGS Units 2 and 3 and documented in the plant's Updated Final Safety Analysis Report (SCE, UFSAR). Little has changed in the geoscience community's overall understanding of the NI/RC Fault Zone's offshore characteristics since the original investigations for SCE's UFSAR. Some refinements were made in the mapped offshore traces of the fault by Fischer and Mills (1991), and slip rate estimates were improved for the on-shore portions of the NI/RC Fault Zone in Huntington Beach by Freeman et al. (1992), Law/Crandall, Inc. (1993), Grant et al. (1997), Shlemon et al. (1995), Franzen et al. (1998), and in Rose Canyon by Lindvall and Rockwell (1995). These changes in the NI/RC Fault Zone's seismic characteristics were incorporated in the source models used in the PSHAs for SONGS by SCE in 1995 and 2001, as well as in UCERF 2 (WGCEP, 2008), the NSHM (USGS, 2008), and in the current USGS implementation of UCERF 2 (2009, PC).

Further support for the strike-slip end-member model, with the high-angle NI/RC Fault Zone as the primary source fault closest to SONGS includes more recent research by Grant and Shearer (2004); Fisher (2009); Fisher et al. (2009a, 2009b); Lee et al. (2009); Ryan et al. (2009); Rockwell (2010); additional proprietary work completed offshore by Fugro West for the oil industry; and work currently underway by Dr. Dan Ponti of the USGS (Ponti, 2010, PC) along subsidiary traces of the onshore NI Fault north of Long Beach. The work completed by Ryan et al. (2009) is essentially an independent assessment of the available data reviewed during SCE's earlier work on the characteristics of the faults located offshore of SONGS, complemented by more recent seismic reflection data. Some of the proprietary marine geophysical survey data recently obtained by the USGS from WesternGeco and used by Ryan et al. (2009) was purchased by SCE years ago (Western Geophysical Company, 1972). Ryan (2010, PC) indicated that the results of the USGS independent assessment of the data are in general agreement with the results of SCE's previous investigations and analysis of the faulting offshore of SONGS.

UCERF 2 (WGCEP, 2008), the USGS (2008), and the current USGS implementation of UCERF 2 (2009, PC) characterize the NI/RC Fault Zone as a high-angle, right-lateral, strike-slip, primary seismic source, with relatively minor alternatives to its geometry onshore north of Long Beach. The map and logic tree used by the USGS (2008) for the NI/RC Fault Zone, with some minor changes to the seismic source characteristics based on USGS (2009, PC), are shown on Figures 2-3, 2-4, and 2-5. The same logic tree was utilized to represent the NI/RC seismic source model in this PSHA for SONGS.

Figures 2-3, 2-4, and 2-5 are an interpreted version of UCERF 2 (WGCEP, 2008), USGS (2008), and the current USGS implementation of UCERF 2 (2009, PC) seismic characterization of the NI/RC Fault Zone with a corresponding logic tree for that fault source. Further details regarding the earthquake recurrence model for the NI/RC Fault Zone used in this 2010 PSHA are presented in Section 3.1.3.3 of this report. Supporting the viability of the strike-slip end-member model is the possibility that the onshore and offshore segments of the NI/RC Fault Zone may be connected and capable of slipping together producing a significant magnitude earthquake. The sense of motion in the ICB offshore SONGS is dominantly NW-directed right-lateral shear at about 6 millimeters per year (mm/yr) based on recent global positioning system (GPS) data (Appendix A, Figure A-3), as discussed in more detail in Section 2.4. The dominance of right-lateral shear in the ICB has been in existence over the past approximately 20 Million Years (Ma) (Nicholson et al., 1994) as evidenced by the 250 km of strike-slip offsets of the Eocene Poway conglomerates from San Diego to the west end of the Channel Islands (Kies and Abbott, 1983; and Rockwell, 2010, PC). The initiation of this offset predates the inception of the San Andreas Fault (~5 Ma; Atwater, 1998). Furthermore, considering the kinematic motions in northern Baja

California, which projects into to ICB, there currently should be a small component of divergence in the Borderland offshore San Diego (Rockwell, 2010, PC). Observations of marine terraces along the coast of San Diego County and northern Baja California indicate that the uplift along this portion of the coast (~ 0.13 mm/yr) is regional in character, evenly distributed, and most likely driven by rift-shoulder uplift caused by the spreading of the Gulf of California (Mueller et al., 2009; and Rockwell, 2010, PC). This interpretation as to the cause of the evenly distributed, regionally persistent, uplifted terraces along the San Diego County/northern Baja California coast is further supported by the lack of folding in the Tertiary rocks beneath the terraces, except locally at the steps and bends in the strike-slip fault systems, such as the NI/RC Fault Zone through San Diego County and the Agua Blanca Fault in northern Baja California (Rockwell, 2010, PC).

Attachment A-2 of Appendix A presents Dr. Tom Rockwell's summary of current information concerning the NI/RC Fault Zone. This and other information form the basis for the weighting of the strike-slip end-member seismic source characterization model used in this study as discussed below in Section 2.4.

2.2 Blind Thrust Seismic Source Characterization Model

Reactivated Miocene detachment surfaces are the key elements of this blind thrust seismic source characterization model with the OBT being closest to SONGS. The OBT Fault was first proposed by Rivero et al. (2000) as an alternative primary active fault that could explain some of the deformation in the ICB region commonly associated with the strike-slip NI/RC Fault Zone. Rivero (2004) completed further assessments of the blind thrust fault systems (including the OBT and Thirtymile Bank Thrust Fault, TMBT) in his Ph.D. research, which was supervised by Professor John Shaw at Harvard University. Rivero et al. (2000), Rivero (2004), Rivero and Shaw (2005), and Rivero and Shaw (2010, in press) provide overviews of the evidence for active folding and blind-thrust faults induced by basin inversion processes in the southern ICB region and characterization of the OBT and TMBT as active fault sources. The OBT and TMBT are included in the CFM, developed by Dr. Andreas Plesch (a Research Associate at Harvard University) (Plesch et al., 2007). However, as noted above, the hypothesized active OBT and TMBT faults are not presently included as fault sources in UCERF 2 (WGCEP, 2008) or the USGS current implementation of UCERF 2 (2009, PC) seismic source characterization model. A focused summary of the seismic source characteristics of these postulated blind thrust fault sources and alternative models to explain the structural relationships among the active blind thrusts and strike-slip faults in the ICB region was prepared for SCE by Drs. Shaw and Plesch (2010, Appendix A, Attachment A-3), to reflect their current interpretation of the fault sources in the vicinity of SONGS.

The basis behind the OBT Fault model is Rivero's interpretation of paper copies of 1980s vintage oil industry digital deep-penetration 2D marine seismic reflection records (see Figures 2-6 and 2-7). Many of these records were proprietary at the time of Rivero's analyses, but have subsequently been released to the public and are being currently used by other researchers (e.g., Sorlien et al., 2009b and Ryan, 2010, PC).

Rivero et al. (2000) and Rivero (2004) formulated the models and sub-models presented on Figures 2-8, 2-9, and 2-10 and in Attachment A-3 of Appendix A based on the following:

- Based on balanced and restored cross-sections of the seismic reflection data, the recognition that compression has resulted in significant shortening of Plio-Pleistocene sediments into folds and faults;

- The 1986 Oceanside and Coronado Bank earthquake sequences;
- Regional uplift as evidenced by elevated onshore marine terraces; and
- To a very limited extent, GPS data.

Utilizing this data, Shaw and Plesch characterized the blind thrust fault sources (i.e., the OBT and TMBT) and their associated hanging wall and footwall subsidiary faults. Possible structural scenarios that represent potential interactions between the steeply-dipping strike-slip faults and the low-angle blind thrust fault sources are outlined in Figure A3-2A. Steeply-dipping, right-lateral strike-slip faults, such as the NI and RC, are incorporated into the blind thrust seismic source characterization model by Rivero (2004) and Rivero and Shaw (2010, in press). Preferred models for the interaction of these faults suggest that the strike-slip faults are segmented and offset at depth under the argument that continuous, through-going, strike-slip faults, as primary fault sources, are not kinematically compatible with the large amount of shortening documented on the OBT fault.

Shaw and Plesch (2010, Appendix A, Attachment A-3) qualitatively assigned weights to the four alternative models as shown on Figure 2-9 based on their observations and confidence in the available data. Utilizing the information developed by Rivero (2004), Rivero and Shaw (2005), and Rivero and Shaw (2010, in press), Shaw and Plesch (2010, Appendix A, Attachment A-3) developed the simplified rupture segmentation models as depicted on Figure 2-11 and depicted in the logic tree shown on Figure 2-12.

The map on Figure 2-11 and the logic tree on Figure 2-12 reflect the complex alternatives of the OBT Fault as the closest hypothesized fault to SONGS in the blind thrust fault end-member model. All of the alternative geometries of the OBT Fault with their single and combined segment rupture possibilities are addressed in this logic tree. The earthquake recurrence rates for these alternatives were calculated using the identified slip rates on Figure 2-12, and are discussed further in Section 3.1.3.3. Refer to the complete discussion by Shaw and Plesch (2010) in Appendix A, Attachment A-3 for additional details.

2.3 Base-case Regional Fault Sources and Background Source Zones

The more distant (with respect to SONGS) regional faults and background source zones used in the strike-slip and blind thrust end-member seismic source characterization models used in this 2010 PSHA are referred to as the base-case model. These base-case regional fault sources are shown on Figure 2-3 and their closest distances from the plant are listed in Table 2-1. The information presented in Table 2-1 is based on the time-independent characteristics of these seismic source faults used in the current implementation of UCERF 2 model provided by the USGS (2009, PC). Table 2-1 also lists non-designated faults (i.e., faults not presently included as seismic sources, but faults that WGCEP [2008] targeted for future consideration).

The use of time-independent characterization of seismic source faults in the PSHA for SONGS is justified by the observations that the seismic sources amenable to time-dependent modeling (such as the San Andreas Fault) are distant sources that are not the controlling sources for seismic hazard at SONGS, and there are uncertainties involved in evaluating time-dependency.

Following UCERF 2 (WGCEP, 2008), the seismic sources provided by the USGS (2009, PC) are designated as either a Type-A fault, a Type-B fault, or a Type-C zone, depending on the level of knowledge tied to the specific seismic source. Type-A faults have known slip rates and paleoseismic recurrence interval estimates; Type-B faults have observed slip rates; and Type-C zones are areas of crustal shear that lack sufficient detailed knowledge to apportion slip onto specific faults. In southern California, Type-A faults include the San Andreas, San Jacinto, Elsinore, and Garlock faults. All other fault sources in southern California represented by the USGS (2009, PC) and used in this SONGS PSHA are designated Type-B faults. The Type-C zones in southern California include the Mojave or Eastern California shear zone, the San Gorgonio zone or "knot," and the Brawley zone, or Imperial Valley zone (WGCEP, 2008; USGS, 2008). Figures 2-5 and 2-12 provide the key source characterization parameters for regional fault sources included in the SONGS PSHA. At a distance of about 38 km to the northeast, the Elsinore Fault is the Type-A designated fault closest to SONGS. The closest Type-B designated fault is the NI/RC Fault Zone, which lies about 8 km offshore to the west of SONGS. The characterization of the NI/RC Fault Zone source as a primary strike-slip fault end-member model is described in Section 2.1. Alternative geometries and slip rate estimates for the NI/RC Fault Zone source based on the blind thrust fault end-member model are presented in Section 2.2.

The next closest Type-B designated fault in UCERF 2 (WGCEP, 2008) is the Palos Verdes/Coronado Bank Fault, which is about 32 km west of SONGS. The San Diego Trough and San Clemente Faults, which lie at closest distances of 46 km and 94 km, respectively, are not presently characterized as fault sources by the USGS (2009, PC). The potential contribution of these faults to the seismic shaking hazard along the onshore portions of southern California, including SONGS, is judged to be negligible for several reasons including, but not exclusively, their location farther offshore, as shown on Figure 2-3, and their relatively low slip rates. These faults were included as faults sources in the SCE (1995, 2001) PSHA, and the results of these studies showed that neither the San Diego Trough nor San Clemente faults contribute significantly to the hazard at SONGS; thus these faults are not included in the PSHA for this study.

Of the three Type-C zones in southern California, the Eastern California Shear zone and Brawley zone are not significant contributors to the SONGS PSHA, due to their distances from SONGS (greater than 100 km), and thus were not included in the PSHA for this study. The San Gorgonio Type-C zone through Banning Pass, as shown on Figure 2-1b, is incorporated in the USGS (2009, PC) characterization as shown on Figure 2-3, as a low slip rate segment of the San Andreas Fault; this approach was followed in this PSHA.

The more distant regional faults listed in Table 2-1a, are included in both end-member seismic source characterization models for this PSHA. In the strike-slip end-member seismic source characterization model, the NI/RC Fault Zone, as characterized by UCERF 2 and USGS (2009, PC), is used; in the blind thrust end-member seismic source characterization model, the OBT and alternative characterizations of the NI and RC faults as defined by Shaw and Plesch (2010, Appendix A, Attachment A-3) are used.

In both end-member seismic source characterization models, the current SONGS PSHA incorporates a background seismicity zone(s) to account for additional seismicity not modeled by the seismic source faults using procedures similar to UCERF 2 (WGCEP, 2008) and the USGS' current implementation of UCERF 2 (2009, PC).

2.4 Weighting of Alternative Models

Figures 2-1b, 2-2, 2-3, 2-6, and 2-8 in this report, and Figures A-7a through A-7f and A-17 in the accompanying Appendix A, present maps of the more recent alternative interpretations of the faulting in the ICB offshore of SONGS, as discussed above and in Appendix A. Figures 13a shows the nearby location of the marine seismic reflection geophysical survey records that follow in Figures 13b through 13h. These geophysical records were used, in part, by Ryan et al. (2009), Sorlien et al. (2009b), and Rivero and Shaw (2010, in press) in their interpretations of the faulting offshore of SONGS. This sequence of figures is used to illustrate the similarity in these geophysical records and to illustrate the similarities and differences in these different researcher's interpretations of these records. This was accomplished by superimposing Ryan et al. (2009) and Rivero and Shaw (2010, in press) records over the Sorlien et al. (2009b) record, in both opaque and transparent overlays.

Generally, this exercise demonstrates that these different researchers are observing essentially the same geophysical record, but offer different interpretations as to what these records illustrate in regard to the location, geometry, and style of faulting in this area. Figure 14 is a consolidated sketch of the interpreted geophysical records based on Ryan et al. (2009), Sorlien et al. (2009b), and Rivero and Shaw (2010, in press). This sketch, and the following simplified sketches in Figure 15 of the two end-member fault models, illustrates the uncertainties in the different interpretations of these marine geophysical records. First, it is unclear how the principal faults interact with each other at depths greater than approximately 4 km. This uncertainty results in the question as to whether the blind thrust end-member model or the strike-slip end-member model is the primary nearby fault source to SONGS. Second, the apparent vertical displacement of the geophysical marker horizons across the inferred faults on these records may not reflect the actual slip and resulting slip rate across the faults in either of the two end-member models. For example, the apparent displacements of geophysical marker horizons inferred to be the top of the Pliocene, Pico or Repetto formations or the top of the basement rocks, across apparent faults, such as the San Mateo Thrust (SMT) Fault, may not reflect the amount of lateral displacement and thus not entirely representing the total amount and direction of slip across the fault. Further, in the area offshore of SONGS, the range in depth and age estimates placed on geophysical marker horizons, such as these, remains broad. This introduces uncertainty in estimates of the level of activity and slip rates on these faults based solely on the geophysical records, particularly uncertainty in the late Quaternary level of activity on these faults. This limitation in the geophysical survey records results in the need for a careful assessment of all available relevant information and the development of reasonable weightings, based on that information, as to which end-member fault model is the more likely the case driving the PSHA for SONGS.

2.4.1 Discussion of Alternative Models

The weights assigned to the two end-member alternative models for potential fault sources that pose the most significant seismic hazard to SONGS (i.e., the OBT and the NI/RC models) are based on available relevant evidence and information regarding their seismogenic potential. The data include their geometry and level of activity, as well as geologic and geodetic evidence that pertains to the style and rate of crustal deformation occurring in the present tectonic environment. The references utilized in this weighting assessment are summarized in Attachment A-1 of Appendix A.

The evidence supporting both the reactivation of parts of the Oceanside detachment (i.e., compressional folding and thrust/reverse faulting) and high-angle, right-lateral strike-slip along the NI/RC Fault Zone is generally unequivocal in the technical community. There is general agreement that detachment faults are present in eastern California, the Transverse Ranges, and portions of the Los Angeles Basin, and ICB. Fisher et al. (2009a) summarize the technical community's current understanding of the paleotectonics of southern California's Continental Borderland, stating: *"A significant complication for hazards research is that during late Mesozoic and Cenozoic time, three* *successive tectonic episodes affected this plate-boundary zone. Each episode imposed its unique structural imprint such that early-formed structures controlled, or at least influenced, the location and development of later ones."* Each episode was driven by changes in tectonic plate motion. During the first episode, in the Mesozoic, thrust faults developed in an accretionary wedge above an east-directed subduction zone. The second episode, during the Miocene, was transtensional in nature, resulting in the development of extensional detachment and normal faults concurrently with rotation and northward translation of the Western Transverse Ranges. The third episode, in Pliocene through Holocene time, was primarily transpressional, resulting in structural inversion of some of the Miocene normal faults as oblique reverse/strike-slip faults, and localized re-activation of low-angle detachment faults as thrust faults.

There is no direct evidence that clearly demonstrates that the Miocene detachment faults have been reactivated as blind thrust faults on a regional scale off of the San Diego County coast. At this time, based on more recent re-evaluations of existing data and more recently collected data, the specific characteristics and the seismogenic potential of these Miocene detachment faults remain in discussion. This led to conservatively considering both end-member seismic source characterization models as contributing to the ground motion hazard at SONGS rather than limiting the evaluation to a single dominate model. In accordance with Senior Seismic Hazard Analysis Committee (SSHAC) guidelines (Budnitz et al., 1997), the weighting of these two end-member seismic source models (i.e., dominated by the high-angle, strike-slip NI/RC or the low-angle OBT) is based on an assessment of the extent of the evidence supporting the respective interpretations and the current understanding of the technical community's judgment regarding the tectonic setting of the region.

A low-angle detachment fault is visible in the marine seismic reflection records and has been recognized by the technical community as an east-northeast-dipping geologic structure beneath the ICB west of the mapped traces of the NI-RC Fault Zone (Bohannon and Geist, 1998; Crouch and Suppe, 1993; Ryan et al., 2009; Sorlien et al., 2009a, 2009b). Some geoscientists have interpreted this fault as having been reactivated on a regional scale in Pliocene through Holocene time as the OBT (Rivero 2004; Shaw and Plesch, 2010, Appendix A, Attachment A-3). However, their research by itself does not entirely resolve discrepancies between the strike-slip and blind thrust end-member models. The structural interaction of the detachment and high-angle faults cannot be resolved based on currently available marine seismic reflection records. More recent marine seismic reflection, coastal geomorphic, paleoseismic, and seismological research, previously not available to Rivero et al. (2000) and Rivero (2004), offer alternative interpretations of the lateral and down-dip extent of the OBT. Further, although the marine seismic reflection data supports Miocene extensional detachments and localized Pliocene through Holocene compressional activity, there is no direct evidence that clearly demonstrates Pleistocene or Holocene activity on the OBT as a major regional through-going thrust fault. Appropriate weight is given in this PSHA to the possibility that the OBT may be a capable seismic source based on the following data, observations, and interpretations:

- The wedge/thrust model developed by Rivero et al. (2000), Rivero and Shaw (2001), and Rivero (2004) to explain fold deformation along southern California's offshore region is based on a systematic analysis and review of an extensive set of seismic data.

- This model provides an alternative explanation of the apparent discontinuity of post-Upper Miocene faulting in this region and explains the significant amounts of Pliocene and post-Pliocene crustal shortening exhibited by the folded strata at and seaward of the shelf break.

- Available seismic reflection data cannot resolve whether the high-angle, strike-slip faults along the NI/RC Fault Zone displace the postulated OBT.

The activity and seismogenic potential of the OBT, however, is not definitive. The evidence cited by Rivero et al. (2000), Rivero and Shaw (2001), and Rivero (2004) is based on their interpretation of:

- Geophysical evidence of post-Pliocene folding and faulting in the offshore region;
- A structural relationship between the San Joaquin Hills and a similar wedge/thrust structure in the offshore;
- Association of the 1986 Oceanside earthquake with a component of the ICB thrust belt system (the Thirtymile Bank blind thrust);
- Regional coastal uplift; and
- Geodetic measurement of contractional crustal strain.

Each of these items of evidence may have some viability for indicating the seismogenic capacity of the OBT, but, as noted below, they are also consistent with a predominantly strike-slip regime.

A stronger case is made in support of the model that characterizes the NI/RC Fault Zone as part of a system of through-going strike-slip faults. The primary data, observations, and interpretations supporting a higher weight given to the strike-slip model are:

- The dominance of strike-slip motions that has occurred on the faults in ICB since the Eocene.
- Marine 2D seismic reflection geophysical records, similar and is some cases the same as those used by Rivero et al. (2000) and by Rivero (2004), led to alternate interpretations by Moore (1972), Western Geophysical (1972), Fischer and Mills (1991), Sliter et al. (2001), Crouch and Suppe (1993), and more recently Legg et al. (2007), Ryan et al. (2009), Sorlien et al. (2009b), and Ryan (2010, PC) as to the relatively continuous zone of recently active en echelon fault traces offshore of southern Orange County and San Diego County linking the onshore traces of the NI Fault and RC Fault, and alternate configurations of the faults further offshore to the west.
- Evidence to support reactivation of the entire OBT in the current tectonic environment is not conclusive. Recent re-analysis of available deep seismic reflection data acquired in the 1970s (Ryan et al., 2009; Sorlien et al., 2009b) provides alternative interpretations that the OBT is not a continuous active tectonic structure, but is composed of smaller, separate segments, not all of which are active.
- Alternatively, late Pleistocene/Holocene faults and associated folding used to support the regionally continuous blind thrust model can also be explained by strain partitioning and contraction in the right-lateral NI/RC Fault Zone, in particular at en echelon left steps or bends in the fault trace. In addition, some compressional elements apparent in the available marine seismic reflection records may be relics of earlier Pliocene compression. Further, local apparent compressional folds and/or discontinuities evident in these marine seismic reflection records

also may be due to translation of sediments over inherited basement protrusions, as suggested by Wright (1991).

- Clockwise rotation of crustal blocks in the ICB, which was postulated in SCE (2001), has been emphasized by Ryan et al. (2009). Rotation of a large crustal block would be consistent with the local reactivation of northern portions of the OBT (i.e., late Quaternary compression on subsidiary reverse faults beneath the continental slope offshore of San Mateo Point west of the NI/RC Fault Zone), but would not require reactivation or rupture of the entire length or depth of the detachment. Late Quaternary inactivity of the OBT further south offshore of Carlsbad and extensional subsidiary fault activity on continental slopes west of the NI/RC between Carlsbad and La Jolla, as suggested by Sorlien et al. (2009b), are consistent with this block rotation model. Geodetic data on the neighboring Peninsula Range block shows similar clockwise rotation as detailed in Appendix A.

- Based on their analysis of the tectonics surrounding the Agua Blanca Fault in Baja California, Wetmore et al. (2010, in review) document evidence that the Agua Blanca Fault becomes transtensive as it transitions offshore into the Borderland. This interpretation is consistent with a current tectonic environment of transtension in the Borderlands offshore of southern California, and suggests that the current kinematic framework offshore is principally transtensional in nature. They state that "Major late Miocene normal faults form an important kinematic component of deformation in the southern half of the central domain, but extreme crustal thinning is partially compensated by north-south shortening associated with detachment folds and conjugate-slip faults." This suggests that the regionally extensive thrust faults in the southern portions of the Peninsular Ranges and the ICB inferred by Rivero et al (2000) may be inherited from the Pliocene before development of the through-going strike-slip faults of the Peninsular Ranges, such as the San Jacinto, Elsinore and NI/RC faults. However, the presence of local compressional folds and faults is not precluded (Rockwell, 2010, PC).

- Seismicity data show that the NI and RC faults are capable strike-slip faults (Hauksson, 1987; Hauksson and Gross, 1991; Astiz and Shearer, 2000; and Grant and Shearer, 2004). Based on discussions with Dr. Ryan of the USGS (2010, PC) regarding her recent assessment of high-resolution seismic reflection data (Conrad et al., 2010) and refined epicenter locations/focal mechanism analyses by Astiz and Shearer (2000), an alternate interpretation for the source behind the thrust mechanism of the 1986 Oceanside earthquake is strain partitioning and contraction in the a left-step in the right-lateral strike-slip San Diego Trough Fault. This interpretation further indicates that strike-slip faults extend to seismogenic depths and are the major seismic source faults in the ICB.

- Paleoseismic data demonstrates that the onshore NI and RC faults are strike-slip faults (Rockwell et al., 1991, 1992; Ponti and Ehman, 2009; Ponti, 2010, PC; and Rockwell, 2010, PC). A dominate long and continuous primary thrust fault between these two northern and southern right-lateral fault sections appears inconsistent with the current dominate tectonic framework of the Peninsular Ranges and the ICB, however, the local presence of blind thrust faults cannot be refuted.

- Regional coastal uplift, which is cited by Rivero et al. (2000) to indicate that the Oceanside and Thirtymile Bank thrusts are active over a region larger than the San Joaquin Hills (Grant et al., 1999 and 2002) or Mount Soledad, (Rockwell, 2010) may be attributed to a large degree to other processes (e.g., rift shoulder thermal isostasy). Studies by Mueller et al. (2009) suggest that the uniform regional uplift observed in southern California may reflect the far-field effect of unloading and rift shoulder development associated with lithospheric thinning in the northern Gulf of California and the Salton Trough.

- There is no marked change in the pattern of coastal uplift across the segmentation boundary between the more shallow dipping northern OBT and the steeper dipping southern OBT as proposed by Rivero (2004), Rivero and Shaw (2010, in press), and Shaw and Plesch (2010, Appendix A, Attachment A-3). This suggests that either the coastal uplift is not directly linked to slip on the OBT, or the southern segment has a lower slip rate. Dr. T. Rockwell notes that there is no evidence for tilting or significant differential uplift along the coast as recorded by the Quaternary marine terraces and underlying Tertiary bedrock (Kern and Rockwell, 1992; Rockwell, 2001, PC and 2010, PC).

- The initiation of structural inversion and thrust faulting in the offshore, which is inferred to have begun in the Pliocene (Crouch and Suppe, 1993; Rivero et al., 2000; and Rivero and Shaw, 2001; Rivero, 2004; Rivero and Shaw, 2010, in press; and Shaw and Plesch, 2010, Appendix A, Attachment A-3), may significantly predate the initiation of coastal uplift as noted above. This suggests that coastal uplift is not directly linked with movement on the ICB thrust system. However, age estimates and correlation of stratigraphy across the fold belts in the offshore are not well constrained due to the paucity of offshore well control. Consequently, the initiation of folding could have been later than previously estimated.

- Geodetic data, as presented in Appendix A, shows that strain in the southern ICB is dominated by northwest directed shear subparallel to the overall North American/Pacific plate motion. Little or no convergence across the ICB normal to the plate boundary is observed in the vicinity of SONGS as detailed in Appendix A. In particular, the lack of significant convergence in the regional signal to the east of the OBT suggests there is not a regional "driving" force that would reactivate a through going seismogenic thrust (SCE, 2001).

- Some of the contractional deformation observed in the ICB could have occurred during the Pliocene or early Quaternary within a different stress regime. Based on geologic evidence that suggests coastal uplift in the San Diego region, as well as activity on the Elsinore Fault, was initiated approximately 0.9 to 1.0 Ma, Dr. Rockwell (2001, PC and 2010, PC) suggests that a reorientation of the plate vector may have occurred in the region during early to middle Quaternary. Dr. Ponti (2001 and 2010, PC) also suggests a change in the tectonic stress regime in that same time frame based on evidence for decreasing Late Quaternary slip rates compared to longer-term rates for some blind thrusts in the Los Angeles basin (e.g., the Compton-Los Alamitos and Las Cienegas faults).

2.4.2 Assigned Weights

Based on these observations and qualitative judgments, weights were assigned to the two alternative end-member seismic source fault characterization models by the seismic source characterization integrator team. The weights assigned reflect the team's professional geoscience judgment as to the extent to which each end-member source fault model would find support from the currently available scientific evidence and best fit the engineering and scientific technical community's current understanding of the tectonic environment surrounding southern California, including SONGS. A 90% weight was assigned by two of the team members and a 85% weight was assigned by the third member to the strike-slip seismic source characterization model, which includes the through-going high-angle, right-lateral strike-slip, NI/RC Fault Zone as the nearest primary active fault system in the ICB offshore of SONGS. The blind thrust seismic source characterization model, which includes the postulated, regionally extensive OBT as the nearest primary fault system in the ICB offshore of SONGS, was assigned the remaining weight of 10 or 15%, respectively. For use in the 2010 PSHA, the weights assigned by the seismic source integrator team were numerically equal to 88% for the strike-slip end-member model and 12% for the blind thrust end-member model.

This weighting is supported by the following key points. First, there is little empirical evidence available to support that oblique slip with the ratio of strike-slip to dip-slip suggested by the available information regarding the OBT would occur on a fault plane dipping between 14 and 24 degrees. Second, recent assessments of offshore earthquakes relative to new mapped fault locations and geometry raise questions as to whether thrust focal mechanisms from recent earthquakes are tied to regionally persistent blind thrust faults or are generated by more local subsidiary blind thrust faults driven by strain partitioning in contractional left-steps or bends in the more dominate right-lateral strike-slip fault system. Finally, more current GPS records do not support a regionally persistent blind thrust model that would extend the full distance of the San Diego County coast line. Locally, there does appear to be indications of reactivation of low-angle Miocene detachment surfaces as thrust faults since late Pliocene time, but in the present tectonic environment, these thrust faults do not appear to make up a continuous, active tectonic structure on a regional scale.

Table 2-1a: Type-A Faults and Type-B Faults

	Fault Name	Closest Distance from SONGS to Rupture Plane Rrup (km)(5)
Type-A Faults(1)	San Andreas(3)	92
	San Jacinto(3)	70
	Elsinore(3)	38
Type-B Faults(1)	Newport-Inglewood/Rose Canyon (NI/RC)(3)	8
	Palos Verdes/Coronado Bank(3)	32

Table 2-1b: Non-Designated Faults

	Fault Name	Closest Distance from SONGS to Rupture Plane Rrup (km)(5)
Non-Designated Faults(2)	Oceanside Blind Thrust (OBT)(4)	7
	San Diego Trough	46
	San Clemente	94

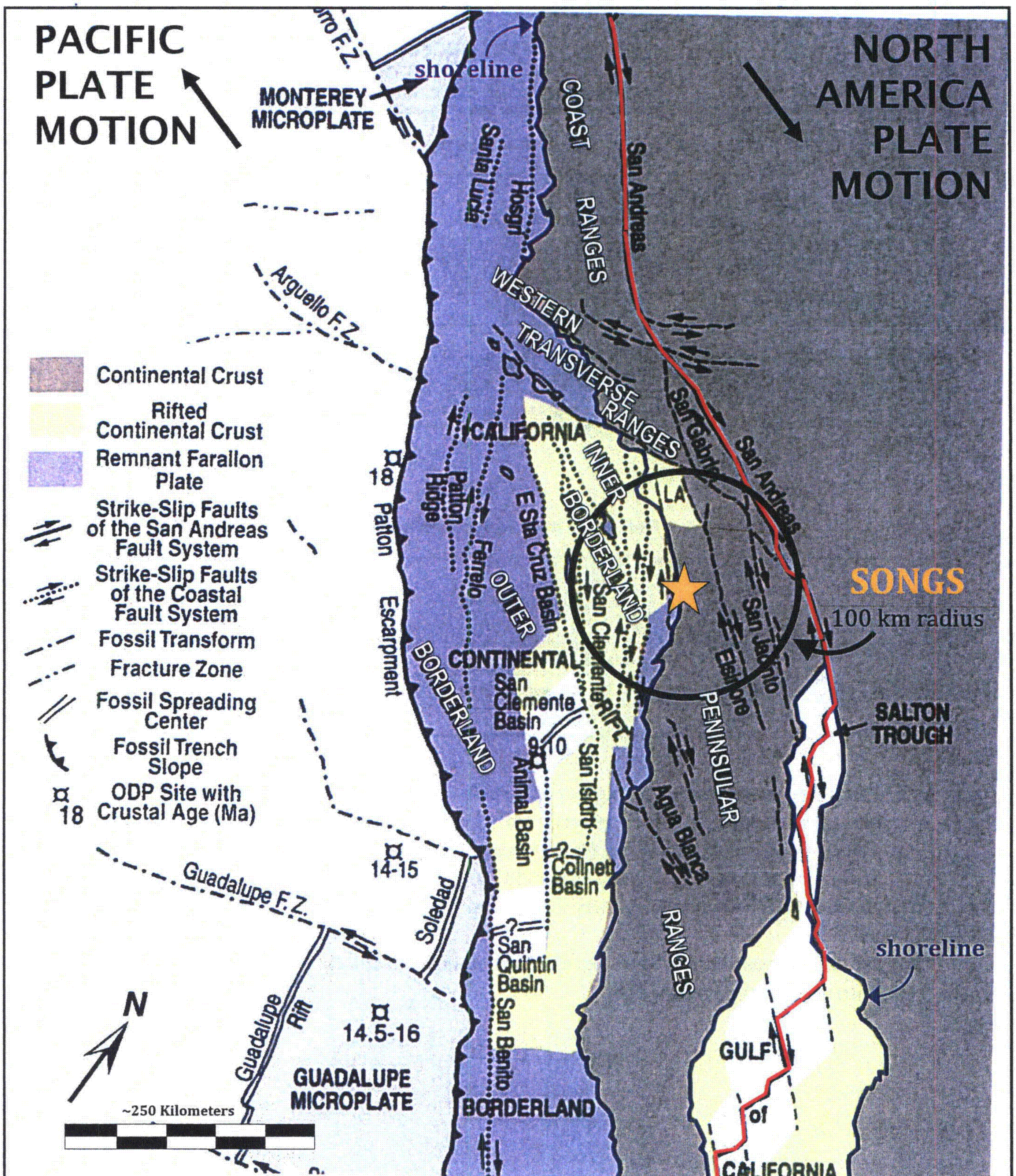
(1) "Type" designated fault; parameters for fault listed in Table 1 of Appendix A in UCERF 2 and used in the current USGS implementation of UCERF 2 (2009, PC) and in this PSHA.

(2) Non-designated fault; parameters for fault being considered for development by WGCEP (2008) as presented in Table 2 of Appendix A in UCERF 2.

(3) Relevant faults models by the current USGS implementation of UCERF 2 (2009, PC) and used in this PSHA.

(4) OBT Fault as hypothesized by Rivero et al. (2000) and Rivero (2004).

(5) Distances taken from Figure 2-3.



Modified from Legg et al. (2004). Plate motion vectors from Argus and Gordon (1991).

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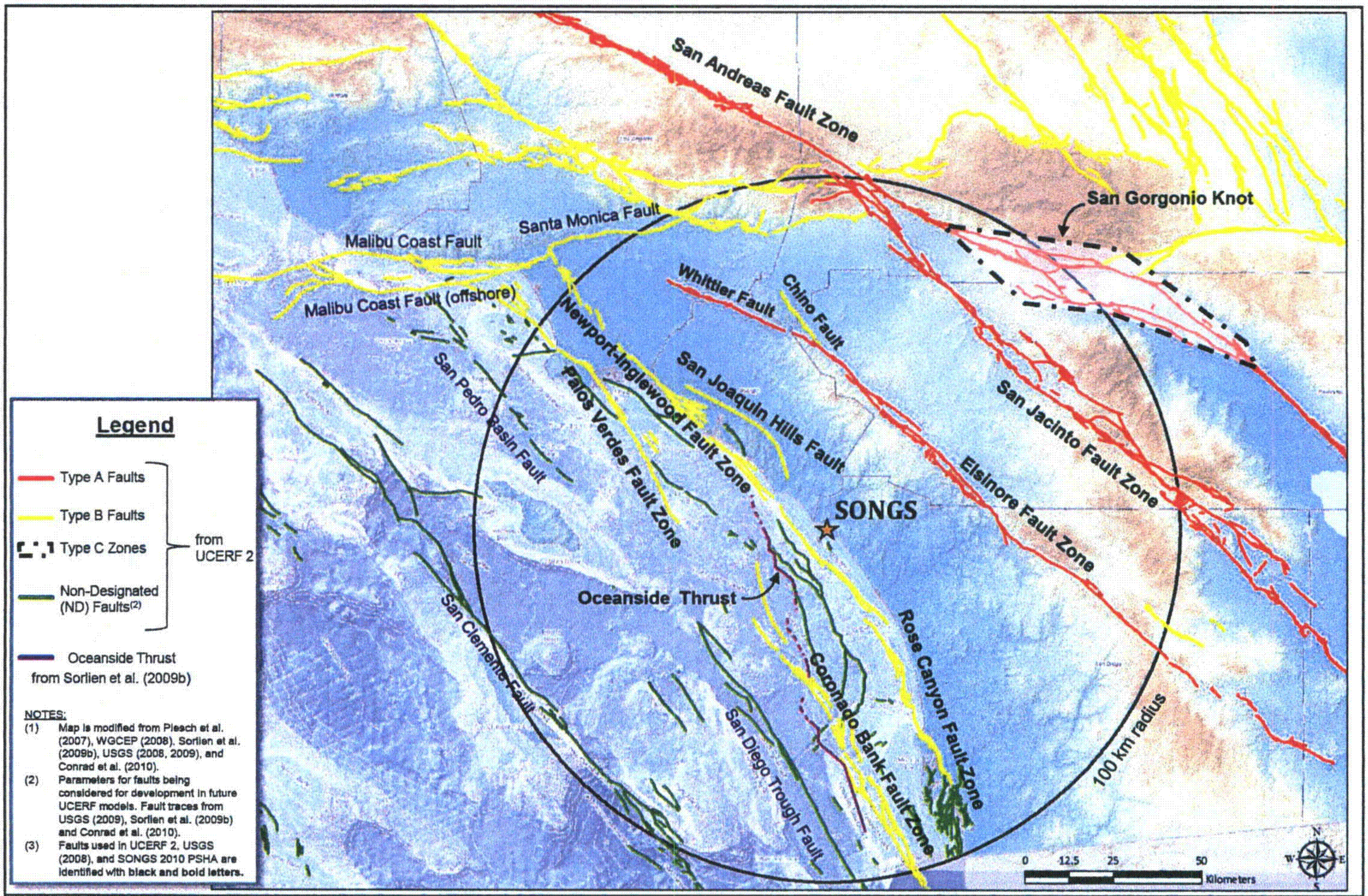
REGIONAL MAP SHOWING TECTONIC BLOCKS OF SOUTHERN CALIFORNIA

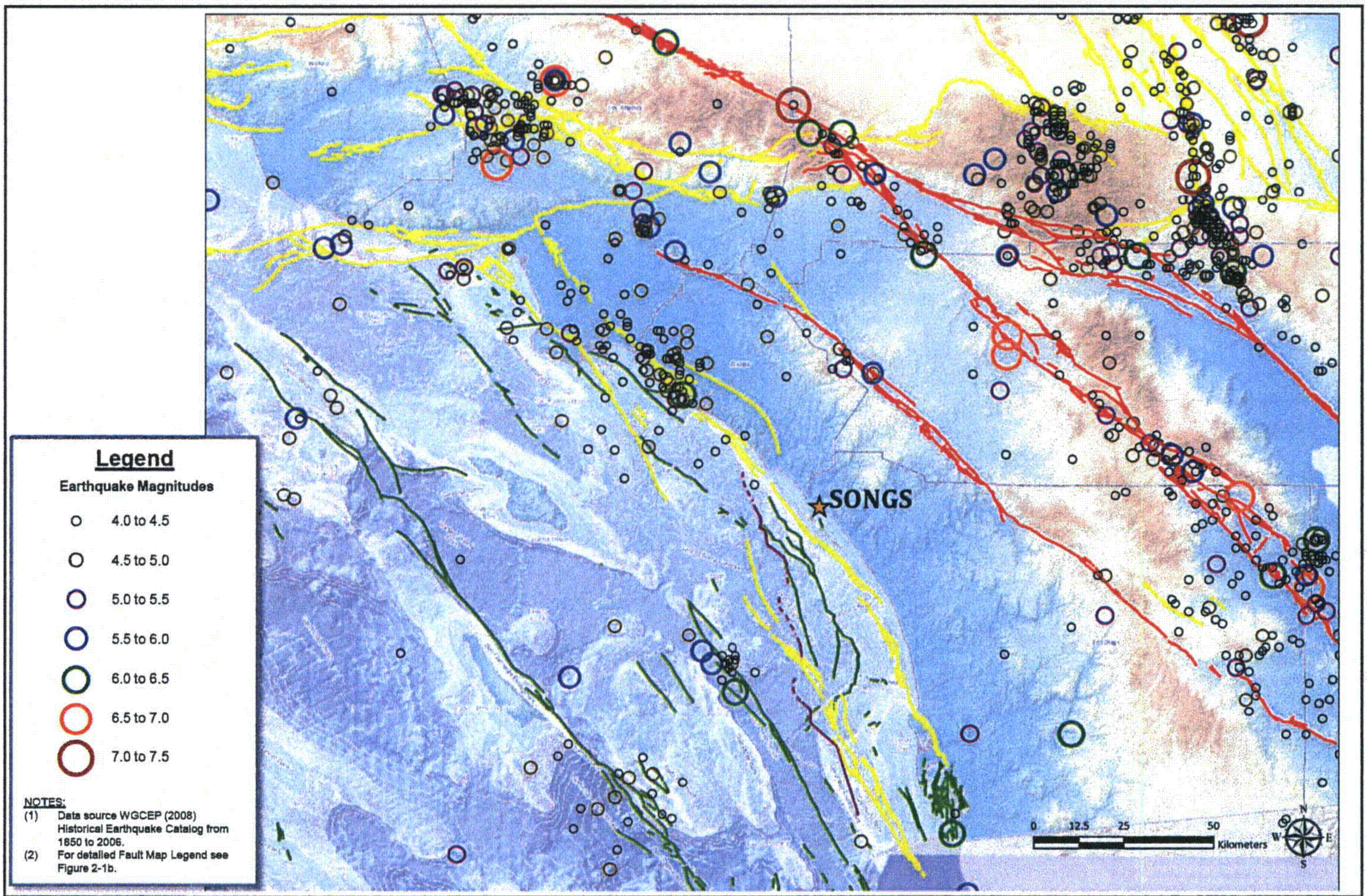
FIGURE 2-1a

SAN ONOFRE NUCLEAR GENERATING STATION

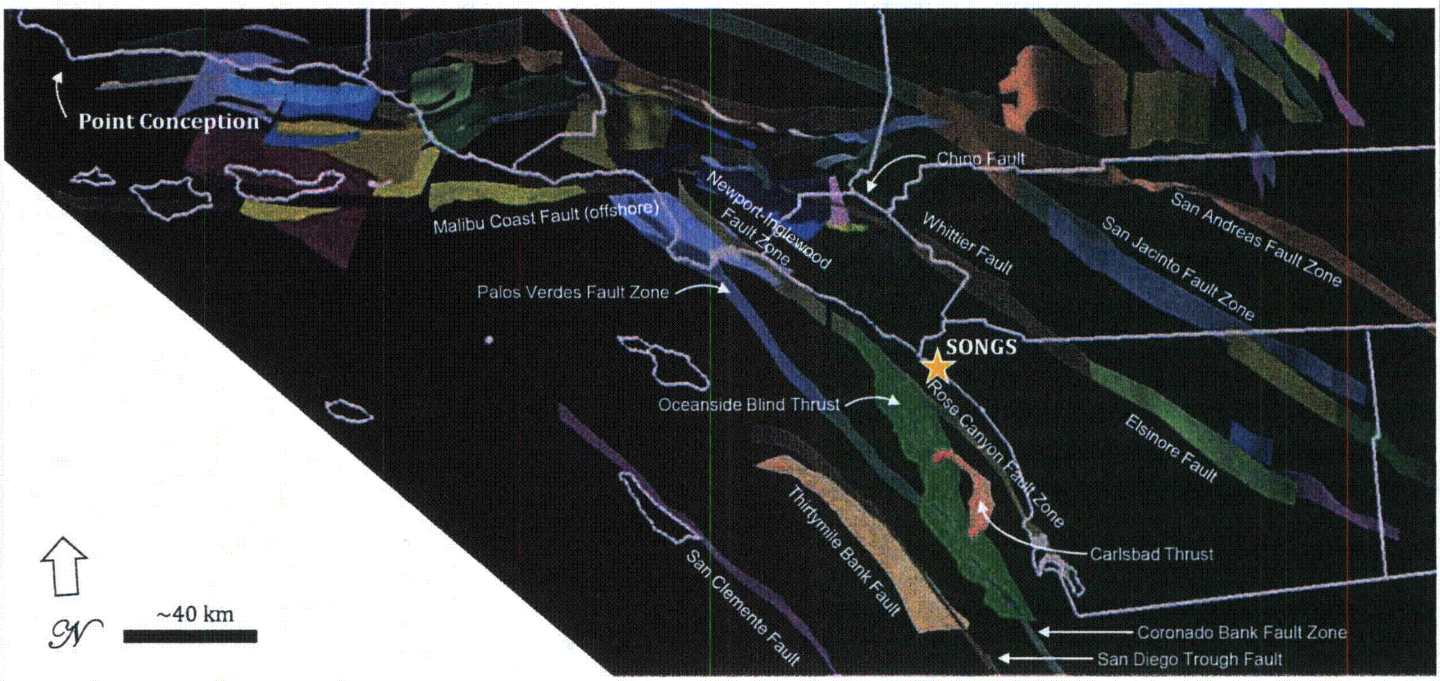
SEISMIC HAZARD ASSESSMENT PROGRAM



GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	POTENTIAL SEISMIC SOURCES	FIGURE 2-1b

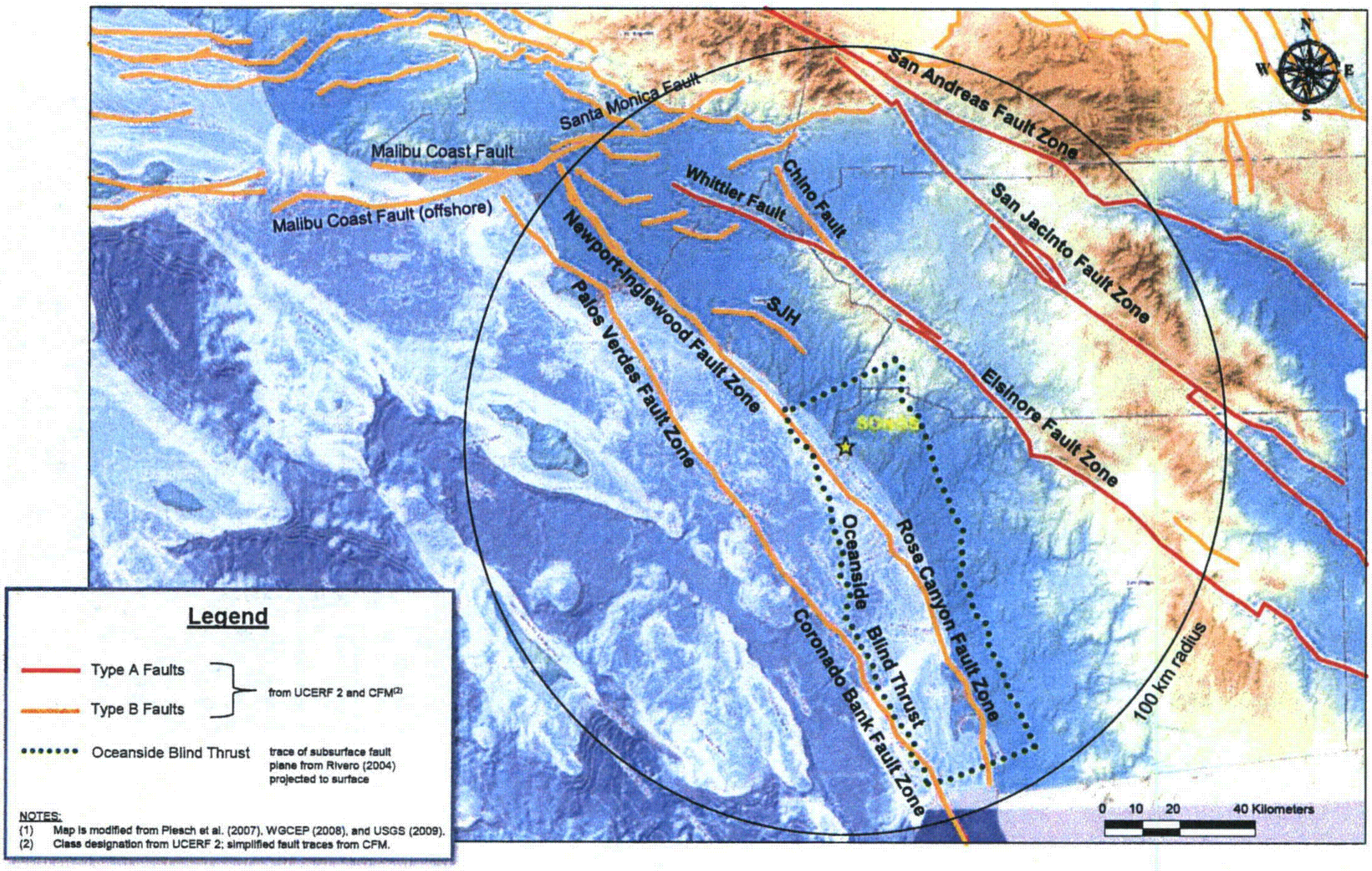


GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	EPICENTERS OF MAINSHOCK AND AFTERSHOCK EARTHQUAKES	FIGURE 2-1c



Modified from CFM (Plesch et al., 2007)

GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	POTENTIAL SEISMIC SOURCES FROM THE COMMUNITY FAULT MODEL (CFM)	FIGURE 2-2

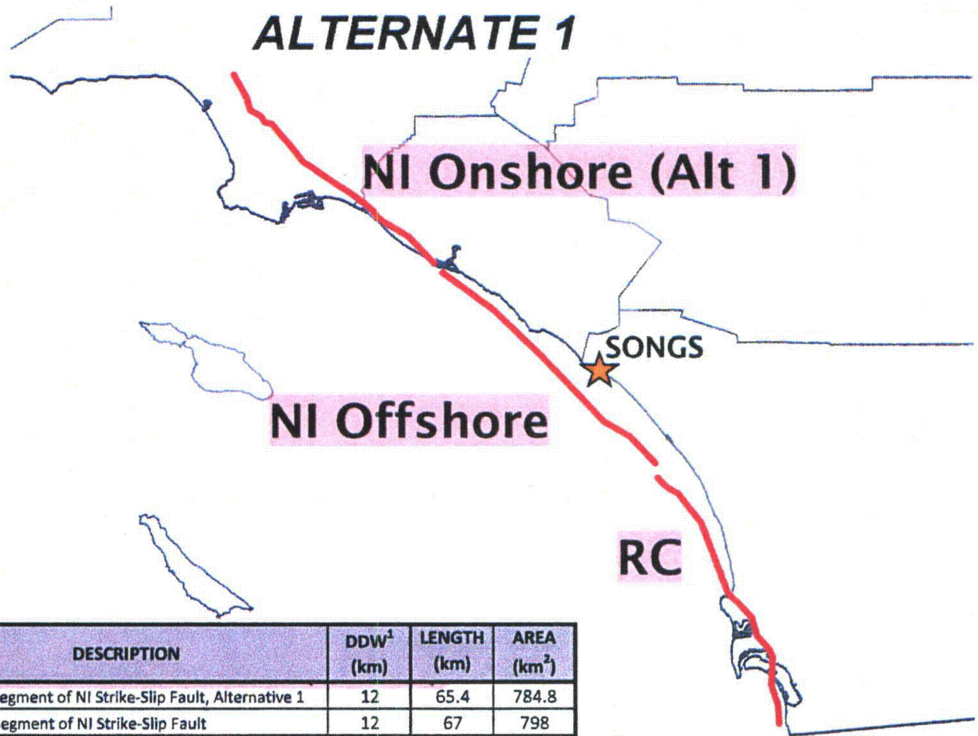


GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	SEISMIC SOURCES CONSIDERED IN HAZARD ANALYSIS	FIGURE 2-3

Notes:

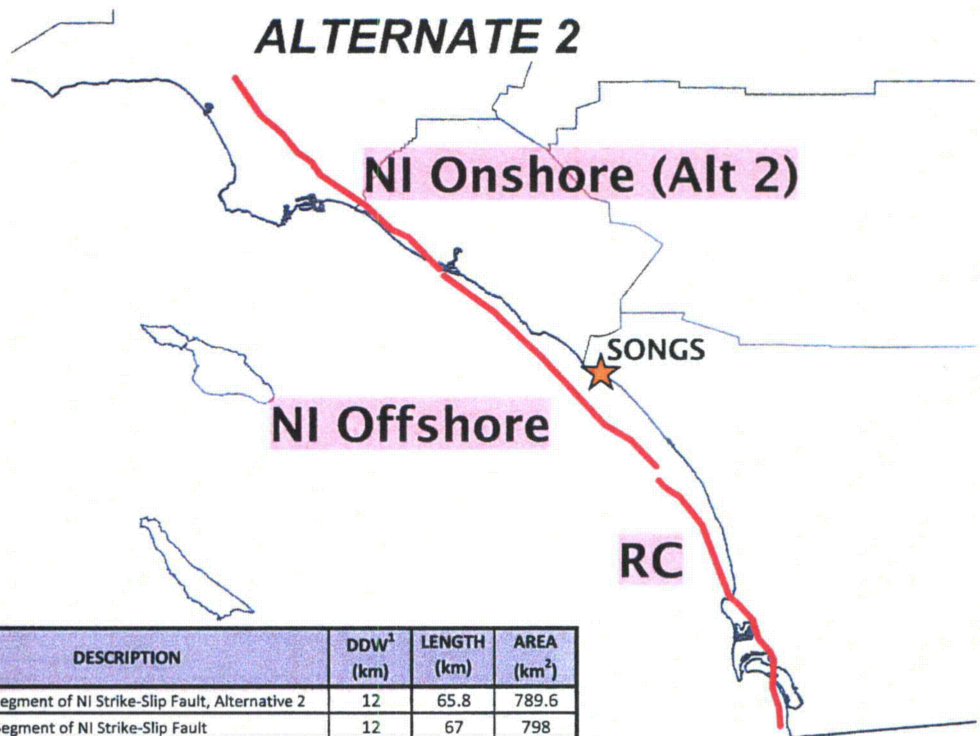
[1] Assuming 5km to 17km Seismogenic Depth

ALTERNATE 1



SEGMENT LABEL	DESCRIPTION	DDW[1] (km)	LENGTH (km)	AREA (km^2)
NI Onshore (Alt 1)	Onshore Segment of NI Strike-Slip Fault, Alternative 1	12	65.4	784.8
NI Offshore	Offshore Segment of NI Strike-Slip Fault	12	67	798
RC	Rose Canyon Strike-Slip Fault	12	70	840

ALTERNATE 2



SEGMENT LABEL	DESCRIPTION	DDW[1] (km)	LENGTH (km)	AREA (km^2)
NI Onshore (Alt 2)	Onshore Segment of NI Strike-Slip Fault, Alternative 2	12	65.8	789.6
NI Offshore	Offshore Segment of NI Strike-Slip Fault	12	67	798
RC	Rose Canyon Strike-Slip Fault	12	70	840

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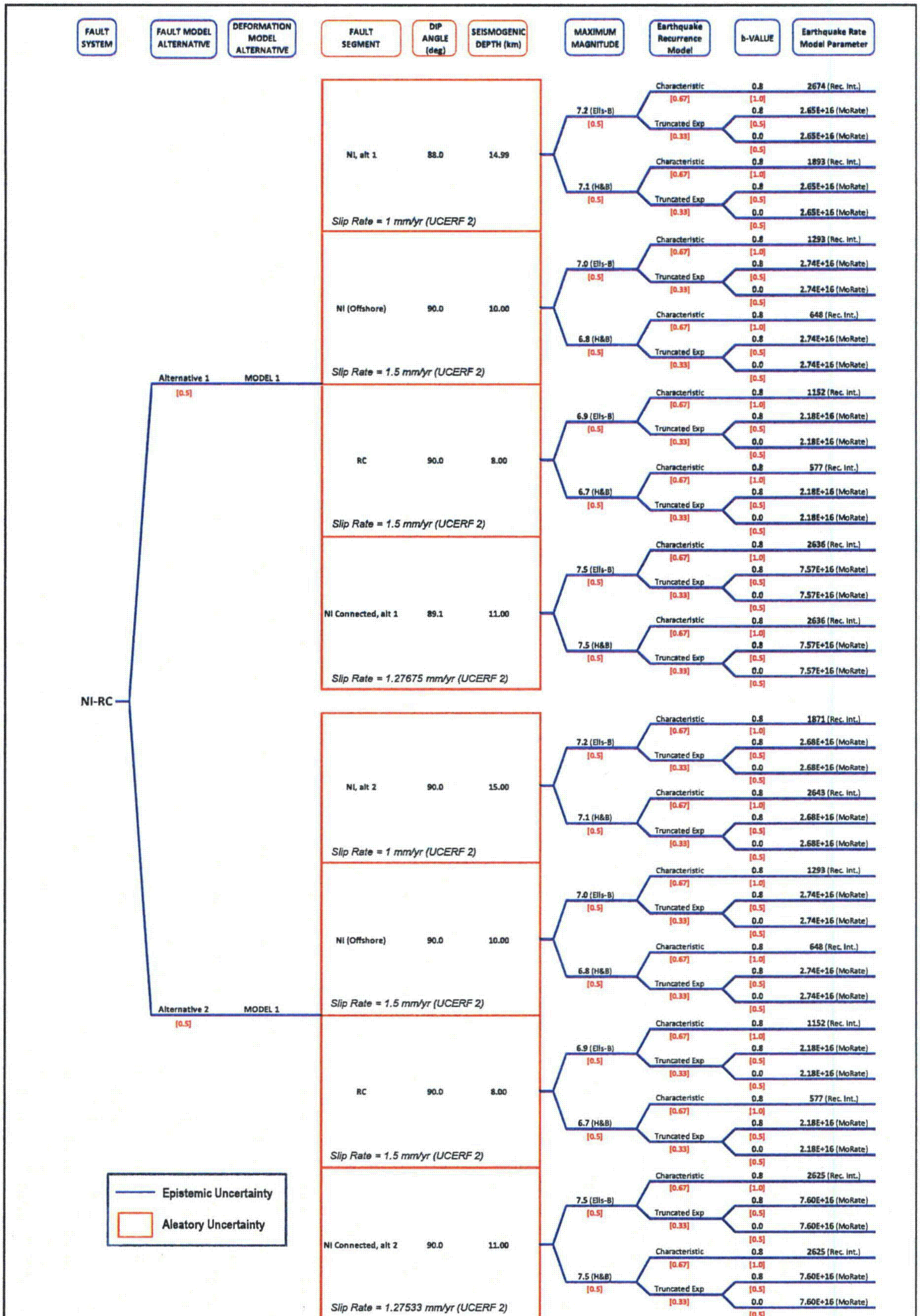
SIMPLIFIED GEOMETRY AND SEGMENTATION FOR STRIKE-SLIP END-MEMBER MODEL

FIGURE 2-4

SAN ONOFRE NUCLEAR GENERATING STATION

SEISMIC HAZARD ASSESSMENT PROGRAM



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NIRC 'LOGIC TREE' – 8 COMBINATIONS OF FAULT SEGMENT RUPTURE

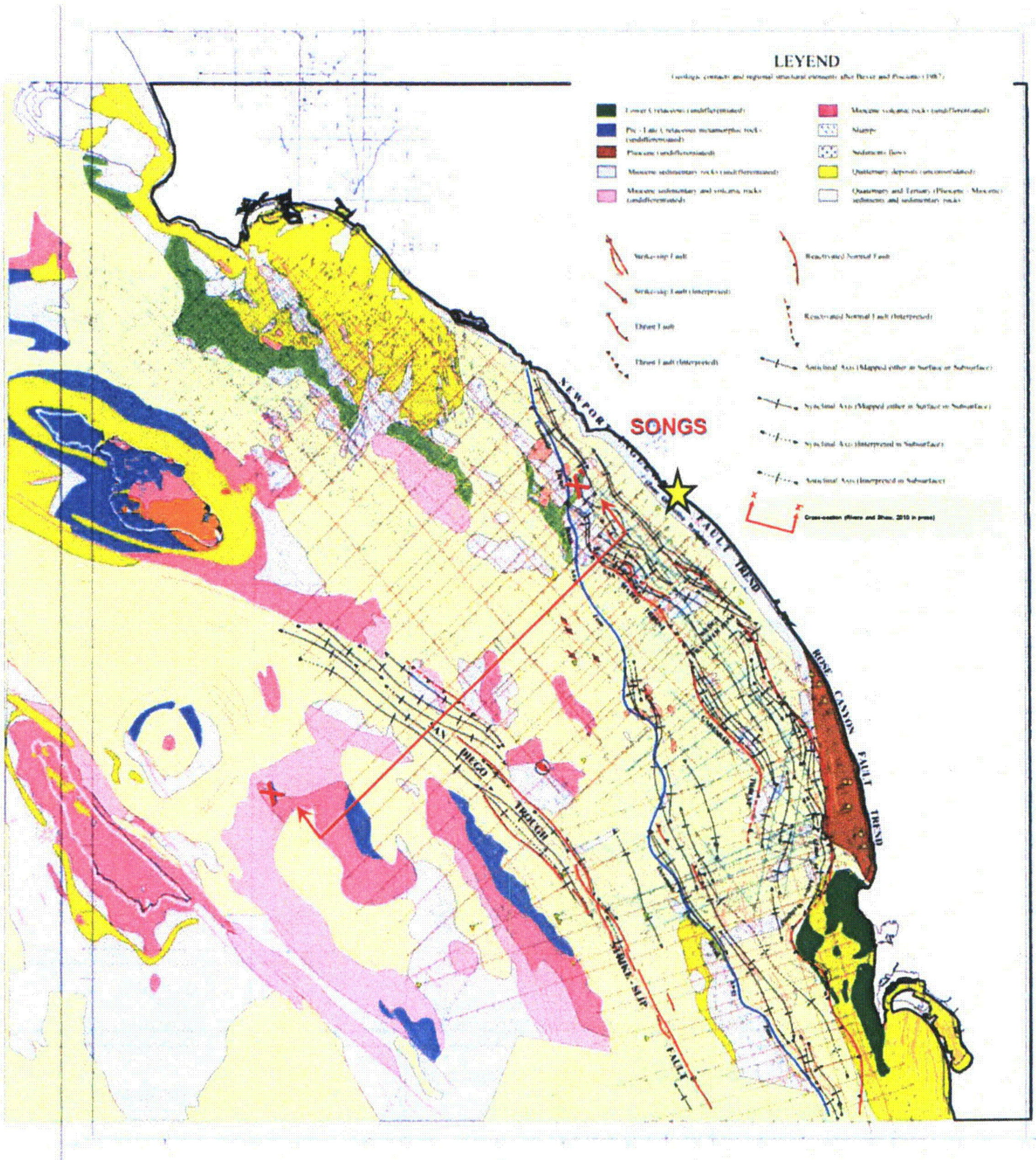
FIGURE 2-5

SAN ONOFRE NUCLEAR GENERATING STATION

SEISMIC HAZARD ASSESSMENT PROGRAM

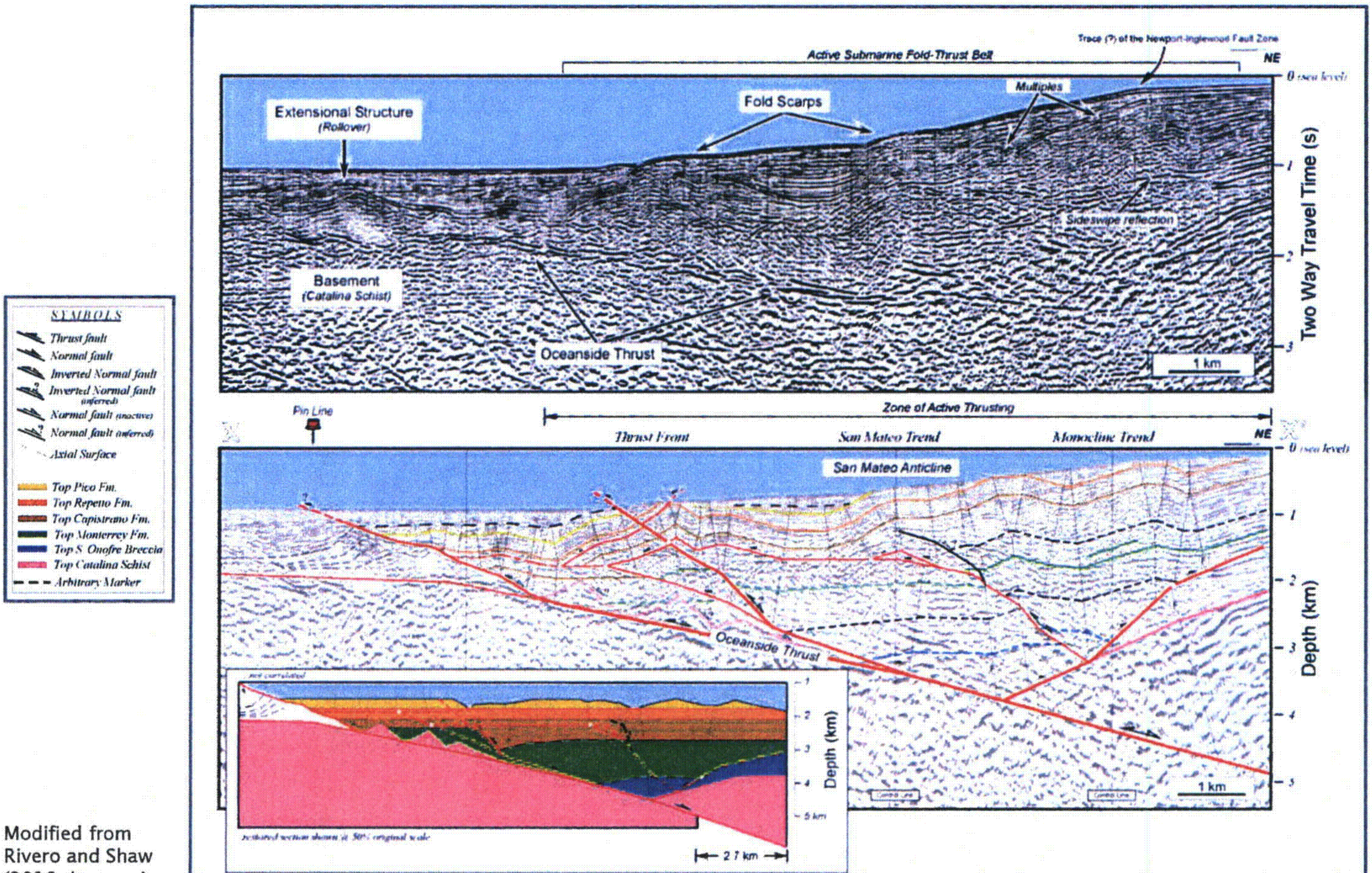
Seismic Reflection Data from Harvard University

Original data compiled from several petroleum industry sources



Modified from Rivero (2004)

GeoPentech	MARINE GEOLOGIC MAP	FIGURE 2-6
	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	



Modified from Rivero and Shaw (2010, in press)

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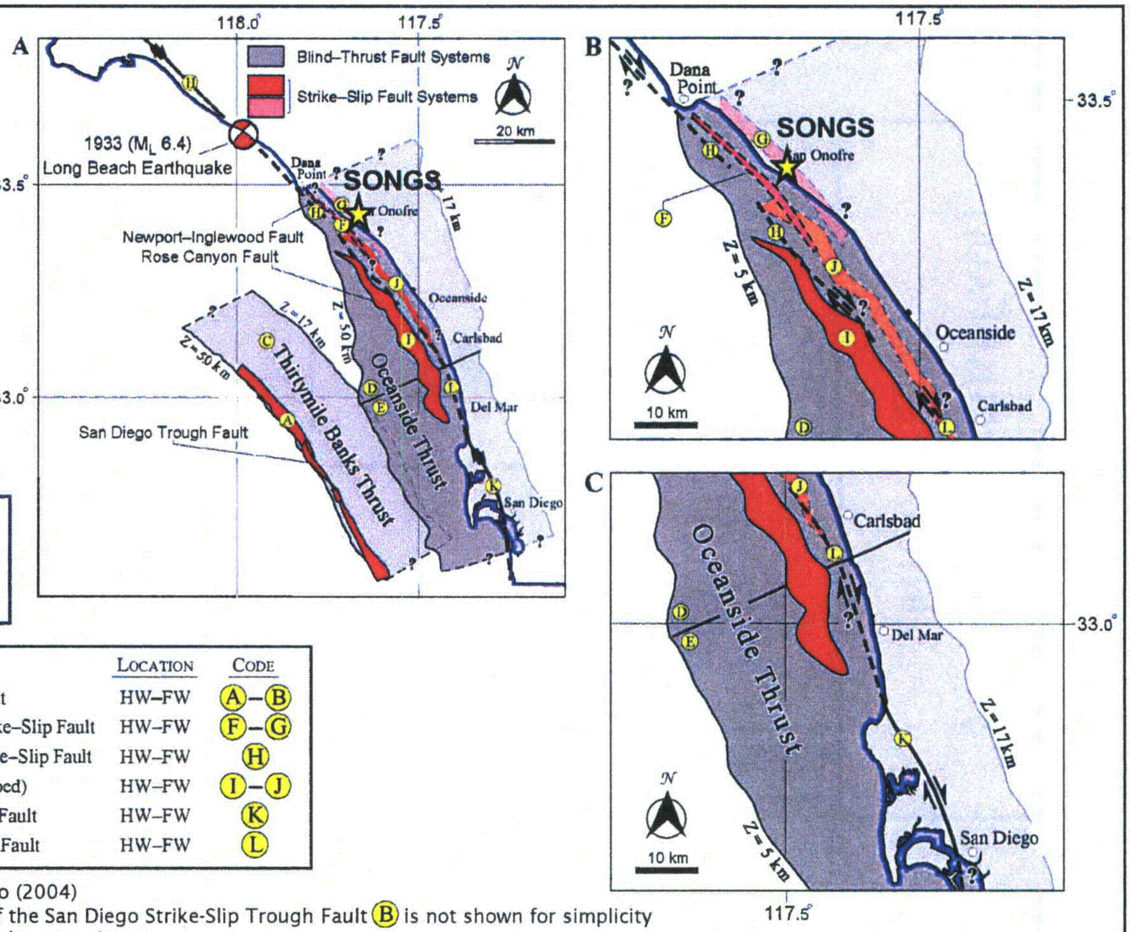
SAN ONOFRE NUCLEAR GENERATING STATION
SEISMIC HAZARD ASSESSMENT PROGRAM

RECORD AND INTERPRETATION

FIGURE 2-7



Thirtymile Banks Thrust		C
Oceanside Thrust:		
North Segment	HW	D
South Segment	FW	E

Fault Segments	Location	Code
San Diego Trough Strike-Slip Fault	HW–FW	A–B
Offshore Newport-Inglewood Strike-Slip Fault	HW–FW	F–G
Onshore Newport-Inglewood Strike-Slip Fault	HW–FW	H
Offshore Rose Canyon Fault (mapped)	HW–FW	I–J
Onshore Rose Canyon Strike-Slip Fault	HW–FW	K
Offshore Rose Canyon Strike-Slip Fault	HW–FW	L

NOTES: (1) Modified from Rivero (2004)
(2) Footwall segment of the San Diego Strike-Slip Trough Fault (B) is not shown for simplicity
(3) Latitude and longitude approximate

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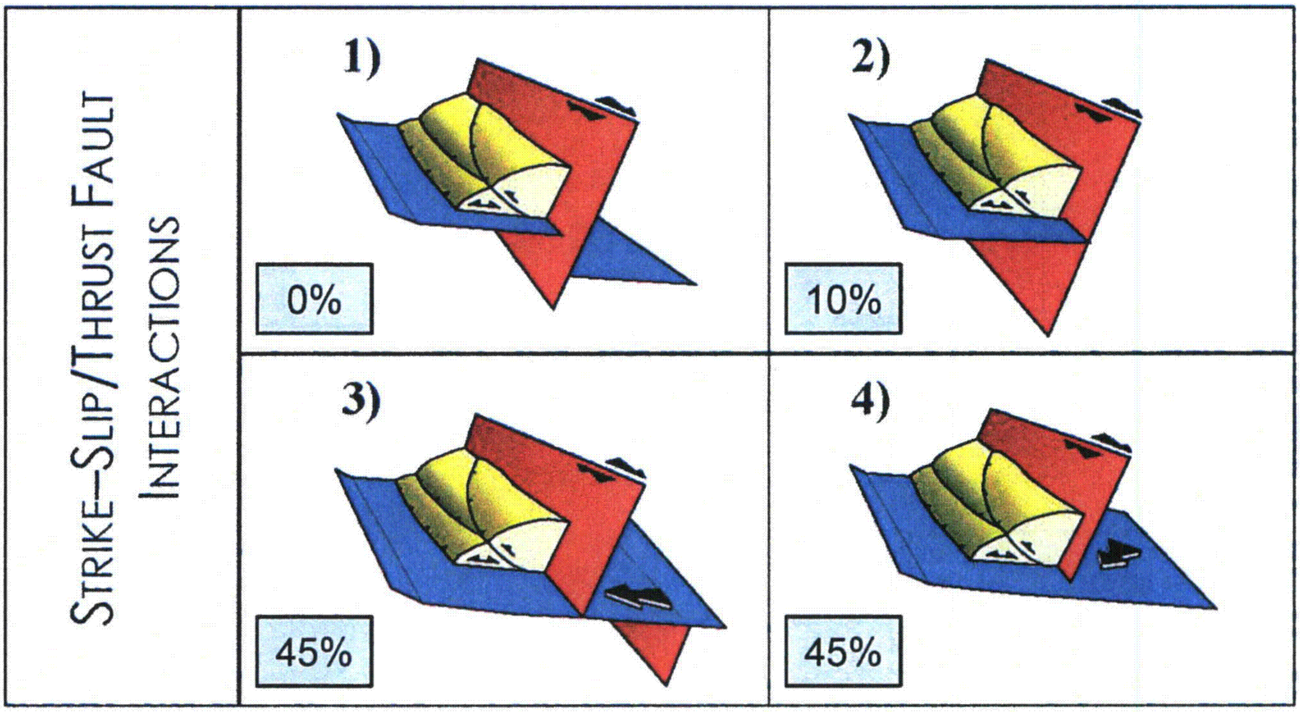
SAN ONOFRE NUCLEAR GENERATING STATION
SEISMIC HAZARD ASSESSMENT PROGRAM

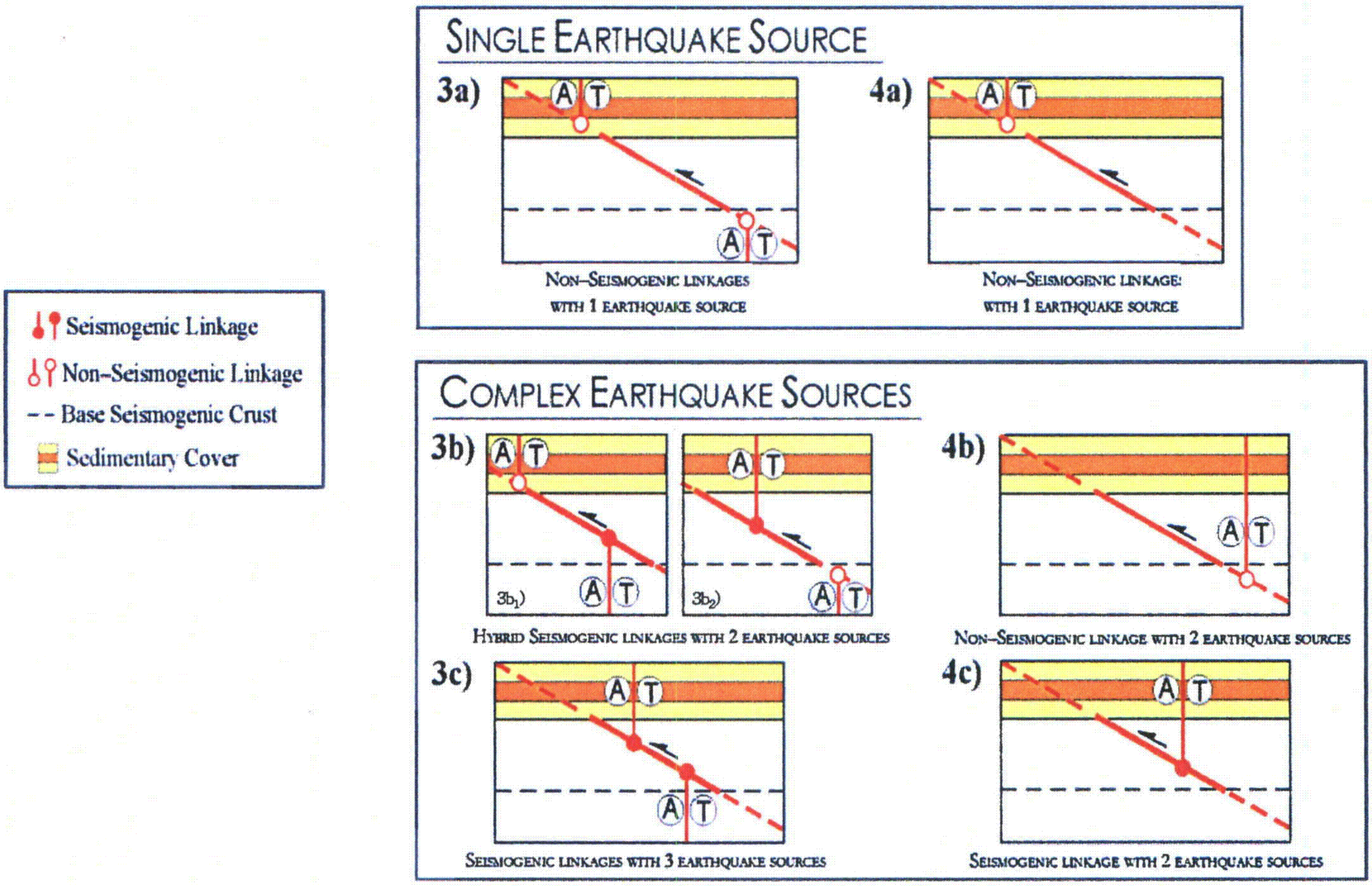
HYPOTHESIZED OBT FAULT SYSTEM

FIGURE 2-8



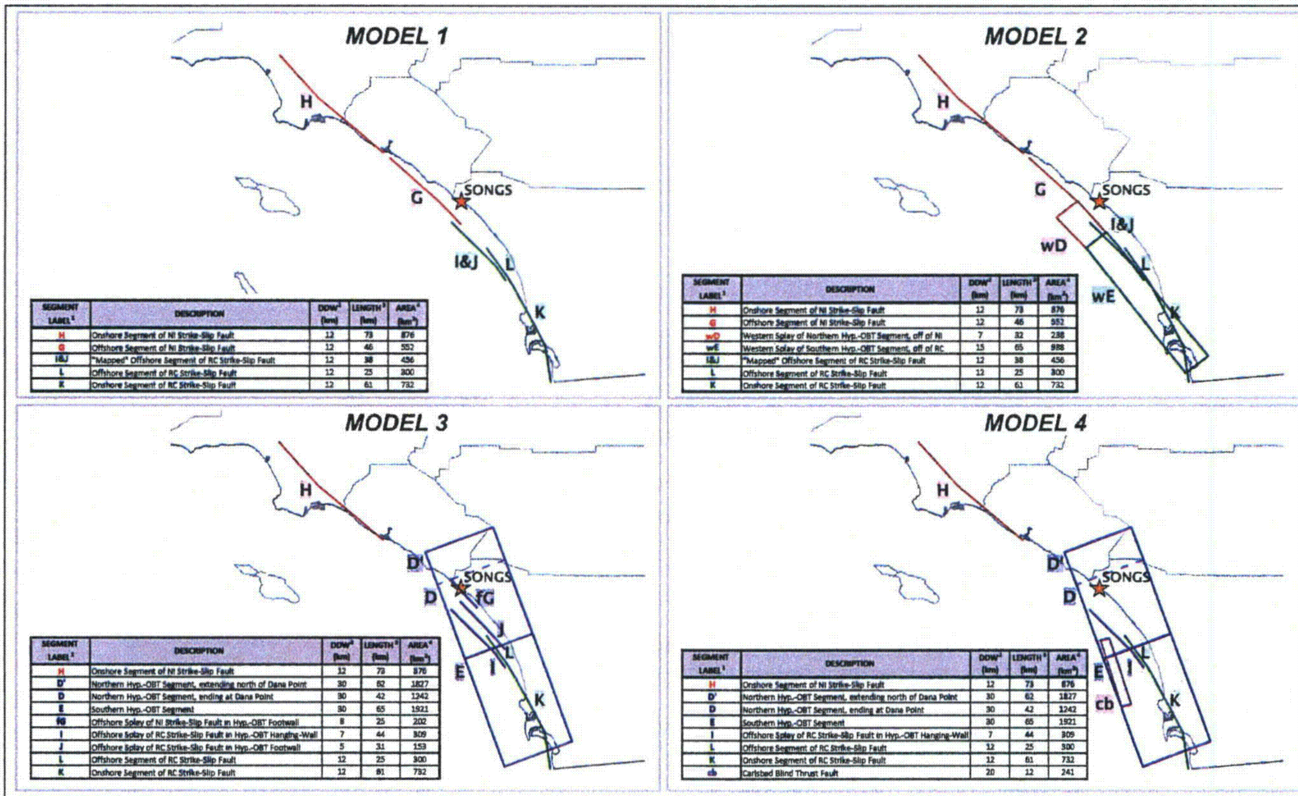
Modified from Rivero (2004)

GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	HYPOTHESIZED OBT FAULT SYSTEM MODEL CONFIGURATIONS WITH EPISTEMIC 'WEIGHTS'	FIGURE 2-9



Modified from Rivero and Shaw (2010, in press)

GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	EPISTEMIC ALTERNATIVES TO HYPOTHESIZED OBT FAULT SYSTEM MODEL CONFIGURATIONS 3 AND 4	FIGURE 2-10



Model 1

SEGMENT LABEL[1]	DESCRIPTION	DDW[2] (km)	LENGTH[3] (km)	AREA[4] (km²)
H	Onshore Segment of NI Strike-Slip Fault	12	73	876
G	Offshore Segment of NI Strike-Slip Fault	12	46	552
I&J	"Mapped" Offshore Segment of RC Strike-Slip Fault	12	38	456
L	Offshore Segment of RC Strike-Slip Fault	12	25	300
K	Onshore Segment of RC Strike-Slip Fault	12	61	732

Model 2

SEGMENT LABEL[1]	DESCRIPTION	DDW[2] (km)	LENGTH[3] (km)	AREA[4] (km²)
H	Onshore Segment of NI Strike-Slip Fault	12	73	876
G	Offshore Segment of NI Strike-Slip Fault	12	46	552
wD	Western Splay of Northern Hyp.-OBT Segment, off of NI	7	32	238
wE	Western Splay of Southern Hyp.-OBT Segment, off of RC	15	65	988
I&J	"Mapped" Offshore Segment of RC Strike-Slip Fault	12	38	456
L	Offshore Segment of RC Strike-Slip Fault	12	25	300
K	Onshore Segment of RC Strike-Slip Fault	12	61	732

Model 3

SEGMENT LABEL[1]	DESCRIPTION	DDW[2] (km)	LENGTH[3] (km)	AREA[4] (km²)
H	Onshore Segment of NI Strike-Slip Fault	12	73	876
D'	Northern Hyp.-OBT Segment, extending north of Dana Point	30	62	1827
D	Northern Hyp.-OBT Segment, ending at Dana Point	30	42	1242
E	Southern Hyp.-OBT Segment	30	65	1921
fG	Offshore Splay of NI Strike-Slip Fault in Hyp.-OBT Footwall	8	25	202
I	Offshore Splay of RC Strike-Slip Fault in Hyp.-OBT Hanging-Wall	7	44	309
J	Offshore Splay of RC Strike-Slip Fault in Hyp.-OBT Footwall	5	31	153
L	Offshore Segment of RC Strike-Slip Fault	12	25	300
K	Onshore Segment of RC Strike-Slip Fault	12	81	732

Model 4

SEGMENT LABEL[1]	DESCRIPTION	DDW[2] (km)	LENGTH[3] (km)	AREA[4] (km²)
H	Onshore Segment of NI Strike-Slip Fault	12	73	876
D'	Northern Hyp.-OBT Segment, extending north of Dana Point	30	62	1827
D	Northern Hyp.-OBT Segment, ending at Dana Point	30	42	1242
E	Southern Hyp.-OBT Segment	30	65	1921
I	Offshore Splay of RC Strike-Slip Fault in Hyp.-OBT Hanging-Wall	7	44	309
L	Offshore Segment of RC Strike-Slip Fault	12	25	300
K	Onshore Segment of RC Strike-Slip Fault	12	61	732
cb	Carlsbad Blind Thrust Fault	20	12	241

Notes:

[1] Labels modified from Figure A-2-1

[2] Assuming 5km to 17km Seismogenic Depth

[3] Based on Rivero (2004)

[4] Calculated based on DDW and Length

[5] See Appendix A, Attachment A-3 for details

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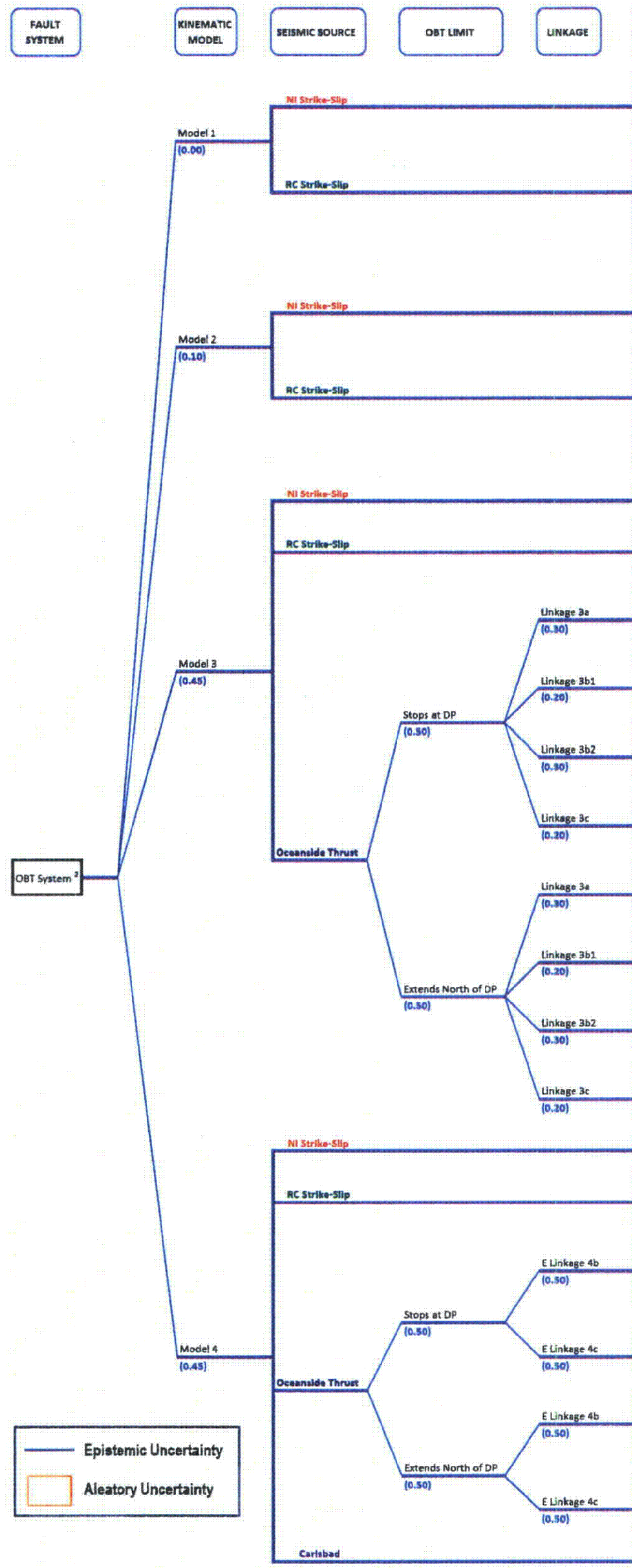
SAN ONOFRE NUCLEAR GENERATING STATION

SEISMIC HAZARD ASSESSMENT PROGRAM

SIMPLIFIED GEOMETRY AND SEGMENTATION FOR OBT FAULT SYSTEM MODEL CONFIGURATIONS

FIGURE 2-11



SEGMENTATION	FAULT SEGMENT COMBINATION	DISTRIBUTION OF SEGMENT RUPTURE	LONG-TERM SLIP RATE (mm/yr)	RECURRENCE MODEL [1]	
Single	G	25%	1.5+/-0.5	Characteristic	Trunc G-R
Single	H	50%	1.0+/-0.5	Characteristic	Trunc G-R
Multi	G + H	25%	1.0+/-0.5	Characteristic	Trunc G-R
Single	I&J	10%	1.07+/-0.03	Characteristic	Trunc G-R
Single	K	20%	1.07+/-0.03	Characteristic	Trunc G-R
Single	L	20%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	I&J + K	10%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	K + L	20%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	I&J + L	10%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	I&J + K + L	10%	1.07+/-0.03	Characteristic	Trunc G-R
Single	G&wD	25%	1.02+/-0.14	Characteristic	Trunc G-R
Single	H	50%	1.0+/-0.5	Characteristic	Trunc G-R
Multi	G&wD + H	25%	1.02+/-0.14	Characteristic	Trunc G-R
Single	I&J&wE	10%	0.82+/-0.12	Characteristic	Trunc G-R
Single	K	20%	1.07+/-0.03	Characteristic	Trunc G-R
Single	L	20%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	I&J&wE + K	10%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	K + L	20%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	I&J&wE + L	10%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	I&J&wE + K + L	10%	0.82+/-0.12	Characteristic	Trunc G-R
Single	H	100%	1.0+/-0.5	Characteristic	Trunc G-R
Single	K	33%	1.07+/-0.03	Characteristic	Trunc G-R
Single	L	33%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	K + L	33%	1.07+/-0.03	Characteristic	Trunc G-R
Single	D	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D + E	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	D&fG	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E&J	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D&fG + E&J	33%	1.74+/-0.2	Characteristic	Trunc G-R
Single	D	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E&I	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D + E&I	33%	1.74+/ 0.2	Characteristic	Trunc G R
Single	D&fG	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E&I&J	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D&fG + E&I&J	33%	1.74+/-0.2	Characteristic	Trunc G-R
Single	D'	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D' + E	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	D'&fG	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E&J	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D'&fG + E&J	33%	1.74+/-0.2	Characteristic	Trunc G-R
Single	D'	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E&I	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D' + E&I	33%	1.74+/-0.2	Characteristic	Trunc G-R
Single	D'&fG	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E&I&J	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D'&fG + E&I&J	33%	1.74+/-0.2	Characteristic	Trunc G-R
Single	H	100%	1.0+/-0.5	Characteristic	Trunc G-R
Single	K	33%	1.07+/-0.03	Characteristic	Trunc G-R
Single	L	33%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	K + L	33%	1.07+/-0.03	Characteristic	Trunc G-R
Single	D	25%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E	25%	0.82+/-0.12	Characteristic	Trunc G-R
Single	I	25%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	D + E	25%	1.02+/-0.14	Characteristic	Trunc G-R
Single	D	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E&I	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D + E&I	33%	1.74+/-0.2	Characteristic	Trunc G-R
Single	D'	25%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E	25%	0.82+/-0.12	Characteristic	Trunc G-R
Single	I	25%	1.07+/-0.03	Characteristic	Trunc G-R
Multi	D' + E	25%	1.02+/-0.14	Characteristic	Trunc G-R
Single	D'	33%	1.02+/-0.14	Characteristic	Trunc G-R
Single	E&I	33%	0.82+/-0.12	Characteristic	Trunc G-R
Multi	D' + E&I	33%	1.74+/-0.2	Characteristic	Trunc G-R
Single	cb	100%	0.25+/-0.08	Characteristic	Trunc G-R

Notes:

[1] Recurrence based on 2/3 Characteristic Model and 1/3 Truncated Gutenberg-Richter Distribution

[2] See Appendix A, Attachment A-3 for details

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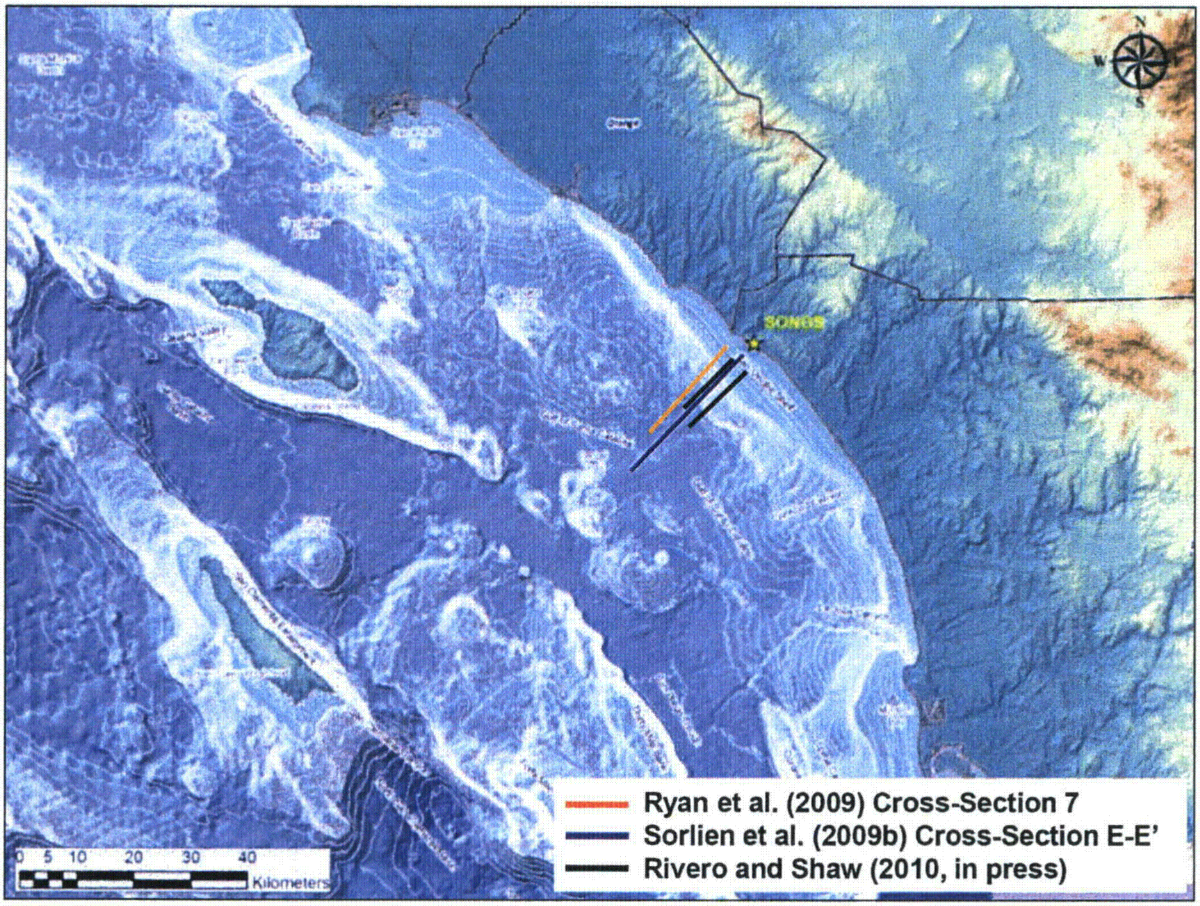
HYPOTHESIZED - OBT 'LOGIC TREE' -
73 COMBINATIONS OF FAULT SEGMENT RUPTURE

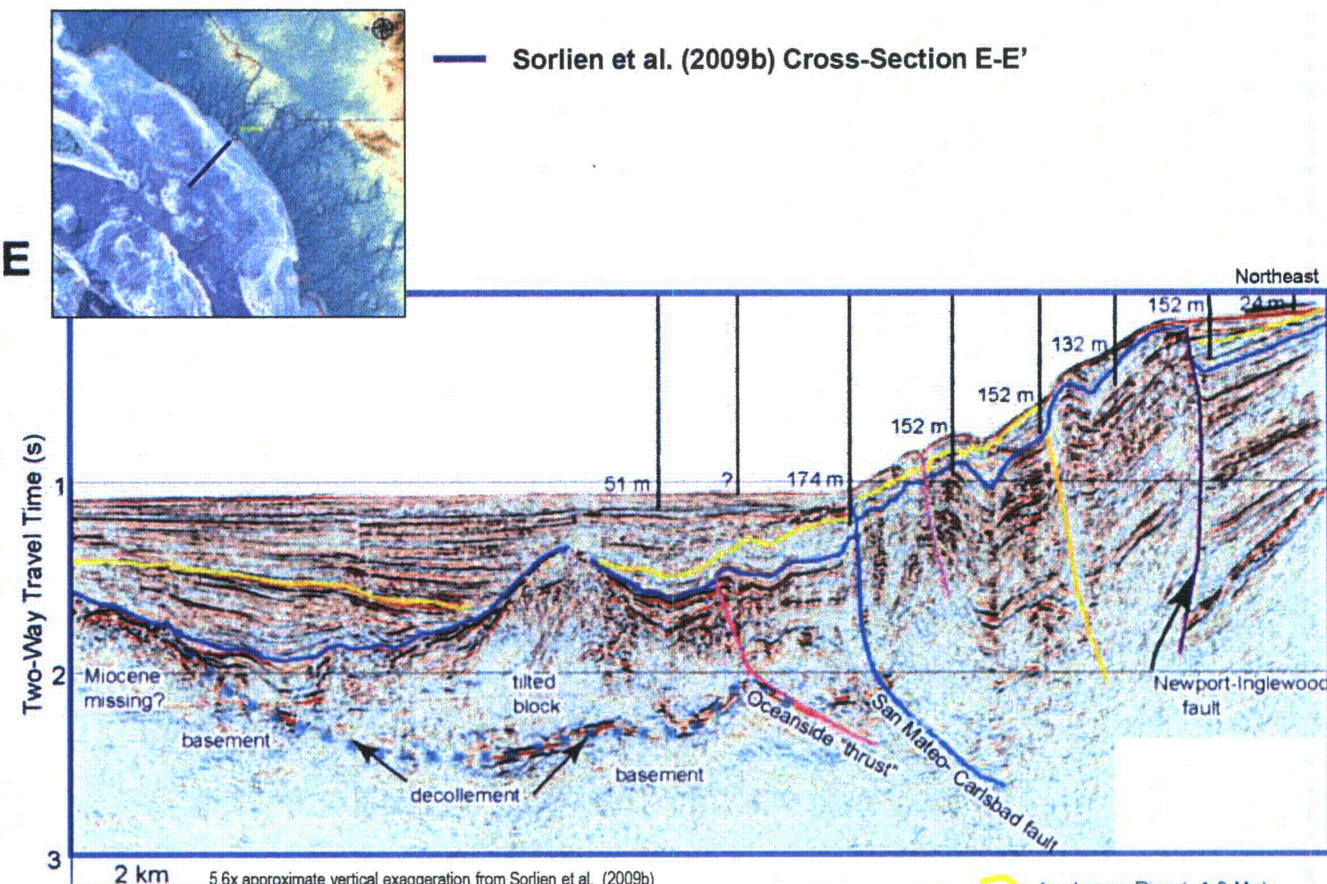
FIGURE
2-12

SAN ONOFRE NUCLEAR GENERATING STATION

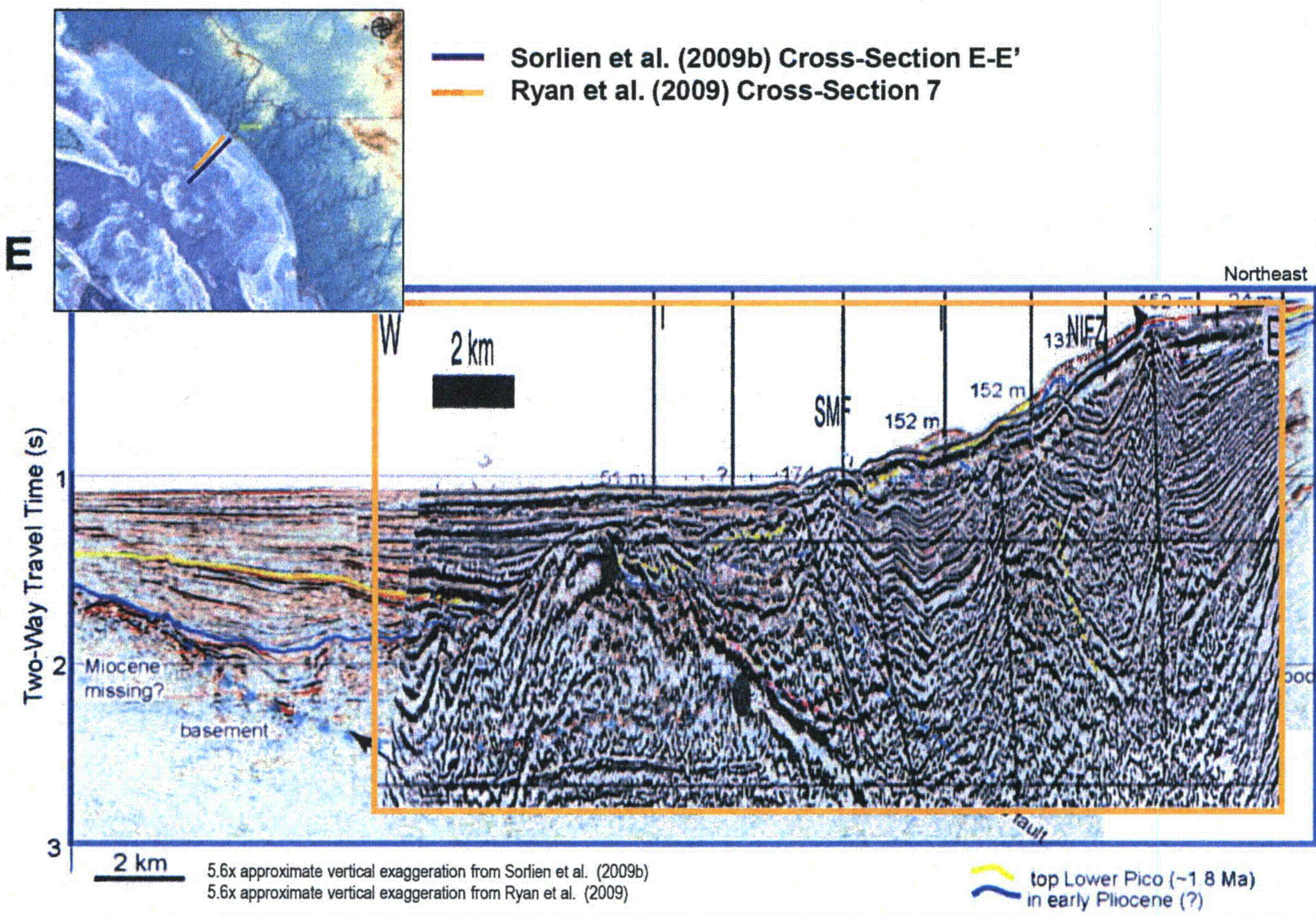
SEISMIC HAZARD ASSESSMENT PROGRAM



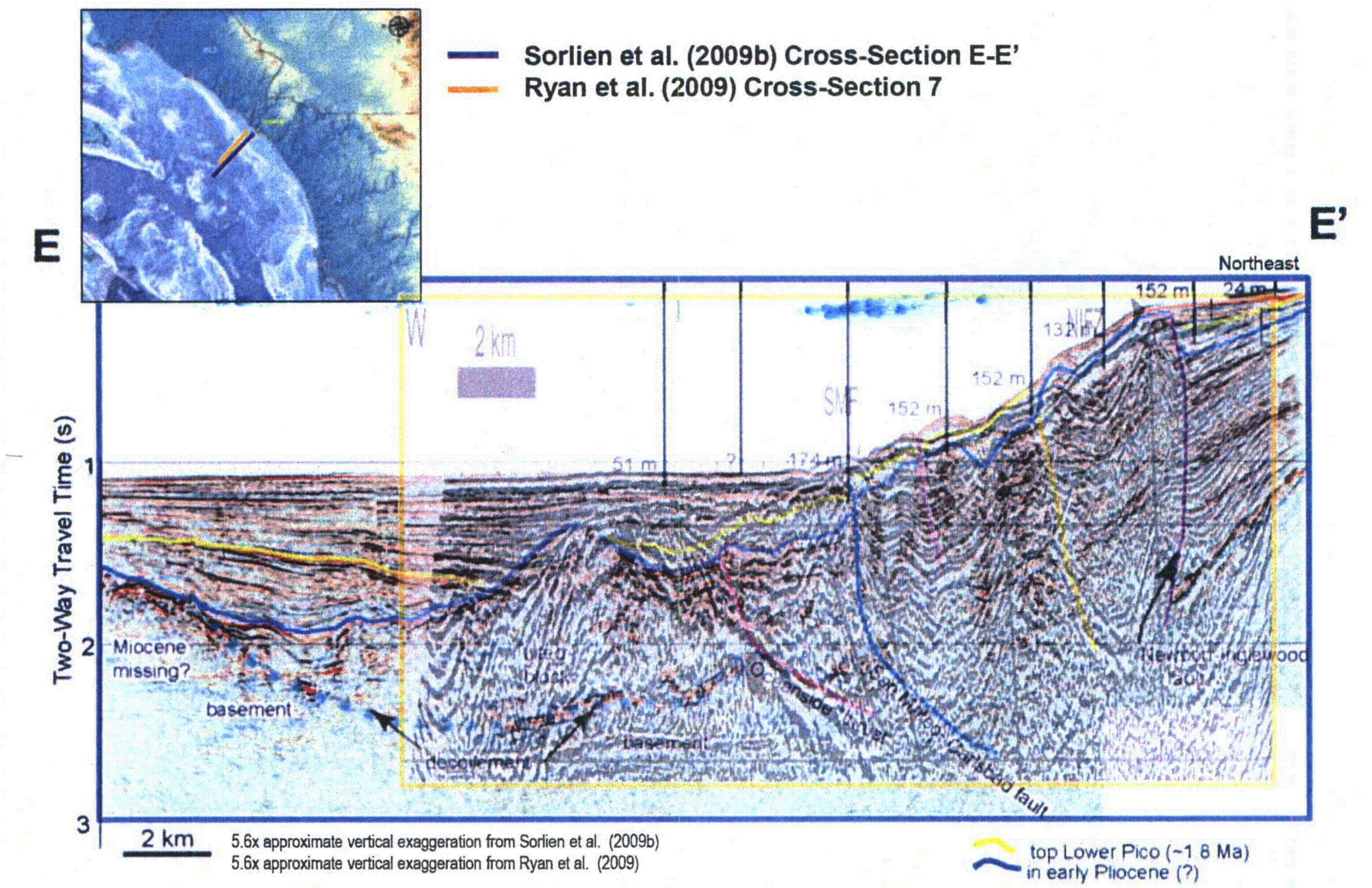
GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	COMPARISON OF SEISMIC REFLECTION LINES	FIGURE 2-13a



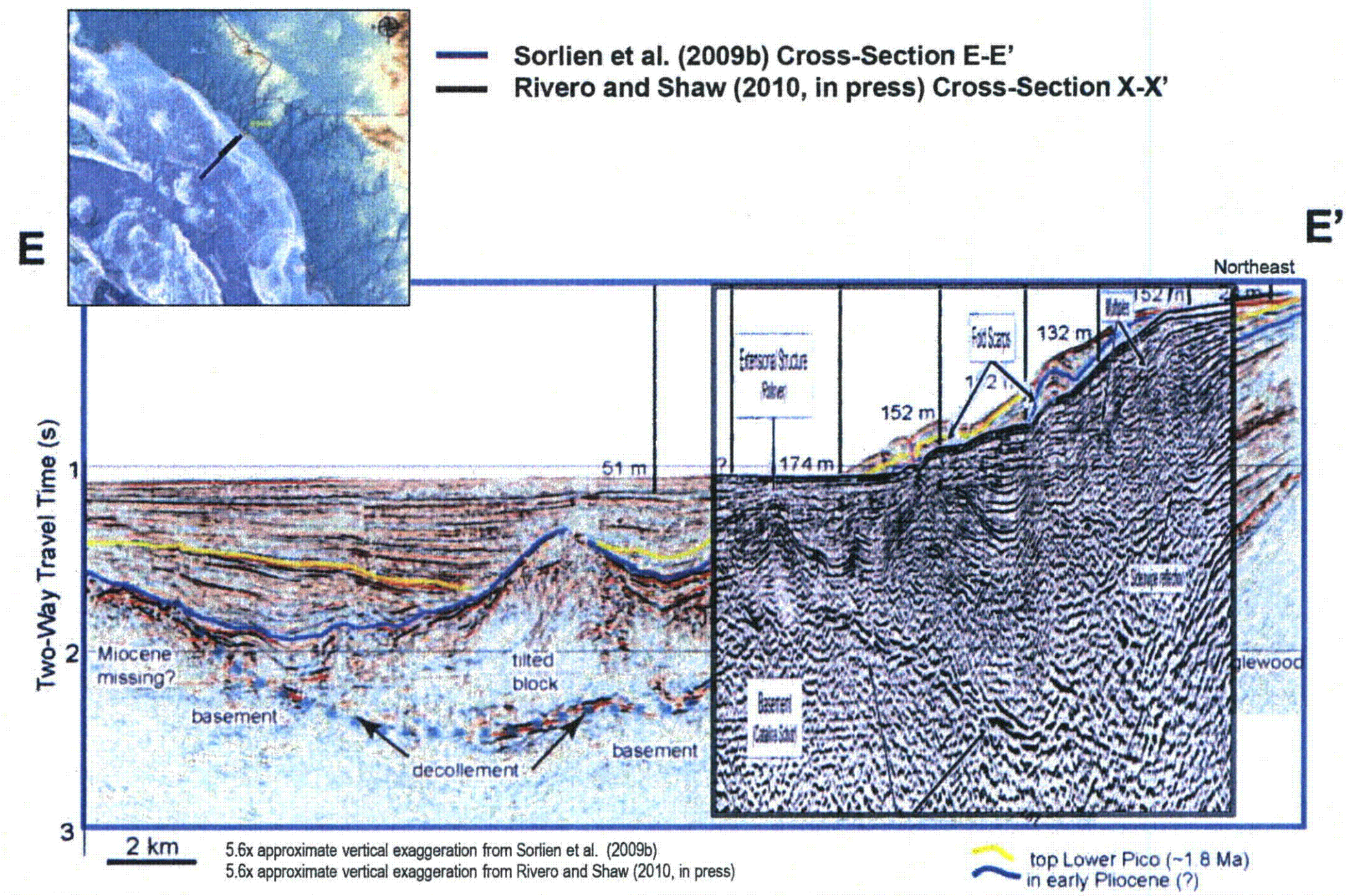
GeoPentech	**SAN ONOFRE NUCLEAR GENERATING STATION** SEISMIC HAZARD ASSESSMENT PROGRAM	**COMPARISON OF SEISMIC REFLECTION LINES**	FIGURE 2-13b



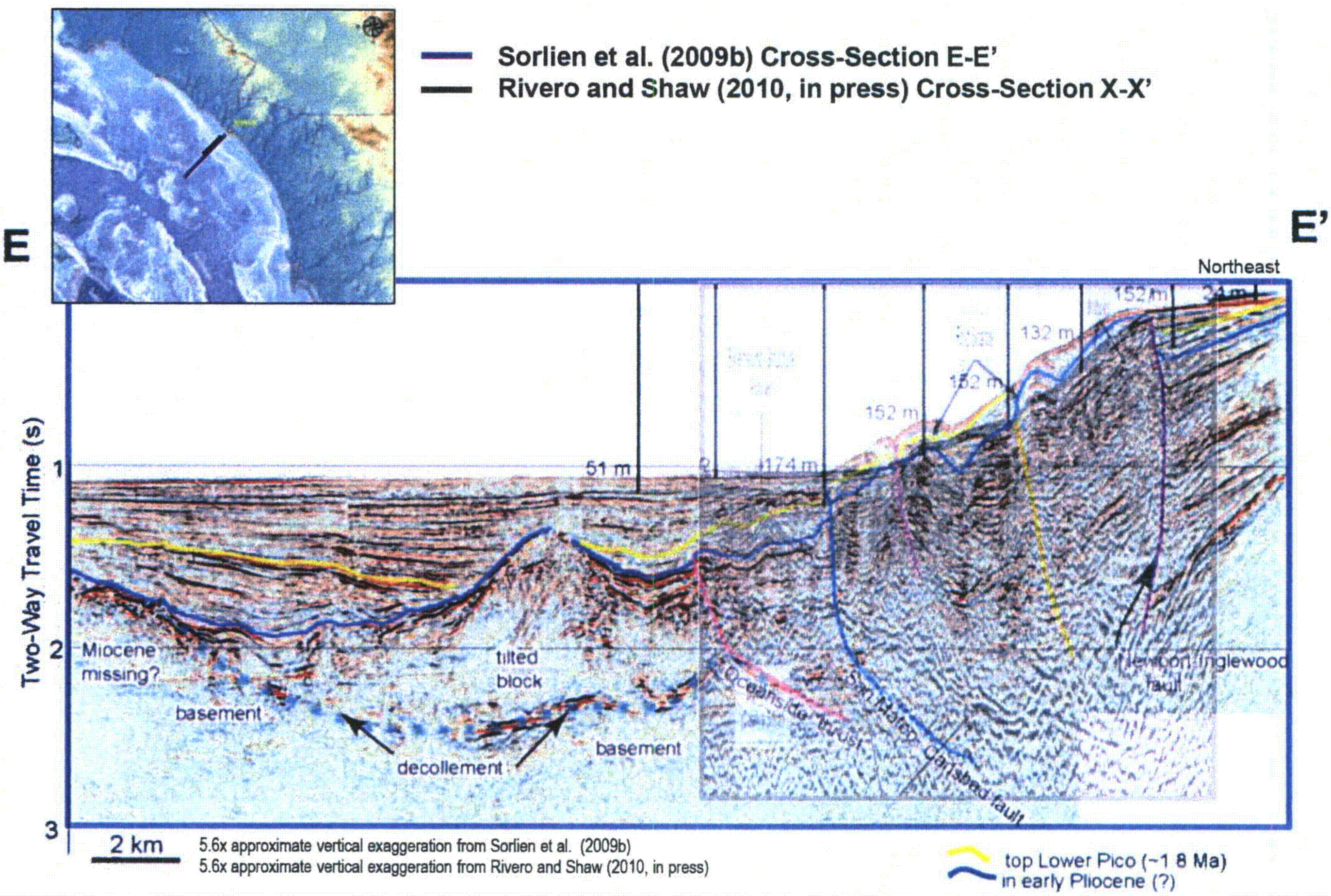
GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	COMPARISON OF SEISMIC REFLECTION LINES	FIGURE 2-13c



GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	COMPARISON OF SEISMIC REFLECTION LINES	FIGURE 2-13d



GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	COMPARISON OF SEISMIC REFLECTION LINES	FIGURE 2-13e



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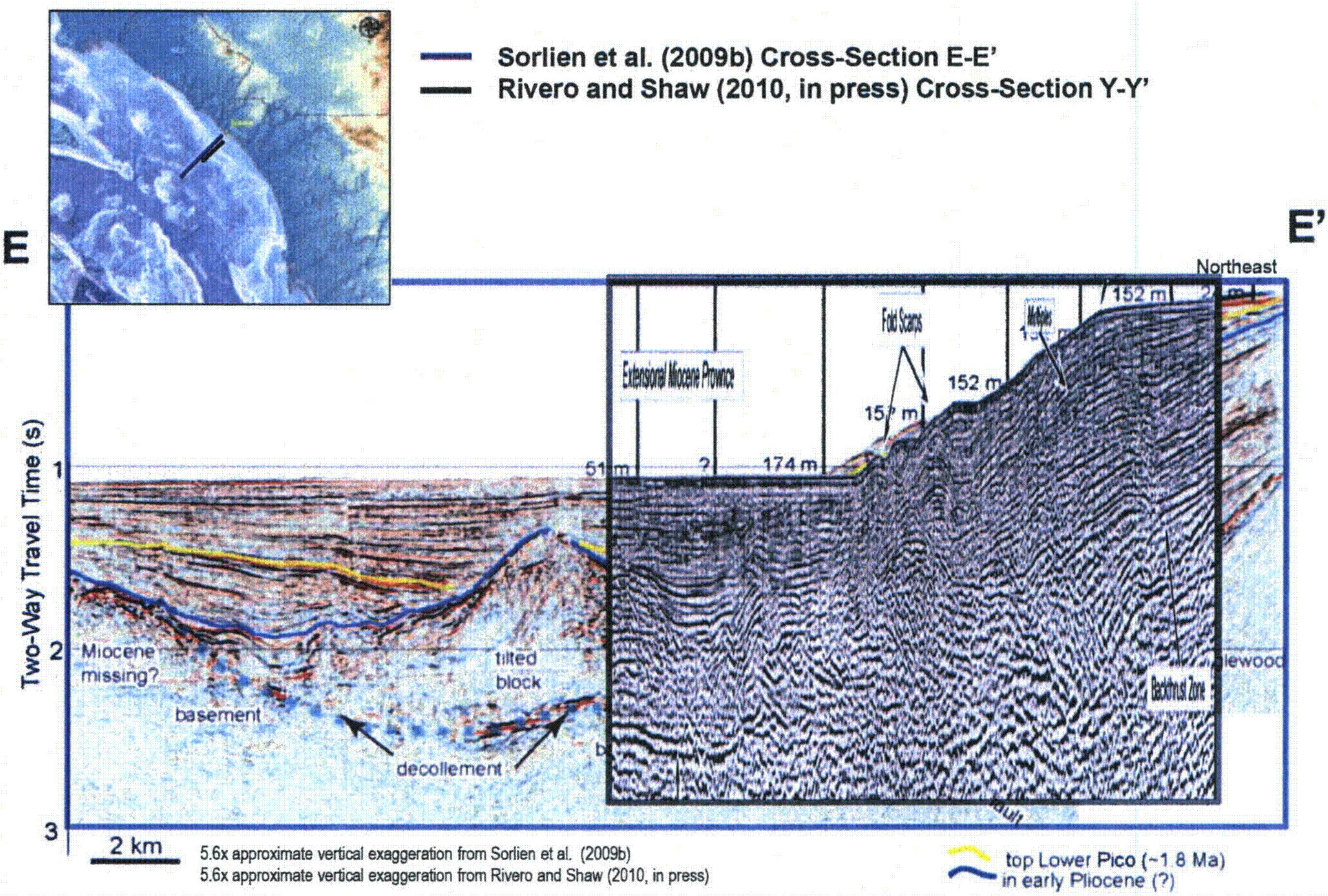
SAN ONOFRE NUCLEAR GENERATING STATION
SEISMIC HAZARD ASSESSMENT PROGRAM

COMPARISON OF SEISMIC REFLECTION LINES

FIGURE 2-13f



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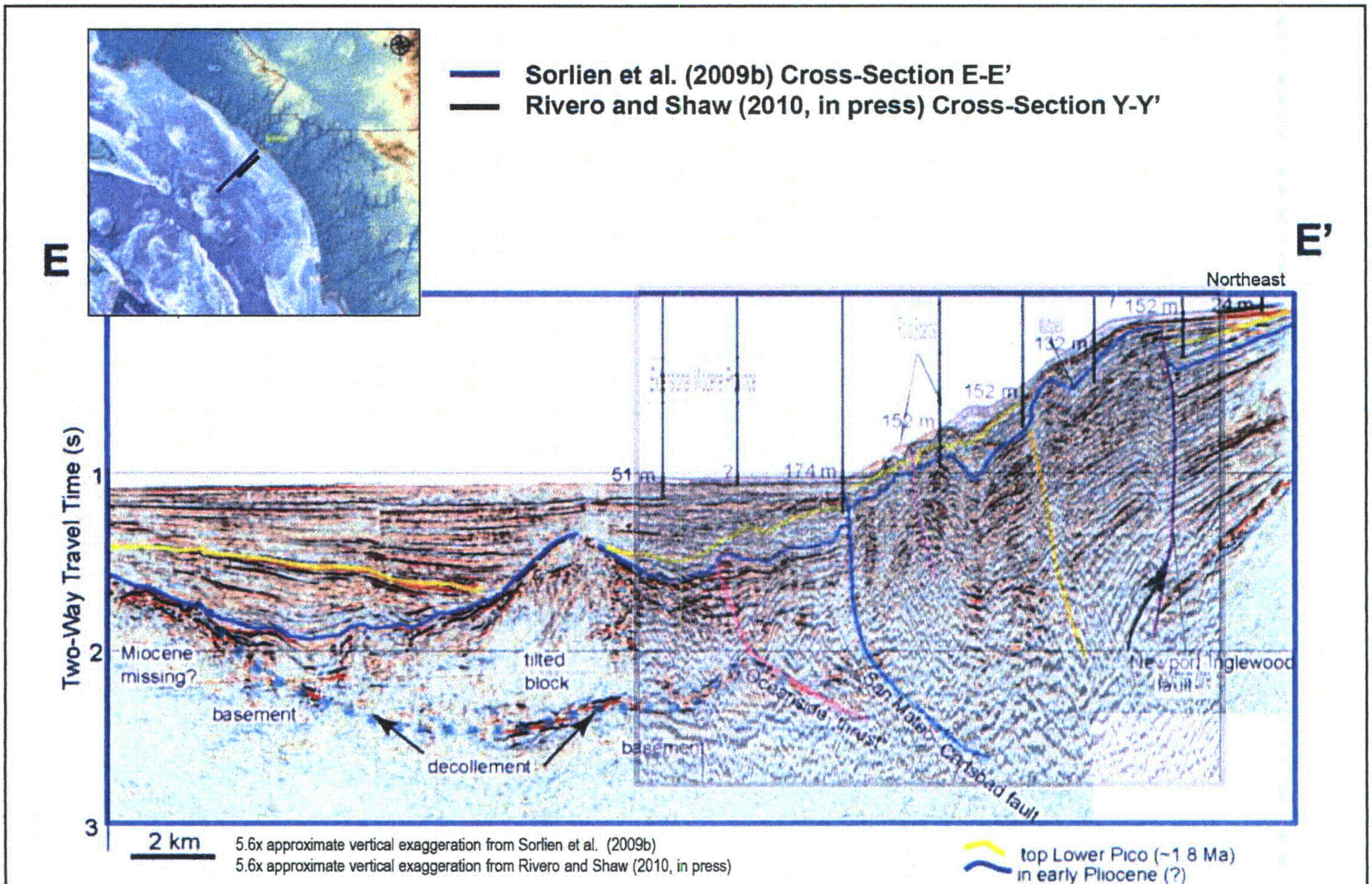
SAN ONOFRE NUCLEAR GENERATING STATION

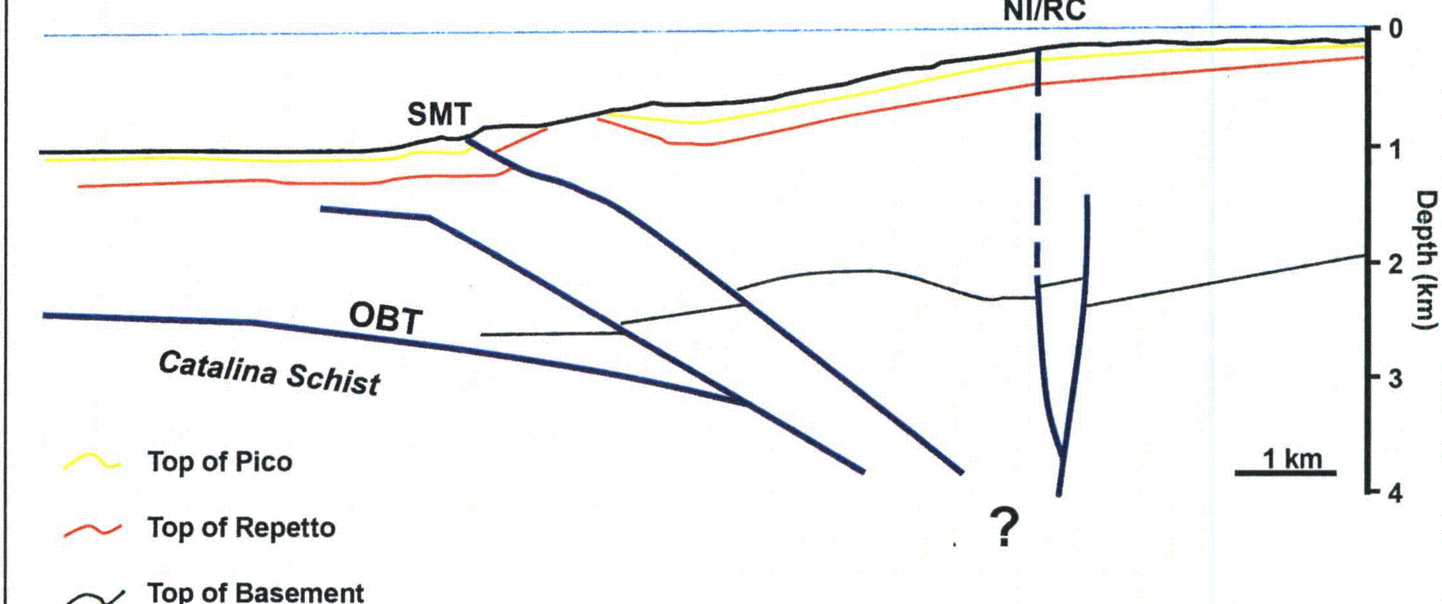
SEISMIC HAZARD ASSESSMENT PROGRAM

COMPARISON OF SEISMIC REFLECTION LINES

FIGURE 2-13g



GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	COMPARISON OF SEISMIC REFLECTION LINES	FIGURE 2-13h



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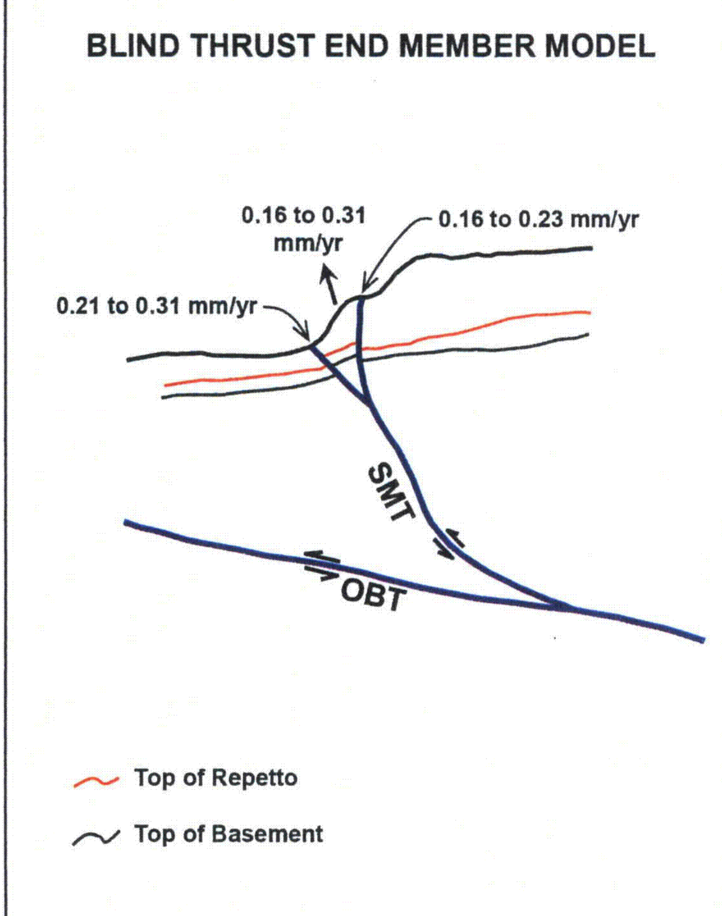
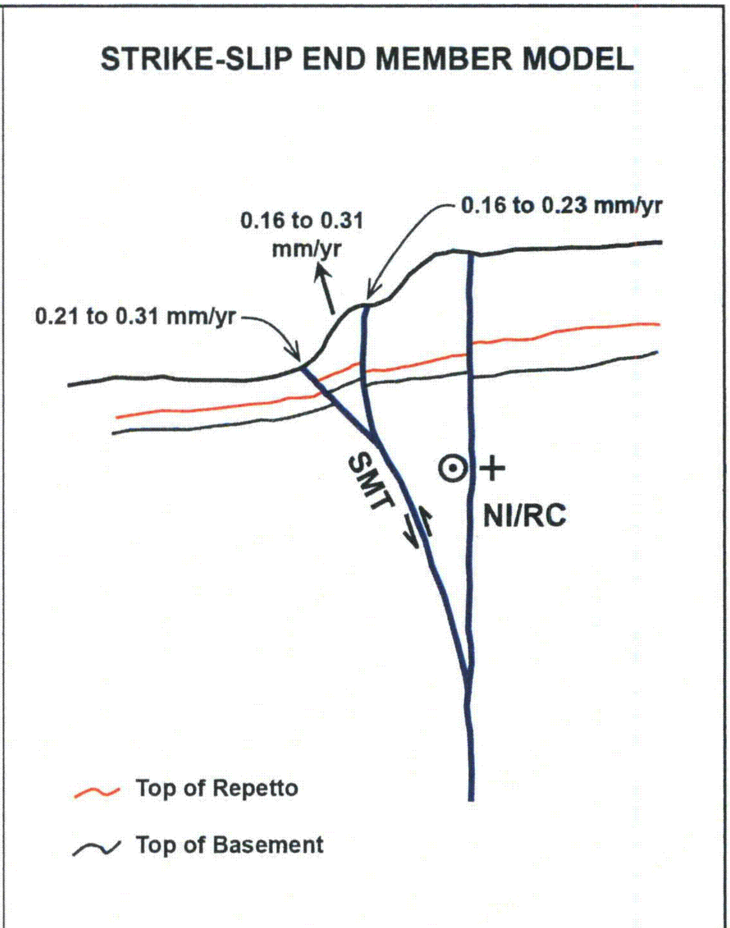
SAN ONOFRE NUCLEAR GENERATING STATION
SEISMIC HAZARD ASSESSMENT PROGRAM

SKETCH OF THE SAN MATEO THRUST, NI/RC FAULT ZONE AND OBT WITH OFFSET STRATIGRAPHY

FIGURE 2-14





GeoPentech	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	SKETCH SHOWING FAULT CONFIGURATIONS AND OFFSET STRATIGRAPHY FOR END MEMBER MODELS	FIGURE 2-15

3.0 PROBABILISTIC SEISMIC HAZARD ANALYSIS

Spectral acceleration values for SONGS were obtained from the PSHA using the seismic sources discussed in Section 2.0. This SONGS 2010 PSHA followed the methods of the 1995 PSHA (SCE, 1995) and the 2001 PSHA (SCE, 2001). The 2001 PSHA results included both response spectral values and time histories, reflecting the effects of near-fault directivity and fling step. Unlike the 2001 PSHA results, the PSHA results reported here focus mainly on high frequency spectral accelerations and do not reflect the effects of near-fault directivity or fling step, which were found to be insignificant for SONGS. Based on the 2001 PSHA, the near-fault directivity and the fling steps only affect the low frequency range below about 1.5 Hertz (Hz), which is outside the frequencies of interest for structures and components at SONGS.

3.1 PSHA Methodology

3.1.1 General

The basic result of PSHA is a relationship between a ground motion parameter "*Z*" (peak ground acceleration [PGA] and spectral acceleration herein) and the mean number of seismic events per year in which "*Z*" at the site exceeds a specified value "*z*". This relationship is called a "hazard curve." The mean number of seismic events per year is referred to as "annual frequency of exceedance" and designated "$\nu(Z \geq z)$". The inverse of this number is called the "return period" (RP) and is expressed in years. Once the relationships between appropriate parameters and annual frequency of exceedance are obtained, various probabilistic calculations can be made assuming a Poisson process. Details of PSHA are available elsewhere (e.g., SSHAC, 1997: http://www.ce.memphis.edu/7137/). Apart from the general discussions below, only the key pertinent topics will be discussed here with some further details presented in Appendix B.

The five major components in PSHA consist of the following:

- Characterization of Seismogenic Sources. The location, geometry, and characteristics of seismic sources (or earthquake generating faults) relative to the site are evaluated and specified. This component is addressed in Section 2.0

- Specification of Recurrence Relationship. In the PSHA, one of the most important characteristics of a seismic source is its recurrence relationship or the relationship showing the annual recurrence of earthquakes of various magnitudes up to the "maximum" magnitude. The recurrence relationship is used to provide the mean number of earthquakes per year having a particular magnitude "m_j" on a given seismic source, "$\dot{N}_s(m_j)$". Two types of recurrence relationships were used: the characteristic and the truncated exponential (Youngs and Coppersmith, 1985). These two recurrence models were selected to be consistent with the UCERF 2 (WGCEP, 2008).

- Evaluation of Probability of Distance to Rupture. Assuming that the typical earthquake generating fault rupture can occur anywhere along the plane of an active fault with an equal probability, the conditional probability is computed so that the rupture plane is at a specified distance, r_k, from the site for the given m_j. This probability is evaluated by considering the rupture plane's dimensions and the distance definition used in the particular attenuation relationship being used.

- Calculation of Exceedance Using Attenuation Equation. The conditional probability that the ground motion parameter "Z" from the earthquake of a certain magnitude "m_j" occurring at a certain distance "r_k" on a particular seismic source fault will exceed a specified level "z" at the site is calculated based on the median and standard deviation of the ground motion given by the attenuation relationship.

- Calculation of Probabilistic Seismic Hazard. By combining the rate of occurrence of earthquakes of a given magnitude with the two conditional probability functions associated with steps 2 through 4 above, for each seismic source fault, the mean number of events per year (annual frequency of exceedance) resulting in "Z" being greater than "z" ($v(Z \geq z)$) at the site is computed for that particular seismic source fault. This process was repeated for each seismic source fault, and the contributions are added to obtain the total seismic hazard at the site for a given z. The complete hazard curve is obtained by repeating these computations for several levels of ground motion parameter z.

Once this mean number of events per year (annual frequency of exceedance) $v(Z \geq z)$ has been determined, the probability of the level of the seismic ground motion parameter being exceeded over a specified time period, t, is calculated by the following equation assuming the Poisson model for the earthquake occurrence:

$$Pr(Z \geq z) = 1 - \exp[-v(Z \geq z) \cdot t] \qquad \textbf{(3-1)}$$

The results of the SONGS 2010 PSHA are presented here in terms of the mean number of events per year or annual frequency of exceedance, $v(Z \geq z)$. The results are presented from an annual frequency of exceedance of 10^{-2} to 10^{-4} corresponding to a RP of 100 to 10,000 years. The computer program Haz4.2 developed by Abrahamson (2010, PC) was used in completing this PSHA. The results of quality assurance/quality control (QA/QC) work performed on the program are summarized in Appendix B.

3.1.2 Attenuation Relationships

The attenuation relationships from the NGA project, which are now called GMPEs, were used in this PSHA and are listed in Table 3-1 along with key parameter values. These attenuation relationships are referred to herein as the "NGA relationships" and consist of the following:

- Abrahamson and Silva (2008)
- Boore and Atkinson (2008)
- Campbell and Bozorgnia (2008)
- Chiou and Youngs (2008)
- Idriss (2008)

Further details of these NGA relationships are provided in Appendix B.

3.1.3 Uncertainties

Two major types of uncertainties are addressed in PSHA. They are as follows:

- Aleatory Uncertainty. Uncertainties in the earthquake recurrence process and in the attenuation of ground motion are the major sources of the aleatory uncertainty in PSHA. This uncertainty is a reflection of the "randomness" inherent to the natural phenomenon of earthquake generation and ground motions. This uncertainty may be based in part on the limited scientific understanding of the natural phenomenon of earthquake generation and seismic wave propagation. This type of uncertainty, in theory, cannot be reduced when additional data or understanding of earthquakes and their effects become available.

- Epistemic Uncertainty. This uncertainty reflects limited available data, limited scientific understanding, and/or limitations in the utility of modeling earthquake and related processes. This type of uncertainty, in theory, can be reduced when additional data or understanding of earthquakes and their effects become available.

The PSHA methodology includes probability models for these two major types of uncertainty. For example, both aleatory uncertainty and epistemic uncertainty are reflected in the logic tree provided for the OBT seismic source fault shown on Figure 2-12 in Section 2.0. Two specific epistemic uncertainties considerations were addressed because of their pertinence to the current PSHA: one is associated with the GMPEs and the other is the NI/RC Fault Zone versus the OBT Fault as the primary seismic source fault.

3.1.3.1 GMPE Uncertainty

In using attenuation relationships, their epistemic uncertainty should be considered. In the past, this epistemic uncertainty was often accommodated by using multiple attenuation relationships. However, given the coordinated process used to develop the NGA relationships, it may not be adequate to address this epistemic uncertainty by just using multiple NGA relationships.

On the basis of the evaluation results presented in Appendix B, an epistemic GMPE uncertainty in addition to the five NGA relationships was used in the current PSHA. This additional uncertainty represents the difference between the GMPE uncertainty that the USGS (2008) is currently using with only three NGA relationships in their seismic hazard mapping program for the building code purposes and the epistemic uncertainty covered by the five NGA relationships and the GMPE uncertainty used in this PSHA.

3.1.3.2 Uncertainty Regarding Strike-slip and Blind Thrust Sources

As discussed in Sections 1 and 2, the seismic sources used in this PSHA consisted of the pertinent time-independent portion of the seismic source fault characterization in UCERF 2 (WGCEP, 2008). For SONGS, the most important seismic source fault in this PSHA's base case set is the NI/RC source, which was also reflected in the 1995 PSHA (SCE, 1995) and a weighted NI/RC and OBT in the 2001 PSHA (SCE, 2001). Since the 2001 PSHA, the OBT has been re-characterized, and new weights have been assigned to the NI/RC (strike-slip) and OBT (blind thrust) models as recommended by the seismic source integration team. Based on the evaluation of the uncertainties associated with both models as discussed in Section 2, the numerically calculated average weights applied to the NI/RC model and the OBT model for use in the PSHA are: 88% and 12% for the strike-slip model and blind thrust end-member models, respectively. The PSHA utilized the above weights applied to the logic trees developed for the NI/RC model as shown on Figure 2-5 and for the OBT as shown on Figure 2-12. These analysis results are, therefore, provided for a single case and referred to as the "2010 PSHA" results.

3.1.3.3 Recurrence Relationships

The recurrence relationships used for the NI/RC source followed UCERF 2 (WGCEP, 2008) and involved using the characteristic recurrence relationship of Youngs and Coppersmith (1985) with a 2/3 weight and the truncated exponential relationship of Molnar (1979) and Anderson (1979) with a 1/3 weight. For the hypothesized OBT source, a comparison of the recurrence model with the available seismicity data presented in Appendix B indicates that using only the characteristic recurrence relationship is more appropriate.

3.2 PSHA Results

The 2010 PSHA results are presented in terms of hazard curves relating spectral acceleration to annual frequency of exceedance on Figure 3-1 for PGA, 25 Hz, 10 Hz, and 5 Hz; similar results are presented on Figure 3-2 for 3.33 Hz, 2.5 Hz, 2 Hz, and 1 Hz. The 2010 PSHA results are also listed in Table 3-2.

3.2.1 Effects of Seismic Sources

The contributions to the total seismic hazard at the SONGS site from various seismic sources are presented for the 2010 PSHA results on Figures 3-3 and 3-4 corresponding to PGA and 1 Hz, respectively.

As shown on Figures 3-3 and 3-4 for the 2010 PSHA results, the NI/RC-OBT source contributes the most to the total hazard for annual frequency of exceedance less than about 10^{-3} for PGA and 1 Hz. For the higher annual frequency of exceedance, the San Jacinto source, the Southern San Andreas source, and, to a lesser degree, the Elsinore source start to contribute more than the NI/RC source.

3.2.2 Deaggregation Results

Figure 3-5 shows the results of deaggregation for the 2010 PSHA results for a RP of 475 years at PGA and 1 Hz; similarly, Figure 3-6 shows the results of deaggregation for a RP of 2,475 years at PGA and 1 Hz. The RP values of 475 and 2,475 years were selected to correspond to numbers often used in current building codes. For the 2010 PSHA results at 475 year RP, the PGA shaking at SONGS is primarily associated with the NI/RC-OBT source with moment magnitude falling in the 6.5 to 7.5 bin at a distance falling in the 5 to 10 km bin, whereas the 1 Hz shaking is somewhat more controlled by the San Jacinto, South San Andreas, and Elsinore faults with moment magnitude falling in the 7 to 8 bin at a distance falling in the 30 to 100 km bin. At 2,475 year RP, however, the ground motion at the SONGS site is dominated by the NI/RC-OBT source with moment magnitude falling in the 6.5 to 7.5 bin at a distance falling in the 5 to 10 km bin.

3.2.3 Comparison with 1995 PSHA Results

The "weighted hazard curve," presented previously (SCE, 1995 and 2001), shows the relationship between the weighted spectral acceleration values and annual frequency of exceedance. At each annual frequency of exceedance value evaluated, the weighted spectral values were obtained as follows: spectral accelerations at frequencies 1 Hz and 10 Hz are multiplied by ½ and added to the sum of spectral accelerations at frequencies 5 Hz and 2.5 Hz with the resulting sum divided by 3.

The weighted hazard curves corresponding to the 2010 PSHA and 1995 PSHA results are presented on Figure 3-7. The results shown on Figure 3-7 indicate that the 2010 PSHA results are lower compared to the 1995 PSHA results throughout the range shown. These weighted hazard curves are also tabulated in Table 3-3.

Table 3-1: NGA Relationships and Related Parameters used in PSHA

NGA	Epistemic Weight	Subsurface Parameters†		
		V_{s30}*	$Z_{1.0\text{-km/s}}$**	$Z_{2.5\text{-km/s}}$***
Abrahamson & Silva (2008)	0.20	500-m/s****	0.31-km	3.35-km
Boore & Atkinson (2008)	0.20			
Campbell & Bozorgnia (2008)	0.20			
Chiou & Youngs (2008)	0.20			
Idriss (2008)	0.20			

Notes:

† Used as needed in each NGA relationship.
* V_{s30} is the average shear wave velocity in the upper 30 meters of a soil profile.
** $Z_{1.0\text{-km/s}}$ is the depth at which the shear wave velocity is 1.0 kilometers per second (km/s).
*** $Z_{2.5\text{-km/s}}$ is the depth at which the shear wave velocity is 2.5 km/s.
**** m/s is meters per second.

Table 3-2: Mean Horizontal Ground Motions (g) at Various Frequencies of Exceedance for 2010 PSHA

Annual Frequency of Exceedance	Average Return Period	Spectral Acceleration - g*								
		PGA	25-Hz	10-Hz	5-Hz	3.33-Hz	2.5-Hz	2-Hz	1-Hz	Weighted**
1.00E-04	10,000	0.778	0.936	1.489	1.895	1.832	1.673	1.456	0.852	1.579
2.00E-04	5,000	0.618	0.736	1.178	1.477	1.413	1.284	1.131	0.661	1.227
5.00E-04	2,000	0.430	0.510	0.813	1.019	0.970	0.875	0.776	0.463	0.844
1.00E-03	1,000	0.318	0.372	0.593	0.746	0.716	0.638	0.576	0.353	0.619
2.00E-03	500	0.233	0.269	0.426	0.542	0.525	0.476	0.422	0.266	0.455
5.00E-03	200	0.152	0.176	0.272	0.356	0.348	0.314	0.280	0.176	0.298
1.00E-02	100	0.108	0.124	0.191	0.251	0.248	0.223	0.198	0.123	0.211
2.11E-03	475	0.227	0.263	0.415	0.530	0.515	0.464	0.413	0.261	0.444
4.04E-04	2,475	0.472	0.554	0.895	1.111	1.056	0.949	0.849	0.501	0.920

Notes: * Spectral Accelerations were interpolated at the provided annual frequencies of exceedance

** Weighted Spectral Acceleration (Sa) is determined as follows:

Weighted Sa = $(0.5*Sa_{10\text{-}Hz} + Sa_{5\text{-}Hz} + Sa_{2.5\text{-}Hz} + 0.5*Sa_{1\text{-}Hz})/3$

where $Sa_{x\text{-}Hz}$ is the spectral acceleration at x-Hz

Table 3-3: Comparison of Weighted Hazard Curves 2010 PSHA and 1995 PSHA

Annual Frequency of Exceedance*	Average Return Period	Weighted Spectral Acceleration – g**	
		2010 PSHA	1995 PSHA***
1.00E-04	10,000	1.579	1.656
2.00E-04	5,000	1.227	1.407
5.00E-04	2,000	0.844	1.015
1.00E-03	1,000	0.619	0.884
2.00E-03	500	0.455	0.675
5.00E-03	200	0.298	0.430
1.00E-02	100	0.211	0.310
2.11E-03	475	0.444	0.655
4.04E-04	2,475	0.920	1.077

Notes:

* Spectral Accelerations were interpolated at the provided annual frequencies of exceedance

** Weighted Spectral Acceleration (Sa) is determined as follows:

$$\text{Weighted } Sa = (0.5*Sa_{10\text{-}Hz} + Sa_{5\text{-}Hz} + Sa_{2.5\text{-}Hz} + 0.5*Sa_{1\text{-}Hz})/3$$

where $Sa_{x\text{-}Hz}$ is the spectral acceleration at x-Hz

*** Spectral Acceleration not calculated for annual frequency of exceedance greater than 1.00E-02 in 1995 results.

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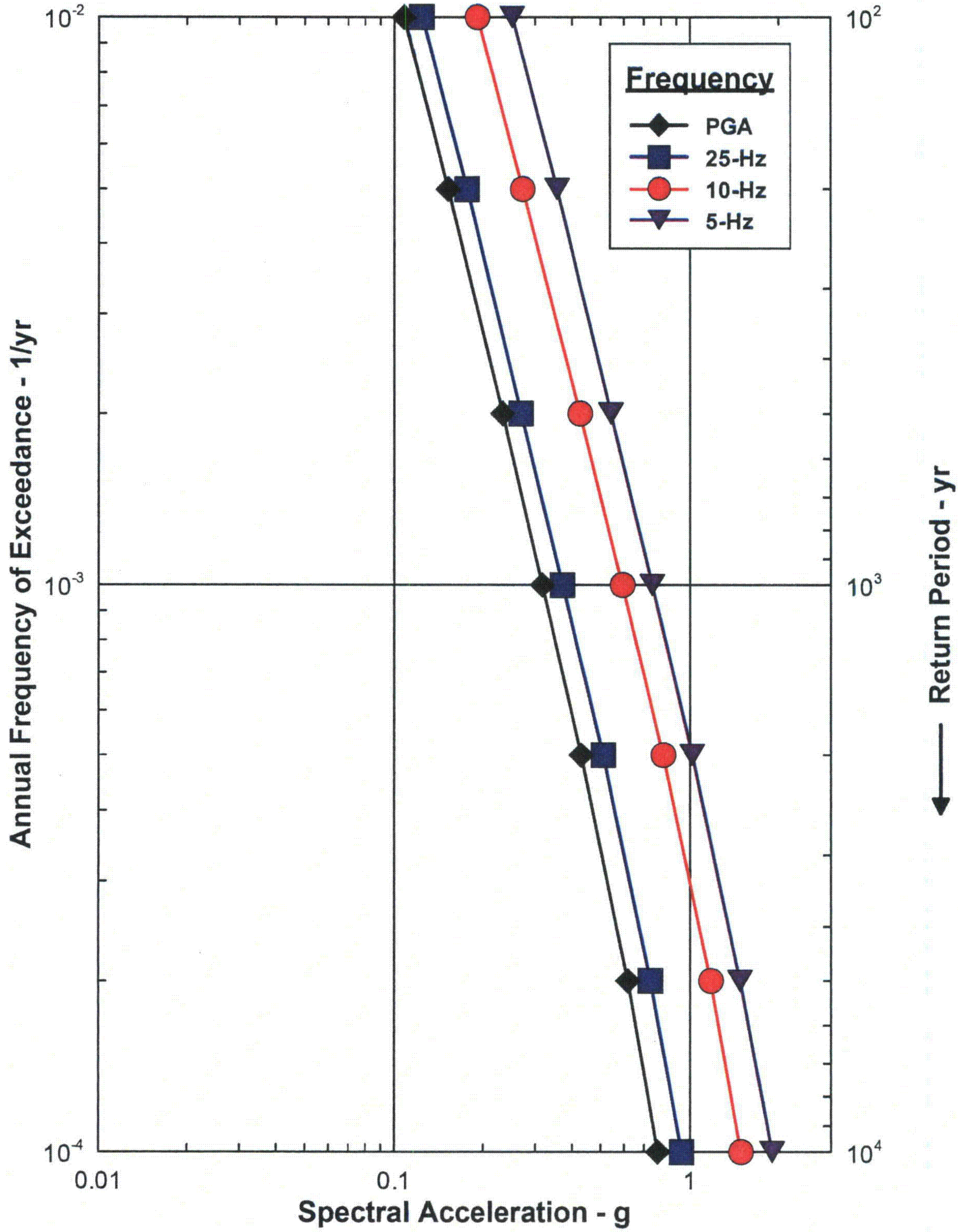
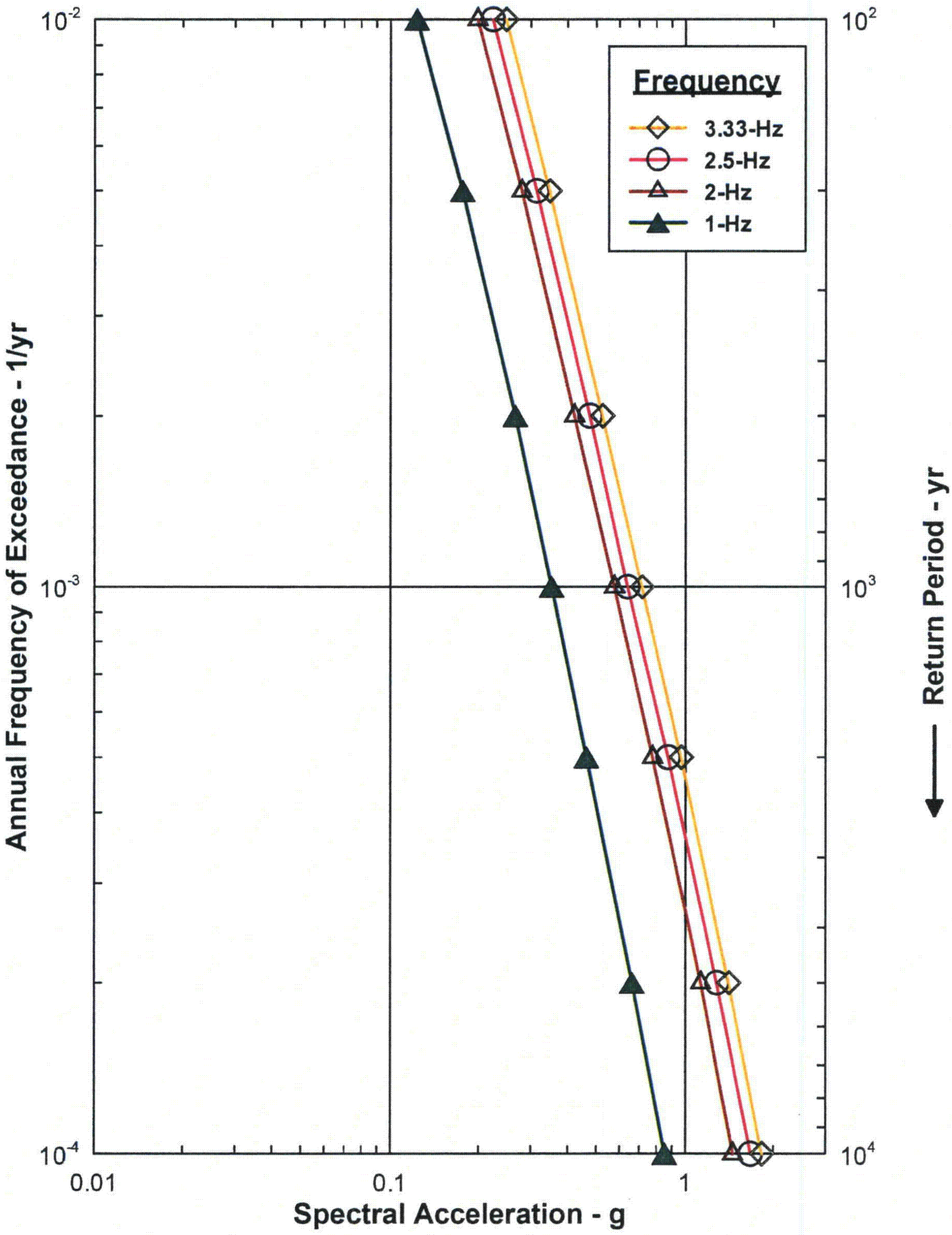


GeoPentech Geotechnical & Geoscience Consultants	2010 PSHA HAZARD CURVES	FIGURE 3-1
	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	



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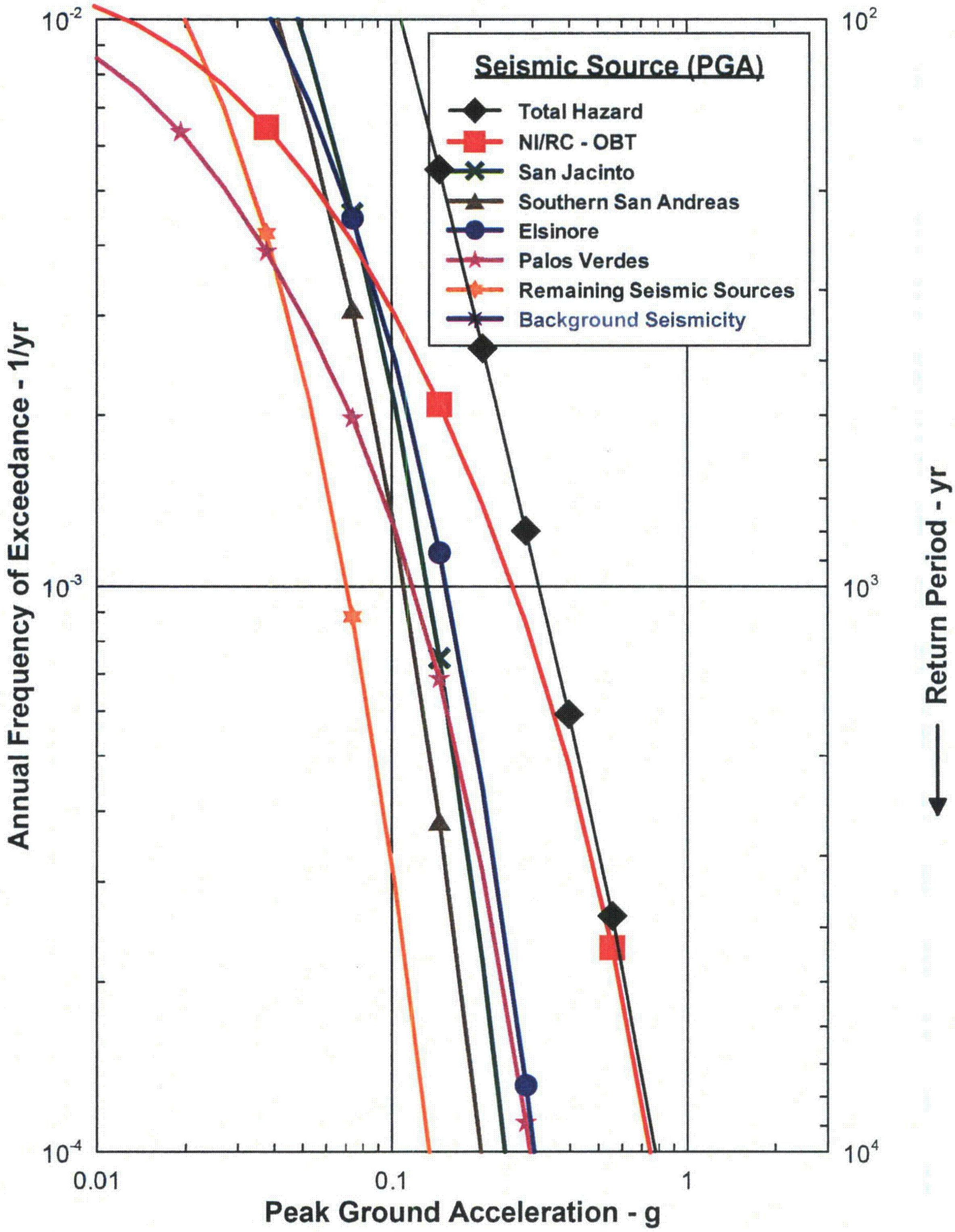
Geotechnical & Geoscience Consultants

2010 PSHA HAZARD CURVES

FIGURE 3-2

SAN ONOFRE NUCLEAR GENERATING STATION

SEISMIC HAZARD ASSESSMENT PROGRAM



GeoPentech Geotechnical & Geoscience Consultants	2010 PSHA - PGA SEISMIC SOURCE CONTRIBUTIONS	FIGURE 3-3
	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	

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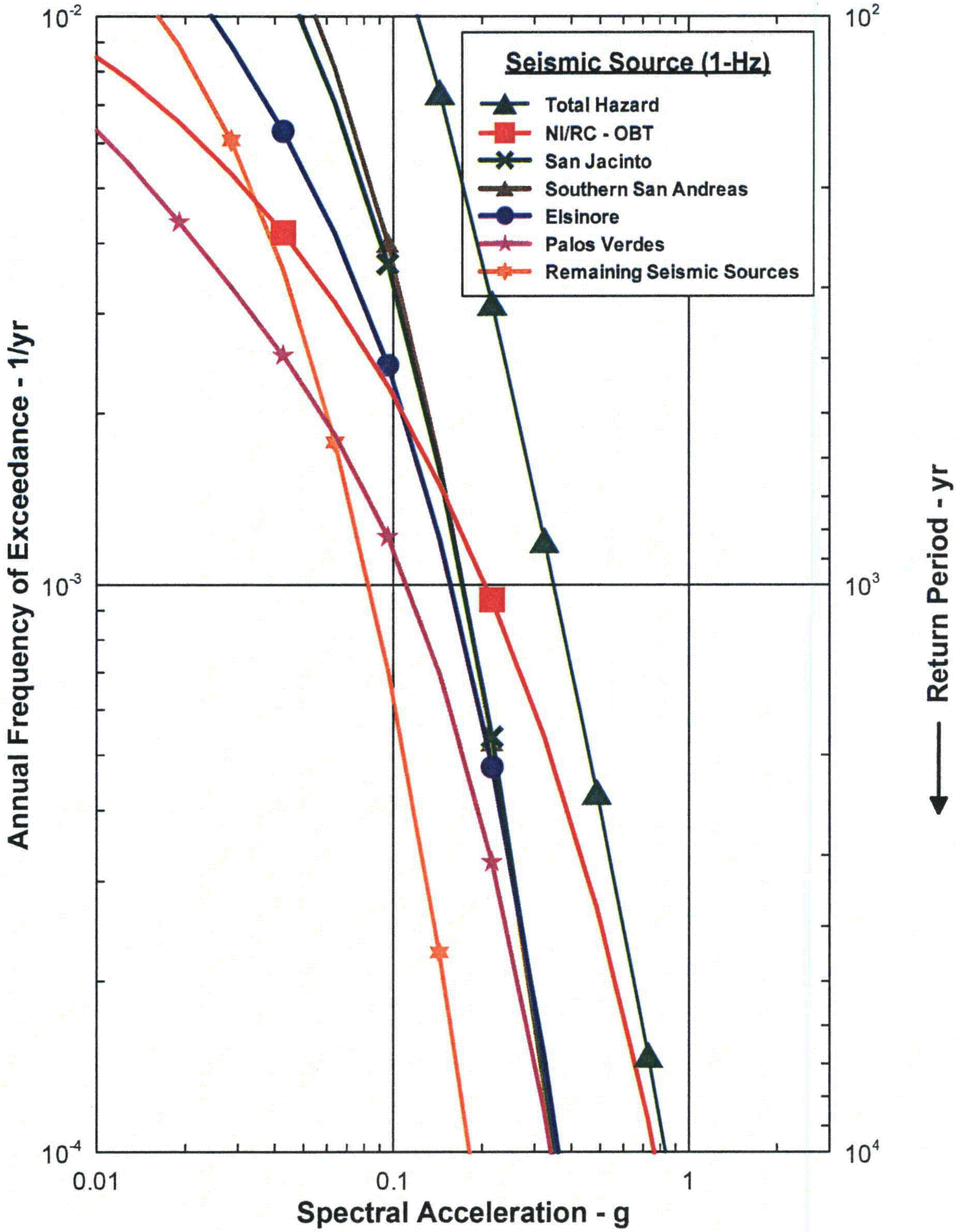
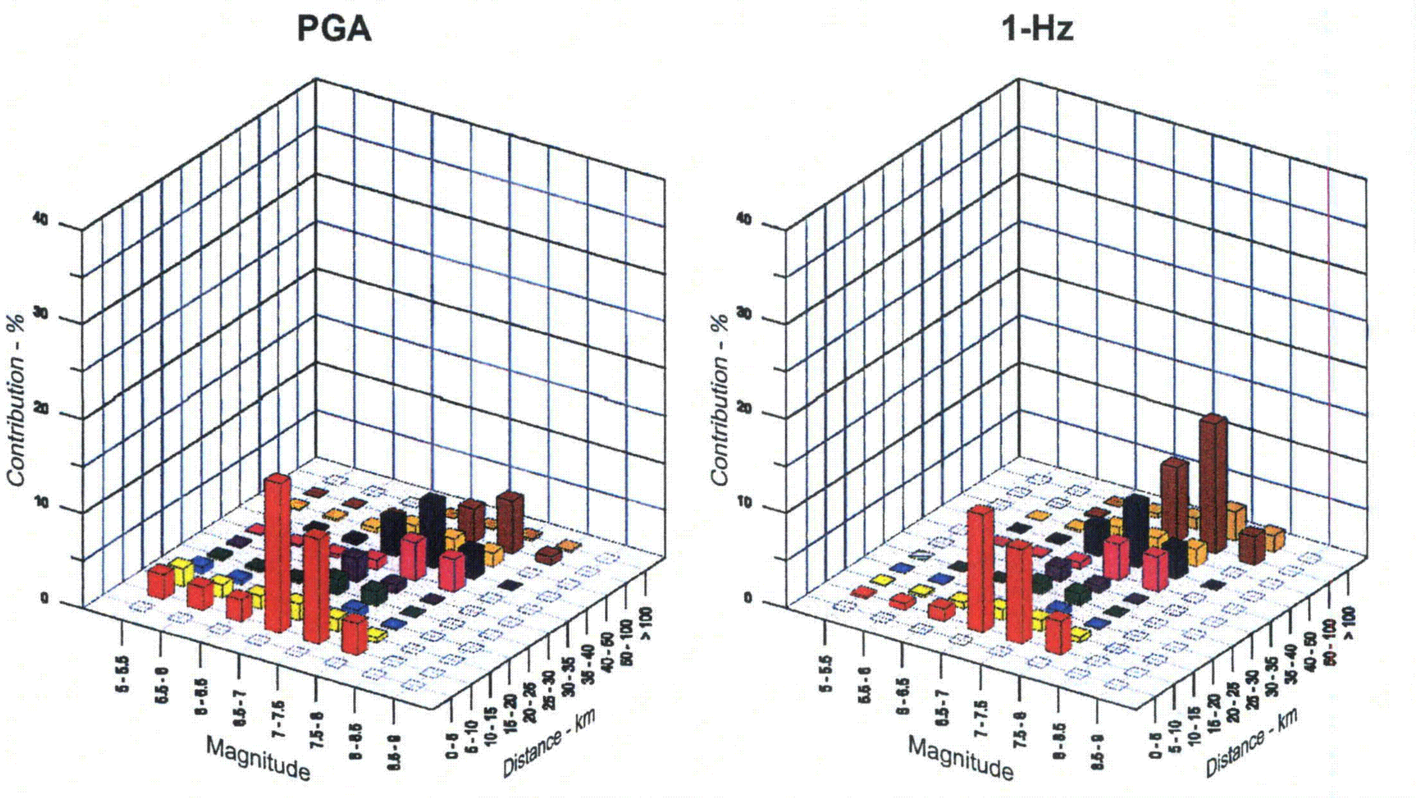


GeoPentech Geotechnical & Geoscience Consultants	2010 PSHA - 1-Hz SEISMIC SOURCE CONTRIBUTIONS	FIGURE 3-4
	SAN ONOFRE NUCLEAR GENERATING STATION SEISMIC HAZARD ASSESSMENT PROGRAM	



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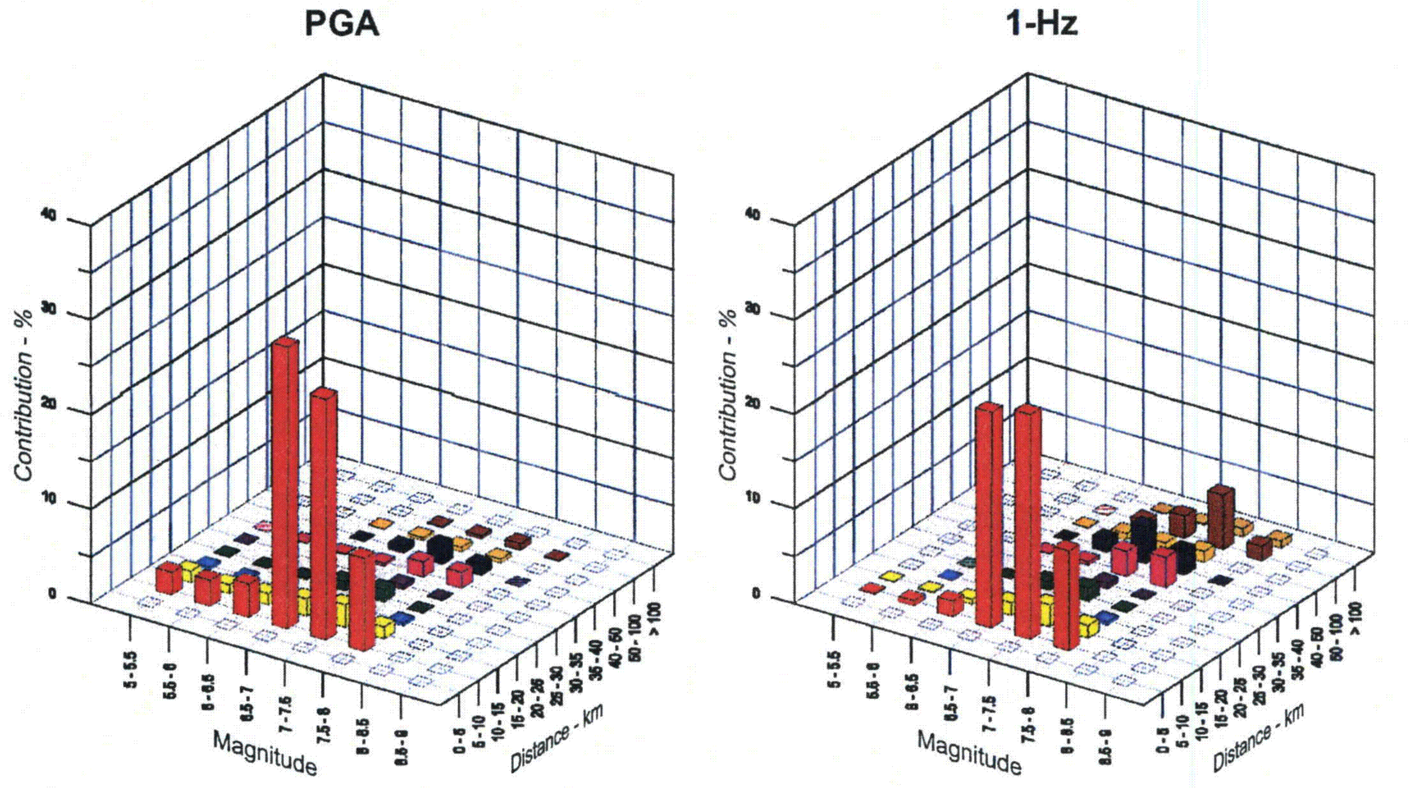
SAN ONOFRE NUCLEAR GENERATING STATION
SEISMIC HAZARD ASSESSMENT PROGRAM

HAZARD DEAGGREGATION
2010 PSHA
FOR 475-yr ARP at PGA and 1-Hz

FIGURE
3-5



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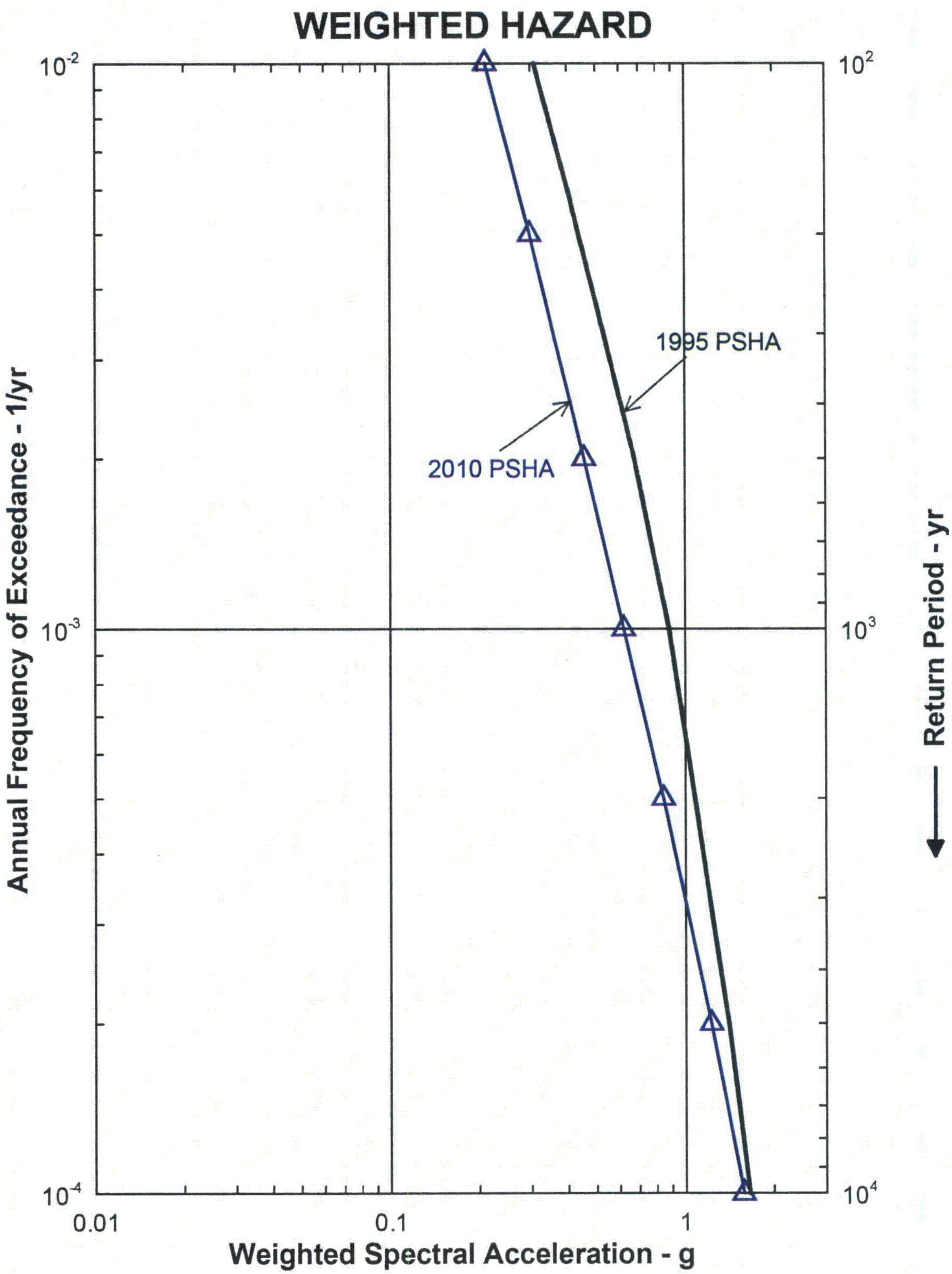
SAN ONOFRE NUCLEAR GENERATING STATION
SEISMIC HAZARD ASSESSMENT PROGRAM

HAZARD DEAGGREGATION OF
2010 PSHA
FOR 2475-yr ARP at PGA and 1-Hz

FIGURE
3-6



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COMPARISON OF WEIGHTED HAZARD CURVES
2010 PSHA AND 1995 PSHA

FIGURE
3-7

SAN ONOFRE NUCLEAR GENERATING STATION

SEISMIC HAZARD ASSESSMENT PROGRAM

4.0 SUMMARY AND CONCLUSIONS

This seismic hazard assessment was completed to evaluate if recent available information has affected the seismic hazard at SONGS. A PSHA was performed utilizing available and regionally relevant seismic geology and seismology information (in particular, the recently released UCERF 2 [WGCEP, 2008], as well as discussions with current academic and USGS researchers) and the recently released five "Next Generation of Ground-Motion Attenuation Models" (NGA, 2008).

On the basis of this analysis, the following conclusions were reached:

- The two fault sources that contribute most to the ground motion hazard at SONGS are the NI/RC Fault Zone, which was the primary source fault governing the licensing of SONGS in the early 1980s, and the recently hypothesized OBT Fault of Rivero et al. (2000) and Rivero (2004). To appropriately represent the generally accepted NI/RC Fault Zone and the recently hypothesized OBT Fault in the 2010 PSHA, the end-member models associated with the NI/RC Fault Zone and OBT were evaluated as described in Section 2 of the report. The relative weights of 88% and 12% were assigned to the NI/RC Fault Zone and the hypothesized OBT, respectively, by the seismic source integration team. The weights are based on the consideration of a number of technical arguments given in the text.

- The mean seismic hazard curves presented on Figures 3-1 and 3-2 are assigned to the combined strike-slip and blind thrust end-member models. The NGA relationships (NGA, 2008) were used in performing this PSHA. This seismic hazard evaluation was limited to annual frequencies of exceedance greater than 10^{-4}. A 10^{-4} annual frequency of exceedance is equivalent to a RP of 10,000 years. At annual frequencies of exceedance lower than 10^{-4}, some issues are to be addressed that potentially could affect the calculated seismic hazard results. These issues consist of those associated with dispersions, i.e., epistemic and aleatory uncertainties in seismic source characterization and ground motion characterization models including the GMPE epistemic uncertainty; and those associated with nonlinear behavior of soils at the site. These issues will be addressed as part of the SONGS on-going seismic hazard program.

- The weighted hazard curves shown on Figure 3-7 indicate that the 2010 PSHA results are lower compared to the 1995 PSHA results throughout the range shown. These weighted hazard curves are also tabulated in Table 3-3.

5.0 REFERENCES

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5.2 Personal Communication

Details of personal communication summarized in Appendix A, Attachment A-1, are denoted with an asterisk.

Abrahamson, N., 2010, personal communication.

*Ponti, D., 2010, personal communication.

*Rockwell, T., 2010, personal communication.

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6.0 GLOSSARY

ALEATORY UNCERTAINTY: Uncertainty arising from or associated with the inherent, irreducible, natural randomness of a system or process

ANNUAL FREQUENCY OF EXCEEDANCE: Mean number of seismic events per year exceeding a specified value

BASE: United States Marine Corps Base at Camp Pendleton

CFM: Community Fault Model of southern California developed by Plesch et al. (2007)[1]

CGS: California Geological Survey

CPT: Cone Penetration Test

dgnd: The median or spectral acceleration uncertainty for any given attenuation relationship

EPISTEMIC UNCERTAINTY: Uncertainty associated with a model of a system or process and its parameters that arises from limitations of the data available or on causal understanding

GMPEs: Ground motion prediction equations

GPS: Global Positioning System

HAZ4.2: PSHA computer program developed by Dr. Norman Abrahamson (2010, PC)[1]

HAZARD CURVE: Plot of the relationship between a ground motion parameter and the mean number of seismic events per year in which the ground motion parameter at the site exceeds a specified value; herein, the ground motion parameters of interest are the peak ground acceleration and spectral acceleration

HECTARE: Unit of surface area equal to 10,000 square meters (i.e., 100 meters by 100 meters); also equal to 2.47 acres

Hz: Hertz

ICB: Inner Continental Borderland

InSAR: Interferometric Synthetic Aperture Radar

ka: Thousand years ago

km: Kilometers

km/s: Kilometers per second

Ma: Million years ago

MIS 5e/5a: Marine Isotope Stages 5e/5a; part of a series of stages 1 through 6

MMS: Minerals Management Services

mm/yr: Millimeters per year

m_j: A variable used in PSHA calculations representing an earthquake of a particular magnitude

m/s: Meters per second

M: A quantity characteristic of the total energy released by an earthquake

M_L: Local magnitude scale developed by Richter in the 1930s

Mw: Moment magnitude scale as presented by Hanks and Kanamori (1979)[1]

NGA: Next Generation Attenuation relationships presented as part of the NGA Relations Project, a five year research program designed to improve earthquake ground motion attenuation relationships for shallow crustal earthquakes in the western United States[1]

NI: Newport-Inglewood (Fault)

NI/RC: Newport-Inglewood/Rose Canyon Fault Zone

NSHM: National Seismic Hazard Maps as presented by USGS (2008; 2009, PC)[1]

$\dot{N}_s(m_j)$: A variable used in PSHA calculations representing the mean number of earthquakes per year having an earthquake magnitude m_j

OBT: Oceanside Blind Thrust Fault as characterized by Rivero et al. (2000)[1], Rivero and Shaw (2001)[1], Rivero (2004)[1], Rivero and Shaw (2005)[1], and Rivero and Shaw (2010, in press)[1]

OZD: Offshore Zone of Deformation

PC: Personal communication

PEER: Pacific Earthquake Engineering Research

PGA: Peak ground acceleration

PSHA: Probabilistic Seismic Hazard Analysis

POISSON PROCESS: A random function which describes the number of random events in a specified interval of time or space; the random events have the following properties: (i) the probability of more than one event during the specified time interval is negligible; (ii) the probability of an event during the specified time interval does not depend on what happened prior to the specified time

QA/QC: Quality Assurance/Quality Control

RC: Rose Canyon (Fault)

RP: Return Period in years; inverse of annual frequency of exceedance value

RECURRENCE RELATIONSHIP: Relationship showing the annual recurrence of earthquakes of various magnitudes up to a maximum magnitude; used to determine the mean number of earthquakes per year

r_k: A variable used in PSHA calculations representing the distance between the site and a fault rupture plane

SA: Spectral Acceleration

SCE: Southern California Edison

SCOZD: South Coast Offshore Zone of Deformation

SDT: San Diego Trough

SONGS: San Onofre Nuclear Generating Station

SOPAC: Scripps Orbit and Permanent Array Center

SSHAC: Senior Seismic Hazard Analysis Committee

STAB: Seismic Technical Advisory Board for SONGS Seismic Hazard Analysis

TMBT: Thirtymile Bank Blind Thrust Fault as characterized by Rivero (2004)[1] and Plesch et al. (2007)[1]

TECHNICAL COMMUNITY: As used in this report, this term refers to geoscientists and engineers that have demonstrated expertise in relevant ground motion and seismotectonic fields of study in the area around SONGS

TYPE-A FAULT: Seismic sources with detailed earthquake recurrence models where the timing of past events and event displacements are available; earthquakes on Type-A Faults are modeled as characteristic earthquakes; faults as presented by WGCEP (2008)[1] and USGS (2008)[1]

TYPE-B FAULT: Seismic sources with measurable slip rates but lacking information of the timing of past events, fault segmentation, and/or event displacements; earthquakes on Type-B Faults are modeled as characteristic earthquakes that rupture the full fault length; faults as presented by WGCEP (2008)[1] and USGS (2008)[1]

TYPE-C ZONE: Regions of distributed shear in which overall rate and style of deformation are unknown; zones as presented by WGCEP (2008)[1] and USGS (2008)[1]

UCERF 2: Uniform California Earthquake Rupture Forecast, Version 2 as developed by the 2007 WGCEP (WGCEP, 2008)[1]

UFSAR: Updated Final Safety Analysis Report

V_{s30}: A variable used in the NGA relationships for the average shear wave velocity from the ground surface to a depth of 30 m

$v(Z \geq z)$: A function used in PSHA calculations representing the annual frequency of exceedance

USGS: United States Geological Survey

WGCEP: Working Group(s) on California Earthquake Probabilities

WEIGHTS: A weight as used in this report is a number between zero and one assigned to a branch of logic trees in such a way that the sum of the weights assigned to the branches associated with any single branching point (a point from which all the branches under considerations are shown) is one. A weight assigned to a branch usually represents the assigner's or assigners' combined judgment regarding how that branch should be counted with respect to the other branches associated with that branching point in the analysis of the probabilistic model represented by the entire logic tree.

Z: A variable used in PSHA calculations representing the ground motion parameters peak ground acceleration (PGA) and spectral acceleration (SA)

z: A variable used in PSHA calculations representing a specified ground motion parameter threshold

$Z_{1.0}$: A variable used in the NGA relationships for the approximate depth to 1.0 km/s shear wave velocity material

$Z_{2.5}$: A variable used in the NGA relationships for the approximate depth to 2.5 km/s shear wave velocity material

[1] Citation contained in Section 5.0 References