2 SITE CHARACTERISTICS

2.1 Conduct of Review

This chapter of the Safety Evaluation Report (SER) evaluates the geographical location of the Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI) and the meteorological, hydrological, seismological, and geological characteristics of the site and surrounding area. This chapter describes the population distribution around the Humboldt Bay ISFSI, land and water uses, and associated site activities. This evaluation was based on information provided by Pacific Gas and Electric Company (PG&E) in Chapter 2, “Site Characteristics,” of the Safety Analysis Report (SAR) (Pacific Gas and Electric Company, 2004a), associated supporting calculations (e.g., Pacific Gas and Electric Company, 2003a), the ISFSI Environmental Report (Pacific Gas and Electric Company, 2004b), and the applicant’s responses to the staff’s request for additional information (Pacific Gas and Electric Company, 2004c). Chapter 2 of the SAR and the corresponding review provided in this chapter of the SER also identify assumptions that are necessary for the evaluation of safety, installation design, and development of design bases for other safety-related evaluations in other chapters of the SAR. The review objectives for this chapter are to determine whether (i) the information about site characteristics properly identifies external natural and human-induced phenomena for inclusion in the design basis and whether design basis levels are adequate, (ii) local land and water use and population were adequately assessed such that important individuals and populations likely to be affected by the ISFSI can be identified, and (iii) transport processes that could move released contamination from the facility to the maximally exposed individuals and nearby populations were sufficiently characterized.

The information and analyses in Chapter 2 of the SAR were reviewed with respect to the applicable siting evaluation regulations in 10 CFR Part 72, Subpart E, and §72.122(b). Where appropriate, findings of regulatory compliance were made in this chapter of the SER for the 10 CFR Part 72 requirements addressed in Chapter 2 of the SAR. Findings of technical adequacy and acceptability were made for each section in Chapter 2 of the SAR. Because compliance with some regulations was determined by an integrated review of several sections in Chapter 2 and other chapters within the SAR, a finding of regulatory compliance was not made in each major section of this chapter unless the specific regulatory requirement was fully addressed.

The review considered how the SAR and related documents addressed the regulatory requirements of 10 CFR §72.24(a), §72.40(c), §72.90(a–f), §72.92(a–c), §72.94(a–c), §72.98(a–c), §72.100(a–b), §72.103(b–f), §72.120(a), and §72.122(b). Complete citations of these regulations are provided in the Appendix of this SER.

2.1.1 Geography and Demography

This section describes the staff review of Section 2.1 of the SAR. Subsections discussed include (i) Site Location, (ii) Site Description, (iii) Population Distribution and Trends, and (iv) Land and Water Uses. The staff reviewed the discussion on geography and demography with respect to regulatory requirements 10 CFR §72.24(a), §72.90(a)–(f), §72.98(a)–(c), and §72.100(a).

2.1.1.1 Site Location

Section 2.1.1 of the SAR describes the site location. The Humboldt Bay ISFSI will be located within the PG&E owner-controlled area at the Humboldt Bay Power Plant (HBPP). The HBPP is located approximately 4.8 km [3.0 mi] south of the city of Eureka, California, on the eastern shore of Humboldt Bay. There are several small residential communities within 8 km [5 mi] of the ISFSI site, including King Salmon, Humboldt Hill, Fields Landing, and other suburban communities south of Eureka, California.

The PG&E-owned site consists of 58 hectares [143 acres] of land located on the northeastern part of Buhne Point opposite the entrance to Humboldt Bay. PG&E also owns the water areas extending approximately 150 m [500 ft] into Humboldt Bay from the HBPP site. The SAR reports the latitude and longitude, the Universal Transverse Mercator coordinates of the ISFSI site, appropriate maps, and aerial photographs.

The staff reviewed the description of the site location and found it acceptable because it clearly described the geographic location of the site, including its relationship to political boundaries and natural and anthropogenic features. The maps provided in the SAR are acceptable because they provide sufficient detail to review the geographical, geological, and engineering features of the Humboldt Bay ISFSI. This information is acceptable for use in other sections of the SAR to develop the design bases for the ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.24(a), §72.90(a), §72.90(e), and §72.98(a) with respect to this topic.

2.1.1.2 Site Description

Section 2.1.2 of the SAR describes the site using maps to delineate the site boundary and controlled area. The Humboldt Bay ISFSI site will be located within the PG&E-owned area at the HBPP.

The location and orientation of the Humboldt Bay ISFSI structures with respect to nearby roads and waterways are shown on maps and plots, and there is no obvious way in which traffic on adjacent transportation links can interfere with ISFSI operations. The ISFSI site will be located within the site boundaries of the existing HBPP site near the top of a small hill surrounded by wetlands to the east and Humboldt Bay to the west. The terrain in the vicinity of the HBPP rises rapidly from the bay on the north side to an elevation of approximately 21m [69 ft] mean lower low water (MLLW)[1] at Buhne Point. Terrain to the northeast of the ISFSI site is generally flat. Figure 2.1-2 of the SAR shows the topography in the vicinity of the ISFSI site.

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[1]Tidal patterns along the western United States coast are mixed semidiurnal such that there are two high and two low tides each day. The semidiurnal tidal pattern is considered "mixed" because the two daily high tides and two daily low tides are of different magnitudes. Elevations in the SAR reference three tidal elevations: (i) MLLW, which is the average of the lower of the two daily low tides; (ii) mean higher high water (MHHW), which is the average of the higher of the two daily high tides; and (iii) mean sea level (MSL), which is the overall average water elevation. In the SAR, the applicant provides analyses relative to MLLW. The applicant reports that at the Humboldt Bay ISFSI site, the difference between MLLW and MHHW is 2.1 m [6.9 ft], and the difference between MLLW and MSL is 1.13 m [3.7 ft].

The owner-controlled area shown in Figure 2.1-2 of the SAR varies between sea level and 19.5 m [64 ft] MLLW and is approximately 274.3 m [900 ft] in width. The only access to the ISFSI site is from the south via King Salmon Avenue, which also serves the community of King Salmon situated on the western part of the peninsula. The applicant has full authority to control all activities within the ISFSI site and owner-controlled area. A public trail to access a breakwater for fishing traverses the controlled area, a condition allowed by 10 CFR §72.106, so long as appropriate and effective arrangements are made to control traffic and protect public health and safety. The public trail crossing the property to the north of the ISFSI is controlled by fencing. Gates will be added as part of the ISFSI project. The location of these gates is shown in Figure 2.2-2 of the SAR. The fencing and gates will allow positive control of all land access within the controlled area. The gates will normally be open so that public access to recreational activities on the breakwater and in the bay will not be restricted by the applicant. In the SAR, the applicant states that the gates will be closed and locked during ISFSI cask transfer and handling activities.

The HBPP consists of five electric generation units. Unit 3 is a boiling water reactor that operated for approximately 13 years before being shut down in July 1976. The reactor has remained inactive since then. Units 1 and 2 are co-located units capable of operating on fuel oil or natural gas. There are also two gas turbines located in the vicinity of the Units 1, 2, and 3 structures. The five generating units, as well as the plant site, are owned by the applicant.

Two small streams near the site discharge into Humboldt Bay. Salmon Creek and Elk River are located within a mile south and north of the site, respectively. These streams are used for watering livestock, but are not used as a potable drinking water supply.

The staff reviewed the site description and relevant literature cited in the SAR. The staff finds that the site description is adequate because the descriptive information and maps clearly delineate the site boundary, controlled area, general natural and man-made features, topography, and surface hydrologic features. The maps have a sufficient level of detail and are of appropriate scale and legibility required for the review of the site and the Humboldt Bay ISFSI. The information is also acceptable to determine distances between the ISFSI site and nearby facilities and cities. This information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.90(a–e) and §72.98(a) with respect to this topic.

2.1.1.3 Population Distribution and Trends

Section 2.1.3 of the SAR and relevant literature cited in the SAR describe the population distribution and trends. The population data used in the SAR were derived from the 2000 census and from estimates of future population provided by the California Department of Finance.

The area within a radius of 80 km [50 mi] of the HBPP site includes most of Humboldt County and a small sparsely populated portion of Trinity County. About half of the area within this 80 km [50 mi] radius is on land. The remaining area is marine and includes areas of Humboldt Bay and the Pacific Ocean.

According to the 2000 census, the population of Humboldt County was 126,518, and the population of Trinity County was 13,022. The same census data show that 49,740 people live within a 16 km [10 mi] radius of the HBPP site. The projected population distribution for 2010 and 2025 published by the California Department of Finance (SAR Figures 2.1-7 and 2.1-8) are based on the assumption that the land usage will not change in character during the next 25 years and that the population growth within 10 miles will be proportional to growth in Humboldt County as a whole (0.61-percent annual growth rate). The SAR also states that Humboldt County receives between 2.1 and 2.2 million visitors per year. There is a seasonal influx of vacation and weekend visitors within a 80-km [50-mi] radius, especially during the summer months.

The staff reviewed the information presented in the SAR and determined that the population distribution and trends in the region have been adequately described and assessed. The source of the population data used in the SAR is appropriate. The basis for population projections is reasonable. The region has been appropriately investigated with respect to the present and future character and distribution of the population; therefore, the staff finds that requirements of 10 CFR §72.98(c)(1) have been met. This information is also acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.90(e), §72.98(a), and §72.100(a) with respect to this topic.

2.1.1.4 Land and Water Uses

Section 2.1.4 of the SAR describes land and water uses in the region surrounding the HBPP site. Humboldt Bay and the surrounding lowlands dominate the regions north, south, and west of the site. The lowland areas around the site are primarily vacant land and are used to a limited extent for grazing cattle. Most of the mountainous area east and southeast of the site is inaccessible; however, there are several small communities located on Humboldt Hill and in the larger valleys. Most of the dairies are located along the Elk River, while the coastal lowlands are used primarily for cattle grazing and ranching. The nearest dairy is 2.9 km [1.8 mi] east of the site. Figure 2.1-5 of the SAR identifies nine farms and ranches and one community vegetable garden within 5 miles of the ISFSI site. The primary industry in the area and in Humboldt County, is lumber and lumber/paper manufacturing. A lumber-loading shipyard is located less than 1 mile south of the ISFSI site. The SAR states that no major new developments are planned for the area within 8 km [5 mi] of the ISFSI site.

The ISFSI site is located in the vicinity of several ports that support commercial and sport fishing activities. Humboldt Bay, inland waterways, and the coastal waters of the Pacific Ocean are used for recreational fishing. Information regarding the level of activity for sport and commercial fishing in terms of the number of fish landed and the poundage of landings is presented in the SAR.

The Humboldt Bay Municipal Water District was identified as the public groundwater supplier to residential and industrial users in the Humboldt Bay area. Figure 2.1-5 of the SAR shows the location of three groundwater wells located within 0.6 km [1 mi] of the ISFSI site.

The staff reviewed the description of the land and water use in the SAR and finds that it has been adequately described and assessed. The region has been investigated, as appropriate, with respect to consideration of present and projected future uses of land and water within the region. This information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with regulatory requirements in 10 CFR §72.98(a–c) with respect to this topic.

2.1.2 Nearby Industrial, Transportation, and Military Facilities

This section describes the staff review of Section 2.2 of the SAR. This information is necessary to evaluate credible potential hazards from these facilities that may endanger the radiological safety of the ISFSI site including onsite and offsite potential hazards. The staff reviewed the discussion on nearby industrial, transportation and military facilities with respect to regulatory requirements 10 CFR §72.24(a), §72.94(a–c), §72.98(a–c), and §72.100(a–b).

The identification of potential hazards includes identifying facilities and determining credible scenarios that may endanger the facility. The facilities identified in the SAR by the applicant include U.S. Highway 101; large cargo vessels and cruise ships in Humboldt Bay; Northwestern Pacific Railroad, which is adjacent to U.S. Highway 101; and aircraft flying in the vicinity of the ISFSI.

The SAR documents that there are no military facilities within 8 km [5 mi] of the ISFSI, except for the U.S. Coast Guard Reservation and Lifeboat Station that is located approximately 2.4 km [1.5 mi] from the HBPP. The U.S. Coast Guard Air Station is located approximately 32 km [20 mi] from the HBPP at the Eureka-Arcata Airport. There are no mining facilities with 8 km [5 mi] of the ISFSI site. There are several lumber mills with lumber storage yards within 40 km [25 mi]. As stated in the SAR, the lumber mills currently use U.S. Highway 101 for transportation.

In the SAR, the applicant notes that Humboldt Bay has two main shipping channels referred to as the North Channel and South Channel. The North Channel is used by private yachts, recreational vessels, large cargo vessels, and passenger cruise ships. The edge of this channel is approximately 1,350 m [4,500 ft] from the ISFSI site. All cargo and most other vessels remain within this shipping channel because navigational depth outside the channel reduces quickly. The smaller South Channel is approximately 770 m [2,600 ft] from the ISFSI site and is used by mostly private yachts and recreational vessels. Occasionally, barges use this shipping channel for transporting lumber. Several piers along the shorelines of the North Channel are used to dock boats and ships. Although the applicant states in the SAR that typically no more than several dozen vessels are docked at one time, a public marina and other nearby piers can accommodate approximately 100 small vessels.

In the SAR, the applicant identifies a possible explosion of a gasoline and diesel oil barge with a fuel capacity of 10,334,000 L [65,000 barrels] as the bounding scenario for potential fire and explosion hazards to the ISFSI site. Approximately once in every eight days, a barge delivers its cargo to the Chevron terminal located approximately 3.2 km [2 mi] north of the ISFSI site.

The Northwestern Pacific Railroad is adjacent to U.S. Highway 101 at a distance of approximately 360 m [1,200 ft] from the ISFSI site. This rail line is not currently active; however, several diesel locomotives remain in the area. These locomotives are used for short-haul movements of heavy equipment.

In the SAR, the applicant identifies (i) large trucks carrying hazardous cargo on U.S. Highway 101, (ii) the fuel barge in the bay, and (iii) locomotives at the Northwestern Pacific Railroad adjacent to the highway as potential explosion hazards. In addition, the applicant also identifies the possibility of civilian aircraft crashing onto the site as a potential explosion hazard. Civilian aircraft with the potential to crash at the facility site include aircraft taking off and landing at nearby Eureka-Arcata, Kneeland, Rohnerville, Eureka Municipal, and Murray Field airports. Aircraft flying along federal routes V-607, V-27, V-195, and V-257 and aircraft flying at high altitudes in the vicinity of the ISFSI are also identified by the applicant as potential aircraft crash hazards.

The staff reviewed the information presented in the SAR and determined that nearby industrial, transportation, and military facilities have been adequately described and assessed. The SAR adequately identifies all nearby facilities that may present a hazard to the ISFSI in accordance with the regulatory requirements in 10 CFR §72.24(a) and §72.94(a). Potential hazards from these facilities are evaluated further in Chapter 15 of this SER.

2.1.3 Meteorology

This section describes the staff's review of Section 2.3 of the SAR. Subsections discussed include (i) Regional Climatology, (ii) Local Meteorology, (iii) Onsite Meteorological Measurement Program, and (iv) Diffusion Estimates. The staff reviewed the discussion on meteorology with respect to regulatory requirements in 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), and §72.122(b).

2.1.3.1 Regional Climatology

Section 2.3.1 of the SAR briefly describes the regional climatology for the region surrounding the HBPP. The climate information was derived from direct meteorological observations at the HBPP and published data from local, state, and federal climate and meteorological sources, including the National Weather Service, National Oceanic and Atmospheric Administration, and the California Department of Water Resources. The first weather station was established in the Eureka area in 1886, and there have been continuous weather observations since then. The current National Weather Service station is on Woodley Island, which is located approximately 10 km [6 mi] northeast of the HBPP.

The regional climate of the HBPP is strongly influenced by the proximity of the site to the Pacific Ocean. In the SAR, the applicant characterizes the climate as Mediterranean. Summers are cool, damp, and foggy, but with little rainfall. Winters are mild and wet, and have frequent passing Pacific winter storms. Temperatures and daily temperature variations are moderate. The average daily January temperatures for the 52-year span between 1949 and 2001 is 8.4 EC [47 EF]. Over the same interval, the average daily August temperature is 14.0 EC [57 EF]. The average difference between the daily maximum and daily minimum temperatures is approximately 5.6EC [10 EF]. The record maximum temperature in the region was 30.6 EC [87 EF] on October 26, 1993. The record minimum temperature in the region was !6.7 EC [20 EF] on January 14, 1888. Average rainfall is just under 100 cm/yr [39 in/yr]. Most of the rain falls between November and March. Snow is rare at the HBPP site. There are only 13 snowfall events in the past 110 years and only the 1907 event resulted in more than 2.5 cm [1 in] of snow accumulation. The largest recorded snowfall was in January 1907 and measured

18 cm [7 in]. Because the 1907 event was the only event with appreciable snow accumulation, it forms the design basis snowfall for the HBPP. Winds are generally light and from the north-northwest during the spring-summer-fall months and from the south-southeast during the winter months. The maximum wind speed recorded in Eureka was 111 kmph [69 mph], which occurred twice in 1981. The only recorded tornado in the Eureka area occurred on March 29, 1958. This was an F2 tornado on the Fujita scale. F2 tornados have maximum winds of 253 kmph [157 mph].

The staff reviewed the information presented in the SAR and determined that the regional climatology has been adequately described and assessed. The source of the climate data used in the SAR is appropriate, and the basis for design loads from climate hazards is adequate. The staff finds that the requirements of 10 CFR §72.90(a–c) have been met because the region has been appropriately investigated with respect to frequency and severity of external natural phenomena. This information is also acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with regulatory requirements in 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), and §72.122(b) with respect to this topic.

2.1.3.2 Local Meteorology

Section 2.3.2 of the SAR describes and characterizes the local meteorology of the HBPP site. The description is based on a summary of local meteorological information from the Environmental Report for Decommissioning (Pacific Gas and Electric Company, 1984). Because the Humboldt Bay ISFSI is within the HBPP site, the local meteorological conditions at the ISFSI site are considered to be the same as those identified at the HBPP and those described in the preceding section on regional climatology.

Solar radiation data were obtained from the National Renewable Energy Laboratory (2005), which is supported by the National Center for Photovoltaics and managed by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. Solar radiation measurements were made at the Arcata Airport, which is located approximately 27 km [17 mi] north-northeast of the HBPP. The maximum flat-plate solar radiation measured insolation for a 24-hour period was 602 g-cal/cm^2/day, which is equivalent to 7.0 kWh/m^2/day [92.6 BTU/hr-ft^2].

The staff reviewed the description of the local meteorology in the SAR and finds that it has been adequately described and assessed. The staff finds the description of the local meteorology in the SAR to be acceptable because it is based largely on general information provided for the HBPP that is also applicable to the ISFSI site. The regulations at 10 CFR §72.40(c) indicate that a site does not require reevaluation when relevant information is covered under previous licensing actions, except where new information could alter the original site evaluation findings. The staff has previously accepted the local meteorology description for the HBPP and has discovered no new information that might alter the relevance of the local meteorology description for the ISFSI location. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.92(a), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.3.3 Onsite Meteorological Measurement Program

Section 2.3.3 of the SAR describes the basis for onsite weather data at the HBPP site. The applicant does not maintain an onsite meteorological measurement program. Instead, the applicant relies on meteorological data collected at the nearby National Weather Service station on Woodley Island, which is located 10 km [6 mi] northeast of the HBPP. The applicant concludes that because of similar site characteristics and the proximity of the Woodley Island station to the HBPP site, the conditions recorded by the National Weather Service on the island are representative of those at the HBPP.

The staff reviewed the rationale for applying the National Weather Service data from the Woodley Island station in lieu of an onsite meteorological measurement program. The staff concurs with the applicant’s approach as it relates to the Humboldt Bay ISFSI. The staff, therefore, concludes that this information is acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.92(a), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4 Surface Hydrology

The staff has reviewed the information presented in Section 2.4 of the SAR. Subsections discussed include (i) Hydrologic Description; (ii) Floods; (iii) Probable Maximum Flood (PMF) on Streams, Rivers, and Bays; (iv) Potential Dam Failures; (v) Probable Maximum Surge and Seiche Flooding; (vi) Probable Maximum Tsunami Flooding; (vii) Ice Flooding; (viii) Flood Protection Requirements; and (ix) Environmental Acceptance of Effluents. The staff reviewed the discussion on surface hydrology with respect to the regulatory requirements of 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), and §72.122(b).

2.1.4.1 Hydrologic Description

Sections 2.4 and 2.4.1 of the SAR describe and characterize the surface hydrological conditions and features pertaining to the ISFSI site. The applicant provides a map of Humboldt Bay and of the streams and rivers in the Humboldt Bay watershed, which comprise the most relevant surface water bodies surrounding the ISFSI site. The applicant summarizes the tidal characteristics of Humboldt Bay and the drainage characteristics of rivers, streams, and sloughs in the Humboldt Bay watershed. The applicant also describes the plant drainage system in the area of the ISFSI site.

The surface hydrologic conditions most relevant to the ISFSI site include those influencing tides within Humboldt Bay, especially when high tides coincide with winter rainfloods of streams and rivers in the Humboldt Bay watershed. Salmon Creek and the Elk River {greater than 3 km [2 mi] south and within 1.6 km [1mi] north of the ISFSI site} are the nearest streams. While used to water livestock, neither Salmon Creek nor the Elk River is used as a potable water supply. The area encompassing the drainage basin for the Elk River is approximately 132.9 km^2 [51.3 mi^2]. The maximum peak discharge measured for the Elk River, was 97,100 L/s [3,430 cfs] on December 22, 1965. Discharge measurements of this river ceased one year later. Elk River data analogous to that recorded for high flow in Jacoby Creek, located approximately 8 miles to the northeast, on March 2, 1972 and January 16, 1974, are not available. It is unknown whether peak discharges of the Elk River on these dates would have represented the annual maximum peak discharge for the year. Using available data, the 10-year average annual maximum peak discharge for Elk Creek is calculated to be 77,450 L/s [2,736 cfs], with standard deviation of 15,170 L/s [536 cfs]. The area encompassing the drainage basin for Salmon Creek is approximately 73.3 km^2 [28.3 mi^2]. Typical flows in the two streams are not described, but do not pose a flooding threat.

The staff reviewed the information in the SAR concerning the surface hydrologic features in the vicinity of the ISFSI site; including information on the location, drainage basins, and measured maximum discharge of the Elk River and other surface water features; topographic maps and watershed characteristics; relevant oceanographic and tidal data; and other applicable information. The staff also reviewed meteorological data significant to the characteristics and hazards associated with surface hydrology.

The staff finds the description of the surface hydrologic features in the SAR acceptable, because these features are adequately described and assessed. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.2 Floods

Section 2.4.2.1 of the SAR discusses the potential for and effects of flooding at the ISFSI site. The applicant's flood design considerations pertain primarily to short duration wet season rainfloods that coincide with high tides. The applicant indicates that the elevation of the ISFSI area is approximately 13 m [44 ft] above MLLW and is approximately 10 m [32 ft] higher than the main power plant elevation, such that any drainage will be away from the ISFSI site. The applicant, therefore, maintains that flooding in the vicinity of the ISFSI is not a concern.

The staff reviewed the information in Section 2.4.2 of the SAR concerning the potential flooding of the ISFSI and considered the local precipitation data, characteristics of the Humboldt Bay drainage basin, and the specific locations and elevations of interest for the ISFSI site. The staff finds the information supplied by the applicant acceptable, based on the relative elevation differences between the ISFSI site and its drainage system, including the elevation of the bay at high tide. Thus, potential flooding is not considered a credible threat to the ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.3 Probable Maximum Flood on Streams and Rivers

Eureka and the Humboldt Bay ISFSI site are located in the rain shadow of surrounding hills; thus, this locality has one of the lowest annual average rainfall records in northwest California. Section 2.4.2.2 of the SAR discusses probable maximum flooding at the ISFSI site caused by winter rainfloods that coincide with high tides. The applicant indicates that because of the relatively low elevation of the area, snowfall and snowmelt are not considerations for flooding. Wet season rainfloods typically have sharp peaks and short durations. Mean annual precipitation, normal monthly precipitation, and annual maximum peak discharges for a river and stream in the area are provided in the SAR. As mentioned previously, the maximum peak discharge measured for the Elk River, was 97,100 L/s [3430 cfs]. A PMF model of the floodwater surface profile, based on 38 years of high tide data collected between 1920 and 1998 and which uses a 95 percent exceedence criterion, indicates that the freeboard estimated for the ISFSI site during the PMF is 10 m [34 ft]. This result supports the applicant's conclusion that flooding in the vicinity of the ISFSI is not a concern.

The staff's review of this information focused on a PMF model of the floodwater surface profile at the ISFSI location. The staff also considered local precipitation data, historical river discharge data, characteristics of the Humboldt Bay drainage basin, and the specific locations and elevations of interest for the ISFSI site. The staff finds the SAR description of PMFs on streams, rivers, and the bay caused by winter rainfloods coinciding with high tides acceptable because the PMF model of the floodwater surface profile at the ISFSI location has been adequately described and model results have been adequately assessed. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.4 Potential Dam Failures (Seismically Induced)

Section 2.4.3 of the SAR discusses the potential for flooding at the ISFSI site as a result of dam failure. The applicant states that the only major dam in the area is associated with the 10-million-m^3 [2.7-billion-gal] capacity Ruth Reservoir on the Mad River, located 21 to 24 km [13 to 15 mi] northeast of the site, which regulates the municipal and industrial water supply for the Arcata-Eureka area. If the Ruth Reservoir were to experience a dam failure, the applicant indicates that flows in the Mad River Sub-Basin would export water to the Eureka Plain Sub-Basin, and then to the Pacific Ocean without impact to the Humboldt Bay watershed area. The applicant, therefore, maintains that floods resulting from a breach of this dam would not be a threat to the ISFSI.

The staff reviewed the information concerning potential dam failures and finds it acceptable because no dams or reservoirs exist whose failure could cause the ISFSI to flood. Thus, dam failure is not considered a credible threat to the ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.5 Probable Maximum Surge and Seiche Flooding

Section 2.4.4 of the SAR discusses flooding from a maximum surge or seiche at the ISFSI site. The applicant modeled a number of peak wind gust scenarios based on measured peak wind gusts in Eureka, California. The most conservative scenario assessed was for the 100-year flood surface with an over-water wind gust of 124 kph [77 mph]. Estimated freeboard for the

ISFSI site was 7.8 m [25.5 ft] for all scenarios considered. The applicant indicates that because of the elevation of the ISFSI site, there is no credible scenario that could cause the ISFSI site to flood from a maximum surge or seiche.

The staff reviewed the information in the SAR concerning probable maximum surge and seiche flooding and finds it acceptable because surge and seiche scenarios were appropriately considered and wave runup estimates indicate that the ISFSI site is not likely to be flooded under such circumstances. The staff concludes that the probable maximum surge and seiche flooding do not pose credible threats to the ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.4.6 Probable Maximum Tsunami Flooding

Section 2.4.5 of the SAR summarizes probable maximum tsunami flooding at the ISFSI site. A detailed analysis of the potential tsunami hazards is provided in Section 2.6.9 of the SAR. This analysis considered (i) historical data on tsunamis in the Humboldt Bay area, (ii) geological information on past tsunamis along the northern California coast, (iii) a comparison of the Humboldt Bay tsunami hazard results to worldwide tsunami runup heights, and (iv) analytical models of potential tsunami inundation.

The applicant concludes that the tsunami hazard at the ISFSI site is dominated by a local tsunami generated by a large magnitude earthquake rupture in the Cascadia subduction zone. This tsunami scenario is consistent with the deterministic earthquake scenario described in Section 2.6.5.1 of the SAR and evaluated in Section 2.1.6.1 of this SER. The maximum runup height at the mouth of Humboldt Bay facing the open ocean from such a tsunami is estimated to be 9.1 to 12.2 m [30 to 40 ft] above MLLW. This wave height is expected to be attenuated within Humboldt Bay by 10 to 30 percent, resulting in a maximum inundation height at the ISFSI site of 6.4 to 11 m [21 to 36 ft] above MLLW. The elevation of the ISFSI vault is 13.4 m [44 ft] above MLLW, which is 2.4 m [8 ft] higher than the maximum tsunami runup height. The only condition in which tsunami runup would overtop the elevation of the ISFSI vault is if the tsunami was coincident with both MHHW and wave runup for a 100-year storm (as documented in SAR Table 2-4.5). The applicant considers that a scenario in which a tsunami is coincident with the 100-year storm is not credible. The applicant's analysis is supported by the geologic conditions at the ISFSI site. There is no geologic evidence of past tsunami inundation anywhere at the HBPP site. The applicant also notes that even if the tsunami waves were to overtop the ISFSI site, there would be no radiological consequences because the casks are protected from tsunami-generated flowing water and water-born debris within the vault. The HI-STAR HB casks can be temporarily wet with seawater without harm.

The staff reviewed the information in the SAR concerning probable maximum tsunami flooding and finds it acceptable because the ISFSI vault is located at elevations higher than runup from a potential tsunami. In addition, there are no dose consequences, even if a tsunami were to inundate the ISFSI vault. The staff finds that there is no credible radiological threat to safety from a probable maximum tsunami flood at the site. The staff, therefore, has determined that this information is acceptable to use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.92(a–c), §72.98(a), §72.98(c)(3), §72.103(f)(2)(iii), and §72.122(b) with respect to this topic.

2.1.4.7 Ice Flooding

In Section 2.4.6 of the SAR, the applicant concluded that flooding at the ISFSI caused by ice melt events is not credible, based on the climatic conditions at the HBPP site. In SAR Section 2.3, the applicant states that, on average, over a 51-year period, the ambient temperature in the Eureka area falls below freezing only 5 days per year. Frozen precipitation in this area falls as small hail or ice pellets following the passage of moderate to strong cold fronts with cold, unstable air masses. There are no published statistics available for the frequency of ice storms in the Eureka area, but they are considered rare events. Snowfall in the area is commonly recorded as "trace"—the exceptions consisting of 13 measurable snowfalls during a 110 year period of record. In January 1907, the largest recorded snowfall was measured at nearly 18 cm [7 in].

In reviewing the SAR in regard to ice flooding, the staff considered regional climatology, local meteorology, historical meteorological data, surface hydrology, and other information relevant to the potential for ice-jam flood formation, wind-driven ice ridges, and ice-producing forces that may affect the ISFSI site. The staff finds the information in the SAR regarding ice flooding acceptable because, based on current knowledge and data, the ISFSI site is not subject to ice-flooding hazards; thus, ice flooding is not considered to be a credible threat to the ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), §72.100(b), and §72.122(b) with respect to this topic.

2.1.4.8 Flood Protection Requirements

Section 2.4.7 of the SAR discusses flood protection requirements for the ISFSI site. The applicant indicates that surface drainage around the ISFSI area flows naturally into the existing plant drainage system and then discharges into the cooling water intake canal, which flows through the plant and discharges to Humboldt Bay through the cooling water discharge canal. The applicant indicates that outside the area served by the plant drainage system, most of the surface runoff drains to the east and into the discharge canal, while the remainder drains into Buhne Slough, a natural drainage for the area, which drains directly into both the intake canal and Humboldt Bay. As a result of ISFSI construction, minor alterations in drainage patterns may occur in the immediate vicinity of the ISFSI site, however, such slight modifications are not expected to adversely affect the ISFSI drainage system (Pacific Gas and Electric Company, 2004b). The applicant states that the drainage system at the ISFSI site is efficient, and flooding of the ISFSI site is not a concern.

The staff reviewed the information in the SAR pertaining to flood protection requirements and finds it acceptable because the analyses pertaining to surface hydrology and flooding indicate that the ISFSI will not be subject to significant flooding or uncontrolled moisture intrusion that would adversely affect the ISFSI. In addition, the proposed ISFSI technical specifications will provide controls and restrictions on cask transport during severe weather (Pacific Gas and Electric Company, 2004b, Attachment C). The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a–d), §72.90(f), §72.92(a–c), §72.98(a), §72.98(c)(3), §72.103(b), and §72.122(b) with respect to this topic.

2.1.4.9 Environmental Acceptance of Effluents

In Section 2.4.8 of the SAR, the applicant states that because the ISFSI site will not produce radioactive waste that can be incorporated into surface runoff, surface runoff from the site will have no radioactive contamination and will not adversely affect the surrounding ecosystem. Moreover, the applicant asserts that there is no surface or subsurface drinking water source at the HBPP (Pacific Gas and Electric Company, 2004b). Thus, the applicant concludes that because no radioactive waste will be produced by the ISFSI site and because onsite surface water and groundwater are not used by the public, a detailed analysis of the acceptance of effluents via surface waters or groundwater as a result of ISFSI operations is not necessary.

The staff reviewed the information in the SAR concerning the potential for the release and transport of radionuclides from the ISFSI site via the hydrologic system and finds it acceptable. The applicant has shown that the HI-STAR HB cask system will contain the spent nuclear fuel for all postulated normal, off-normal and accident conditions. Consequently, no radioactive waste will be released into surface or groundwater systems. Thus, the staff concludes there will be no release of radioactive effluents. The staff, therefore has determined that this information is acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(a), §72.92(a–c), §72.98(b), §72.100(b), and §72.122(b) with respect to this topic.

2.1.5 Subsurface Hydrology

Section 2.5 of the SAR discusses the characteristics of groundwater regionally and at the HBPP and ISFSI sites. The applicant indicates that the elevation of the ISFSI area is approximately 13 m [44 ft] above MLLW. Subsections discussed in the following text include (i) Stratigraphy; (ii) Aquifers; (iii) Groundwater Recharge, Gradients, and Discharge; (iv) Hydraulic Properties of Aquifers; (v) Groundwater Use; (vi) Groundwater Quality, and (vii) Contaminant Transport Analysis. The staff reviewed the discussion on subsurface hydrology with respect to the regulatory requirements in 10 CFR §72.98(a), §72.98(c) and §72.122(b)(4). Information presented in the SAR, and in the Humboldt Bay ISFSI Environmental Report (Pacific Gas and Electric Company, 2004b), shows that groundwater quality at the site will not be adversely affected by the ISFSI, nor will groundwater conditions at the HBPP site impact construction and operation of the ISFSI.

2.1.5.1 Stratigraphy

Sections 2.5.1 and 2.6.4.3 of the SAR summarize the stratigraphy directly beneath the ISFSI site. With the exception of a clayey surface layer of artificial fill 0 to 3.2 m [0 to 10.4 ft] thick, the SAR indicates that the ISFSI site is immediately underlain by the Hookton Formation, which is approximately 330 m [1,100 ft] thick beneath the ISFSI site area. Hookton Formation strata consists of interbedded shallow marine, estuarine, and fluvial facies, many that grade or interfinger laterally.

Important groundwater aquifers in the ISFSI vicinity reside in the Hookton Formation, which is composed of an upper and lower member. The upper member is 18 to 24 m [60 to 80 ft] thick and is divided into two informal lithologic units; the first contains silt, clay, and silty sand beds overlying the first bay clay, and the second contains sand and gravel beds overlying the discontinuous clay bed and aquitard known as the second bay clay. The lower member contains alternating sand, silty sand, gravel, gravelly sand, silty clay, and clay. The upper 8 to 46 m [26 to 150 ft] of this lower member consists of sand and gravel overlying the 15-m [50-ft]-thick Unit F clay, which functions as a regional aquitard. Below the Unit F clay lie alternating beds of clean, well-sorted sand and clay. Locally overlying the Hookton Formation in the vicinity of Buhne Point Hill are Holocene deposits consisting of colluvial, landslide, alluvial, and estuarine marsh facies.

As described in Section 2.5.1 of the SAR, the Unit F clay of the lower Hookton Formation lies at elevations between !29 and !34 m [!95 and !110 ft] with respect to MLLW and is at a depth of approximately 40 m [130 ft] immediately below the ISFSI site. The Unit F clay is observed to be continuous across an uplifted fault block between the Buhne Point Splay Fault and the Discharge Canal Fault. The SAR states that trench studies provide direct evidence that the upper part of the lower Hookton Formation (including the Unit F clay) and the upper Hookton Formation deposits are not faulted and, thus, exhibit continuous strata (except for facies gradations) in the near surface beneath the ISFSI site.

The staff finds the description of the stratigraphy in Sections 2.5.1 and 2.6.4.3 of the SAR as they relate to subsurface hydrologic conditions acceptable because the basic stratigraphic and structural characteristics of the site and vicinity are described in adequate detail to allow evaluation of the subsurface hydrology in the vicinity of the Humboldt Bay ISFSI site. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.2 Aquifers

Section 2.5.2 of the SAR reviews major aquifers in the region of the HBPP, including unconfined aquifers within alluvium, terrace deposits, and dune sands, and confined and unconfined aquifers within the Hookton Formation. In the immediate ISFSI site vicinity, the Elk River Valley alluvial aquifer is the main water-bearing unit. Terrace deposits at the ISFSI site are discontinuous and undeveloped as aquifers. Dune sand aquifers are not present at the ISFSI site. As discussed in the previous section, the lower Hookton Formation is an important water-bearing confined aquifer beneath the ISFSI site.

The 67 borings at the HBPP identify several aquifers and zones of perched groundwater. The first zone of perched groundwater in the area is located within Holocene silt and clay deposits; below this zone are several other discontinuous perched water bodies in the 9-m [30-ft]-thick upper Hookton silt and clay beds. No information is available regarding Holocene perched water in the immediate vicinity of the ISFSI site. Perched water is indicated, however, at depths from 3 to 4.6 m [10 to 15 ft] below the ISFSI surface elevation within the upper Hookton silt and clay beds. In comparison, the base of the HI-STAR HB cask system will be located at a depth of 3.3 m [10.7 ft], and the ISFSI vault will be located at a depth of 4.2 m [13.7 ft] below the ISFSI surface. Brackish groundwater is found in the semiconfined upper Hookton aquifer, which is greater than 33 m [100 ft] thick, and located between the Unit F clay and the overlying silt and clay beds of the upper Hookton Formation. The applicant indicates that the elevation of the ISFSI area is approximately 13m [44 ft] above MLLW. According to data collected in 1999, the piezometric surface of the semiconfined upper Hookton aquifer near the ISFSI site is estimated at approximately 1.3 m [4.4 ft] above MLLW, as reported in SAR Figure 2.5-9. Thus, there is approximately 12 m [40 ft] between the ISFSI surface elevation and groundwater table. The piezometric surface in the upper Hookton aquifer lags tidal variations in the bay and changes in elevation by approximately 1 m [3 ft] during each tidal cycle. The discontinuous second bay clay is present below the ISFSI, and where present, it confines the lower portion of the upper Hookton aquifer. Freshwater is found below the Unit F clay in the sands and gravels of the confined lower Hookton aquifer.

The staff finds the description of aquifers in Section 2.5.2 of the SAR acceptable because the regional and local water-bearing units are described in adequate detail to allow evaluation of the subsurface hydrologic characteristics of the Humboldt Bay ISFSI. The applicant indicates that the occurrence of perched groundwater at the base of an ISFSI excavation will not impact the construction or operation of the ISFSI site (Pacific Gas and Electric Company, 2004b). The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.3 Groundwater Recharge, Gradients, and Discharge

Sections 2.5.3 and 2.5.4.2 of the SAR summarize groundwater recharge, gradients, and discharge regionally and in the vicinity of the ISFSI site. The SAR notes that groundwater level and flow direction at the site are largely controlled by topography, tides within Humboldt Bay, and stratigraphy.

Recharge to shallow water-bearing units in the area is generally from precipitation; lateral flow from adjacent formations; tide-induced seawater intrusion; and river, stream, and canal seepage. Deeper confined aquifers are recharged where the formations outcrop far from the ISFSI site (e.g., at Humboldt Hill) and also from the Elk River alluvial aquifers. Regionally, groundwater generally flows west to northwest toward the coast. Locally, some water flows upward because of leakage between water-bearing units. Because the stratigraphy dips to the southeast, discharge from local perched water bodies is directed to nearby marshes or to either the intake or discharge canal. Discharge in the region occurs through subsurface flow into springs, rivers, streams, tidal estuaries, the bay, and the ocean and by evapotranspiration and pumping or artesian flow from wells.

The staff finds the description of groundwater recharge, gradients, and discharge in Sections 2.5.3 and 2.5.4.2 of the SAR acceptable because groundwater sources, sinks, and gradients are described in adequate detail to allow evaluation of the subsurface hydrologic characteristics of the Humboldt Bay ISFSI. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.4 Hydraulic Properties of Aquifers

Section 2.5.4 of the SAR summarizes regional well yields and hydraulic properties of aquifers and perched water zones in the vicinity of the ISFSI site. Regional, along-river alluvial aquifers are significant water-bearing units in the Humboldt Bay area. Specific capacities for wells in these aquifers range between 4 and 72 L/s per meter [20 and 350 gpm per foot] of drawdown. Alluvial aquifers, however, do not lie below the ISFSI site. Specific capacities for wells in the lower Hookton aquifer are much lower than for wells in the nearby alluvial aquifers, with values on the order of 0.1 L/s per meter [0.5 gpm per foot].

The staff reviewed information concerning vertical and lateral groundwater gradients, vertical and lateral hydraulic conductivities, vertical and lateral flow velocities, transmissivities, and storativity in aquifers and perched water zones below the ISFSI site. The staff finds the description of regional well yields and hydraulic properties of aquifers in the SAR acceptable because these topics are described in adequate detail to allow evaluation of the subsurface hydrologic characteristics of the Humboldt Bay ISFSI. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.5 Groundwater Use

Section 2.5.5 of the SAR summarizes regional and local groundwater use, as well as use in the vicinity of the ISFSI site. The water supply needed for the nearby city of Eureka is exclusively met by surface water from the Mad River and Ruth Reservoir. All other water needs in Humboldt County are met by groundwater. Groundwater is used for irrigation, industrial, public, and domestic water supply needs. Groundwater is mainly extracted from shallow wells in along-river alluvial aquifers or in terrace deposits in the Eel, Mad, and Van Duzen River valleys. The lower Hookton Formation is an important aquifer, but well yields are substantially less than those from alluvial aquifers. There are at least 37 active wells located within a 3.2 km [2 mi] radius of the ISFSI site. Two of these wells are industrial; four are for monitoring; one is a test well; sixteen are domestic; six are for irrigation; one is a dual-purpose domestic/irrigation well; five are municipal, water companies, or commercial; and two are dual-purpose domestic/water company wells. Apart from small amounts of onsite water used for dust control and wash down of equipment during the construction phase, construction and operation of the ISFSI site is not expected to result in additional consumption of or discharge to groundwater below the ISFSI. Potable water for operations will come from existing HBPP supplies (Pacific Gas and Electric Company, 2004b). There is no surface or subsurface drinking water source on site (Pacific Gas and Electric Company, 2004b).

The staff finds the description of groundwater use in Section 2.5.5 of the SAR acceptable because the detail provided is adequate for evaluation of the degree to which aquifers below the ISFSI site are groundwater resources. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.6 Groundwater Quality

Sections 2.5.6 and 2.5.2.2 of the SAR provide information on regional groundwater quality, as well as quality in the vicinity of the ISFSI site. The staff reviewed information provided by the applicant regarding regional chloride concentrations. All perched water bodies in the vicinity of the ISFSI site are brackish, with electrical conductivity of the upper Hookton aquifer between 1,100 and 26,000 µÉ/cm and conductivity of the lower Hookton aquifer between 140 and 200 µÉ/cm. Apart from the naturally brackish conditions of perched water bodies and the semiconfined upper Hookton aquifer, there is no known groundwater contamination below the ISFSI site. The applicant concludes in the SAR that groundwater quality will not be affected by the ISFSI.

The staff finds the description of regional and onsite groundwater quality in the SAR acceptable because the detail is adequate to allow evaluation of the impact a potential ISFSI would have on groundwater quality. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.5.7 Contaminant Transport Analysis

In Sections 2.5.7 and 2.4.8 of the SAR, the applicant states that because the ISFSI will not produce radioactive waste that can be incorporated into surface runoff, no radioactive contamination will be produced that could adversely affect the surrounding ecosystem. Thus, the applicant indicates that because no radioactive waste will be produced by the ISFSI, a detailed analysis of contaminant transport in groundwater as a result of ISFSI operation is not necessary.

The staff reviewed the applicant's information in Section 2.5.7 of the SAR concerning the potential for the release and transport of radionuclides from the ISFSI site via the hydrologic system and finds it acceptable.

The applicant has shown that the HI-STAR HB cask system cask will contain the radioactive waste during all normal, off-normal and postulated accident conditions. Consequently, no waste will be incorporated into the groundwater system. Thus, the staff concludes there will be no radioactive contaminant transport. The staff, therefore, has determined that this information is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.98(c)(2) and §72.122(b)(4) with respect to this topic.

2.1.6 Geology and Seismology

Section 2.6 of the SAR describes the geological, seismological, and tectonic setting of the Humboldt Bay ISFSI. The staff reviewed Sections 2.6.1 through 2.6.8 of the SAR. The staff reviewed the geology and seismology with respect to the regulatory requirements in 10 CFR §72.90(a–d), §72.92(a–c), §72.94(a–c), §72.98(a–c), §72.103 (c–f), and §72.122(b)(4).

2.1.6.1 Basic Geologic and Seismic Information

Basic geologic and seismic characteristics of the site and vicinity are presented in Sections 2.6.1 through 2.6.5 of the SAR. This information forms the basis for establishing site geological and seismological conditions and supports the development of the seismic, faulting, and tsunami hazard assessments for the ISFSI site. Site investigations related to these natural hazards have been ongoing at the HBPP since before construction of the 63 MW Humboldt Bay nuclear reactor in 1962. In the SAR, the applicant summarizes the geological, geophysical, and tectonic studies conducted to develop site-specific seismic, faulting, and tsunami hazards for the ISFSI site. In addition to site-specific and region-specific data, the applicant examined recent earthquakes in Turkey and Taiwan, as well as tectonic and seismotectonic information from Alaska, as appropriate analogs to site conditions at the HBPP site.

<u>Tectonic Framework</u>

Section 2.6.2 of the SAR summarizes the tectonic framework of the Humboldt Bay ISFSI site. The ISFSI site lies within the southernmost extent of the Cascadia subduction zone and just north of the Mendocino triple junction. This region is structurally complex and seismically active. The active tectonics results from plate-boundary interactions between the North American, Gorda-Juan de Fuca, and Pacific tectonic plates. The Mendocino triple junction is a zone of complex deformation where all three tectonic plates meet. North of the Mendocino triple junction, the Gorda-Juan de Fuca tectonic plate subducts eastward beneath the North American plate along the 1,100 km-long Cascadia subduction zone. South of the triple junction, the Pacific tectonic plate is moving north-northwest relative to North America along a series of right-lateral strike slip faults within the San Andreas fault zone. West of the triple junction, the relative west-northwest motion of the Pacific tectonic plate with respect to the Gorda-Juan de Fuca plate occurs along the east-west Mendocino transform fault zone. The motion is transpressive, with components of right-lateral strike slip and contractional deformation. Historic seismic and paleoseismic data indicate large earthquakes [with moment magnitude ($\mathbf{M}_W$) > 7.0] have occurred throughout the region as the results of these tectonic plate motions.

Convergence between the Gorda-Juan de Fuca and North American plates along the Cascadia subduction zone is accommodated by the plate boundary megathrust, which serves as the interface between the down-going oceanic and over-riding continental lithospheric plates. In addition, convergence is manifest in a broad west-vergent fold and thrust belt that is shortening the continental crust in response to tectonic convergence of the lithosphere plates.

According to the SAR, slip on the Cascadia subduction zone is partitioned among three megathrust segments. The main segment is 1,000 km [620 mi] long and extends from just north of Humboldt Bay to north British Columbia. Two smaller segments, the 80-km [50-mi]-

long Eel River segment and the 25- to 30-km [15- to 19-mi-]-long Petrolia segment, extend south from the ISFSI site to the Mendocino triple junction. Each of these three segments has a unique slip history based on seismic and paleoseismic information. As a result, the applicant treats them as three unique seismic sources in their seismic hazard assessment. The two smaller Petrolia and Eel River segments of the subduction zone are the result of a high degree of internal deformation within the southern Gorda-Juan de Fuca plate, possibly because of asymmetrical spreading at the Gorda rise coupled with left shear within the southern Gorda-Juan de Fuca plate.

The applicant identifies the main Cascadia subduction zone as belonging to a class of subduction zones in which the down-going and over-riding lithospheric plates are strongly coupled. Strongly-coupled subduction zones are characterized by long ruptures (up to 1,000 km [621 mi]), oblique convergence, subduction of relatively young ocean lithosphere leading to shallow subduction angles (10E or less), and moderate convergence rates (on the order of 2.0 to 5.0 cm/yr [0.8 to 2.0 in/yr] based on geophysical plate kinematic models). Worldwide data shows that strongly coupled subduction zones produce infrequent but large-magnitude earthquakes. The $\mathbf{M_w}$ = 9.5 1960 Chilean earthquake and the $\mathbf{M_w}$ = 9.2 1964 Good Friday earthquake in Alaska both occurred on megathrusts in strongly coupled subduction zones.

There are no direct historical accounts of such large-magnitude earthquakes on the Cascadia subduction zone. Paleoseismic data from numerous sites in the northwest United States indicate, however, that a great earthquake ruptured the Cascadia megathrust in approximately AD 1700. This event correlates with historical accounts of a large trans-pacific tsunami that struck Kuwagasaki, Japan, on January 27, 1700. Similarly, there are no historic earthquake records for the rupture of the Eel River segment. Paleoseismic evidence in that region, suggests, however, that a significant earthquake ruptured this megathrust segment in the early 1800s. There was a large $\mathbf{M_w}$ = 7.1 earthquake on the Petrolia segment in 1992, which produced a horizontal peak ground acceleration of 0.22 g at the HBPP. This earthquake serves as the model for the seismogenic potential of the Petrolia and Eel River subplates in the applicant’s seismic hazard assessment.

In the SAR, the applicant concludes that slip on thrust faults in the west-vergent fold and thrust is directly related to the rupture of the Cascadia subduction zone megathrust. The two main thrust fault zones that make up the onshore portion of the fold and thrust belt are the Little Salmon and Mad River fault zones. Geologic evidence suggests that slip on the Little Salmon and Mad River fault zones is coseismic with the rupture of the main Cascadia subduction zone megathrust.

The applicant suggests that the Cascadia subduction zone and its associated fold and thrust belt are analogous to the Aleutian subduction zone and its uplifted accretionary prism fold. During the 1964 Good Friday earthquake in Alaska, the rupture of the eastern part of the Aleutian subduction zone produced coseismic slip on the Patton Bay and Hanning Bay faults, which are thrust faults within the accretionary prism. This earthquake is interpreted by the applicant as an appropriate analog for a large earthquake on the Cascadia subduction zone. In their seismic hazard assessment, the applicant develops seismic sources and ground motion attenuation models that explicitly incorporate the potential for coseismic rupture of the Little

Salmon fault system as the result of a megathrust earthquake in the Cascadia subduction zone. This scenario is directly analogous to the 1964 Good Friday earthquake in Alaska.

Stratigraphy

Section 2.6.3.2.1 of the SAR provides a summary of relevant information regarding the regional and local stratigraphy. In that summary, the applicant notes that the HBPP site is located within the broad Eel River forearc basin, which is filled by a thick accumulation of more than 3,500 m [11,500 ft] of Tertiary [65 to 2.0 Ma] and Quaternary [2.0 Ma to the present] marine sedimentary rocks. The youngest rocks of the sedimentary deposits are Pleistocene gravels, sands, silts, and clays of the Hookton Formation, which constitute the strata directly beneath the ISFSI site. The thick accumulation of marine sedimentary rocks rests unconformably over Late Jurassic to Early Tertiary basement rocks of the Franciscan Complex. The Franciscan Complex is a lithologically heterogenous assemblage, or mélange, of oceanic crust and mantle and deep marine sedimentary strata mixed chaotically with submarine landslide material (turbidites) shed from the continental margin. The applicant documents that the marine strata beneath the ISFSI site contains numerous horizontally continuous marker horizons, especially clay beds, that are used to denote the displacement history of nearby faults. The younger units also contain evidence of marine terraces, which also record the uplift and subsidence of the basins in response to faulting and the growth of fault-related folds.

Regional Structural Geology

Section 2.6.3.2.2 of the SAR, describes the regional structural geology as the result of accumulated deformation along north-northwest trending contractional structures that formed during three phases of plate tectonic convergence over the past 150 million years. These three phases are (i) Mesozoic [245 to 65 Ma] and early Tertiary [65 to ~35 Ma] accretion of the Franciscan Complex basement rocks; (ii) middle Tertiary [~35 to ~20 Ma] subduction of the Farallon plate, prior to the development of the San Andreas fault system and modern Cascadia subduction zone; and (iii) late Tertiary and Quaternary [~20 Ma to present-day] Cascadia subduction of the Gorda-Juan de Fuca plate coupled with the northward migration of the Mendocino triple junction.

Regional structures related to all three phases of plate tectonic convergence are evident in the Humboldt Bay region, although only those associated with the present-day Cascadia subduction are of primary concern to the seismic and fault-displacement hazard assessments. Near the HBPP site, contraction associated with the Cascadia subduction is manifest as the active Cascadia fold and thrust belt. In this fold and thrust belt, actively growing fault-related anticlines in the hanging walls of the thrust faults produce uplifted regions. Active hanging wall folds include the Table Bluff, Humboldt Hill, and Fickle Hill anticlines. Between the uplifts are broad and flat-floored footwall synclines that result in actively subsiding depositional basins, including the Freshwater, South Bay, and Eel River synclines. Asymmetry of the folds indicates that the structures verge to the south-southwest.

The applicant identified the Mad River and the Little Salmon fault systems as the two major thrust faults in the vicinity of the HBPP site. Both structures displace Franciscan Complex basement and lower Wildcat Group strata south-southwest thrust over upper Wildcat Group strata and younger sediments. Slip rate estimates for individual faults within the Mad River fault zone, based on marine terrace uplift rates and offsets of dated stratigraphic markers, are in the 1 to 2 mm/yr [0.04 to 0.08 in/yr] range. The applicant reports a combined slip rate across the entire Mad River fault zone, based on recently published information in the scientific literature, of 5 to 9 mm/yr [0.2 to 0.35 in/yr]. Slip rates for the Salmon River fault system are similar. The applicant cites published results showing that both the long-term slip rates, based on stratigraphic markers juxtaposed across the thrust faults, and short-term slip rates, based on paleoseismic investigations, are 8 to 13 mm/yr [0.3 to 0.5 in/yr]. Recurrence intervals are on the order of 500 years, with 1 to 6 m [3.3 to 19.7 ft] of fault displacement per event. Based on the coincidence of the earthquakes on individual thrust faults within the Little Salmon fault system with geologic evidence for rapid subsidence of the intervening synclinal basins, the applicant concludes that the thrust fault events were triggered by the coseismic rupture of the southern Cascadia subduction zone interface.

Historic Earthquake Record

Section 2.6.3.3 of the SAR provides a detailed summary of historic earthquakes, which includes historical and instrumentally recorded earthquakes from 1850 through April 2002. Historical earthquakes have inferred magnitudes based on damage intensity and, thus, are limited to events with a $\mathbf{M_W}$ of 5.0 to 5.5 and larger. Although seismographic stations have existed in the region since 1932, the reliable instrumental record began in 1974, with the installation of a seismic network at the HBPP site. The applicant's analysis includes a discussion of earthquakes with a $\mathbf{M_W}$ of 3 or greater within 160 km [100 mi] of the site and earthquakes with a $\mathbf{M_W}$ of 2.0 and greater within 40 km [25 mi] of the site.

The earthquake record compiled by the applicant documents 121 earthquakes with a $\mathbf{M_W}$ of 5 and larger within 160 km [100 mi] of the site since 1850. (An earthquake magnitude scale depends on the specific source for the tabulated information and includes moment magnitude, body wave magnitude, Gutenberg-Richter magnitude, Gutenberg local magnitude, and magnitudes estimated from intensity data). The number is a minimum because, prior to the deployment of seismographs and seismic networks, an undetermined number of moderate to large magnitude earthquakes could have occurred offshore without causing recordable damage to onshore structures. Details of each of these 121 earthquakes are provided in SAR Table 2.6-4. The detailed list considered a range of earthquake catalog sources, including the University of California at Berkeley (2002) and the U.S. Geologic Survey (2002). Of the 121 earthquakes listed in the SAR, 53 occurred after commercial operation began in August 1963.

In addition to the catalog of local and regional earthquakes, the SAR also lists two prominent earthquakes that are known or inferred from historical data. These inferred earthquakes are the 1700 great Cascadia subduction zone earthquake and the 1906 San Francisco earthquake. The earthquake on the Cascadia subduction zone is interpreted from regional paleoseismic and paleotsunami data coupled with historical data from native tribes and from a detailed historical account of a trans-pacific tsunami wave that struck Japan on January 27, 1700. There was considerable damage reported by nearby communities after the earthquake.

Strong-motion recordings have been collected at the site since 1974. Six earthquakes since then have produced peak ground accelerations at the site in excess of 0.10 g. The largest ground motion recorded at the site was a peak horizontal acceleration (north-south component) of 0.55 g produced by a $\mathbf{M_W}$ = 5.4 earthquake approximately 8 km [5 mi] west of the HBPP site.

None of these six earthquakes resulted in significant structural damage to existing facilities at the HBPP site.

Site Geology

Section 2.6.4 of the SAR provides a detailed description of the site geology that is consistent with the guidance provided in NUREG-1567 (U.S. Nuclear Regulatory Commission, 2000). The description of the site geology is based on surface mapping, boreholes, and trenching studies conducted over the past 40 years. The site is underlain by more than 900 m [2,950 ft] of predominantly Pleistocene (1.6 Ma to 10 ka) and Holocene (last 10 ka) sedimentary strata. These strata are well bedded and comprise the Rio Dell, Scotia Bluffs, and Hookton formations, as well as late Pleistocene (last 250 ka) and Holocene paleosols and other surficial deposits.

The ISFSI site is situated on the hanging wall of the Little Salmon fault zone, which consists of four mapped fault traces. These four fault traces are the Little Salmon, Bay Entrance, Buhne Point, and Discharge Canal faults. Although all faults show evidence for geologically recent displacements, the continuity of several strata markers across the site indicate that significant fault slip is largely confined to the individual fault surfaces. In addition, the applicant concludes that because the late Pleistocene (last 80 ka) upper Hookton Formation strata is continuous across the site, there has been no significant faulting at the site in the last 80,000 years.

Seismic Source Characterization

In Section 2.6.5 of the SAR, the applicant provides both probabilistic and deterministic seismic hazard assessments. As discussed in Section 2.1.6.2 of this SER, the Design Earthquake (DE) for the ISFSI is based on the deterministic hazard assessment, which the applicant shows envelopes the 2,000-year return period probabilistic uniform hazard spectra.

The approach used by the applicant to develop seismic source characteristics for their deterministic seismic hazard assessment is consistent with U.S. Nuclear Regulatory Commission (NRC) guidance (e.g., U.S. Nuclear Regulatory Commission, 2003a). The deterministic seismic hazard assessment is based on the Cascadia subduction zone earthquake developed by the California Division of Mines and Geology (Toppozada, et al., 1995). This scenario considers a large-magnitude rupture of the subduction zone interface along the 240-km-long [150-mi-long] Gorda segment coupled with a coseismic rupture of the Little Salmon thrust fault. Based on geometric characteristics of the subduction zone interface and Little Salmon fault zone, the applicant assigns a maximum $\mathbf{M_W}$ of 7.7 to the Little Salmon fault zone and a $\mathbf{M_W}$ of 8.8 to the subduction zone interface. Closest mapped approaches of the ISFSI site to these sources are used for site-to-source distances. The site-to-source distances are used in the ground motion attenuation relationships to define how close an earthquake rupture could occur. In the deterministic analysis, the applicant used the closest possible distance from the site to the source because this assumption is conservative.

For the probabilistic seismic hazard assessment, the applicant developed six contributing seismic sources: (i) the main Cascadia subduction zone interface; (ii) the Cascadia Eel River subplate; (iii) the Cascadia Petrolia subplate; (iv) Little Salmon fault; (v) the Gorda plate; (vi) Zone D, a background source zone (Geomatrix Consultants Inc., 1994); (vii) the Mad River fault zone; (viii) the Mendocino fault zone; and (ix) the North San Andreas fault. Source characteristics were derived from available geologic and geophysical information coupled with length- and area-scaling relationships for magnitudes (e.g., Wells and Coppersmith, 1994). Detailed source information is provided in calculation package GEO.HBIP.03.04 (Pacific Gas and Electric Company, 2003a).

The staff reviewed the information in the SAR concerning basic geology and seismic information and finds it acceptable because the applicant adequately considered all necessary and relevant information in their assessment. Consistent with 10 CFR §72.92(a–b) and §72.98(a), the information in the SAR is sufficient to identify and assess potential earthquake hazards with respect to the safe operation of the ISFSI. The information in the SAR provides a comprehensive evaluation of the tectonics setting, regional and local stratigraphy, regional and local structural geology, and historic seismicity such that reliable and robust seismic sources could be identified and characterized to support an estimation of the DE as prescribed in 10 CFR §72.103(f). The staff, therefore, determined that this information is acceptable for use in other sections of the SAR to develop the design basis ground motions for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.92(a–b), §72.98(a), §72.103(f), and §72.122(b) with respect to this topic.

2.1.6.2 Ground Vibration

Section 2.6.6 of the SAR discusses the development of design basis vibratory ground motions associated with credible levels of vibratory ground motions that may be experienced at the ISFSI site. In reviewing the applicant’s development of vibratory ground motions, the staff considered factors related to the principal elements of seismic hazard analyses and procedures for determining the DE. The staff reviewed the applicant’s investigations of basic geologic and seismic information, as discussed in Section 2.1.6.1 of this SER, and the following essential aspects of ground vibration at the Humboldt Bay ISFSI: (i) applicable ground motion attenuation relations, (ii) synchronous rupture, (iii) near source effects, (iv) site response analyses, (v) deterministic and probabilistic seismic hazard analyses, and (vi) design spectra and spectrum compatible time histories.

The applicant cites 10 CFR Part 72 as the basis for determining ISFSI DE ground motions. Until its revision in October 2003, this regulation and, in particular, 10 CFR §72.102, required the development of a DE in accordance with 10 CFR Part 100, Appendix A. The seismic hazard methodology in 10 CFR Part 100, Appendix A, is based on a deterministic approach in which the largest credible earthquake that could occur on the closest approach of the seismic source to the site is considered as the DE. In 2003, 10 CFR Part 72 was amended. The rule change requires that uncertainties inherent in estimates of the DE be addressed through an appropriate analysis, such as probabilistic seismic hazard analyses (PSHA) or suitable sensitivity analyses, as set forth by 10 CFR §72.103. Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) provides general guidance on procedures acceptable to the NRC staff in conducting the PSHA and developing the DE to satisfy the requirement of 10 CFR Part 72. Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) further specifies that the controlling earthquakes are to be developed for the ground motion level corresponding to the mean reference probability of 5×10^{-4} per year, which is approximately equal to the 2,000-year return period earthquake.

The approach followed by the applicant in characterizing ground vibration consists of (i) developing the design basis response spectra based on a deterministic approach, consistent with the requirements of 10 CFR Part 100, Appendix A; (ii) developing the licensing basis response spectra based on a probabilistic approach, consistent with 10 CFR §72.103 and Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a); (iii) demonstrating that the deterministic design basis spectra envelopes the corresponding PSHA-based licensing basis spectra at all spectral periods; and (iv) developing four sets of ground motion time histories that are compatible with the design basis spectra for use in analyses and design.

Ground Motion Attenuation

In the applicant's deterministic and probabilistic seismic hazard analyses, earthquakes occurring on the Cascadia interface and within the Gorda-Juan de Fuca Plate were considered subduction interface and subduction intra-slab earthquakes, respectively. All other earthquakes were considered crustal earthquakes. For the subduction interface and intra-slab earthquakes, the Youngs, et al. (1997) attenuation model was used to calculate horizontal rock motions, which were then scaled to soil surface ground motions using site-specific amplification factors (Pacific Gas and Electric Company, 2003a). The Youngs, et al. (1997) model does not include calculation of the vertical component of ground motion; therefore, surface vertical motions for subduction earthquakes were scaled from soil surface horizontal motions using the scaling factors of Abrahamson and Silva (1997). For crustal earthquakes, the attenuation models of Abrahamson and Silva (1997), Sadigh, et al. (1997), Idriss (1991, 1994, 1995), and Campbell (1997) were used with equal weight to calculate horizontal rock motions, which were then scaled to soil motions using site-specific amplification factors (Pacific Gas and Electric Company, 2002a,b). The vertical motions from crustal earthquakes were calculated using the Abrahamson and Silva (1997) model directly for the surface soil conditions. Spectral values for all calculations were extrapolated to a spectral period of 10 seconds to cover a broader spectral range.

In response to a request for additional information (Pacific Gas and Electric Company, 2004c), the applicant evaluated two recently published attenuation models, namely Gregor, et al. (2002) for subduction interface earthquakes and Atkinson and Boore (2003) for subduction intra-slab earthquakes. Hazard results were recalculated to include these two new models. The new results show that using the Atkinson and Boore (2003) model does not lead to a significant difference in hazard results. The Gregor, et al. (2002) model, on the other hand, produced much larger long period ground motions than the Youngs, et al. (1997) model. Nevertheless, the deterministic design spectra used for the evaluation of the facility envelope the updated spectra using the Gregor, et al. (2002) model and, therefore, are conservative. The applicant further concludes that the empirically based Youngs, et al. (1997) model is more reliable than the numerically based Gregor, et al. (2002) model because it predicts ground motions that are more consistent with recorded ground motions from past earthquakes. In addition, the current state of development of the numerical simulations is limited to a small range in spectral frequency and earthquake magnitudes. These observations are consistent with the staff independent evaluations of subduction interface ground motion attenuation models, including Gregor, et al. (2002), Atkinson and Boore (2003), and Youngs, et al. (1997).

Synchronous Rupture

As discussed in the previous section on seismic sources, the applicant considered that the Little Salmon fault is a splay of the main Cascadia Subduction interface and that the two structures rupture simultaneously (synchronous rupture). The effect of synchronous rupture was considered in the development of response spectra and time histories, based on the assumption that the Fourier phase angles for the two subsources are uncorrelated (random differences in the phase angles between the two subsources).

Based on the random vibration theory, the response spectra for synchronous rupture in both the deterministic seismic hazard analysis (DSHA) and PSHA were calculated as the square root of the sum of squares (SRSS) of the response spectral values of the individual subsources. The staff compared the SRSS and total moment approaches.

In general, the SRSS method yields higher ground motion, although the difference decreases with decreasing frequency. Consequently, the SRSS method is the more conservative method. The total moment approach estimates the total moment for multiple ruptures as the sum of seismic moments from each rupture. The corresponding combined magnitude is then calculated using the $\mathbf{M_W}$ relationship of Hanks and Kanamori (1979). The combined moment magnitude and site-to-source distance to the nearest rupture is used to calculate ground motion for multiple ruptures. The approach based on the random vibration theory is the approach taken by the applicant. This approach computes ground motion for multiple ruptures as the square root of the SRSS of the motions from the individual ruptures. This approach assumes that the motions from each rupture overlap in time at the site and that the motions from each rupture are uncorrelated (interfere randomly).

The staff analyzed the characteristic magnitudes and weight distributions assigned by the applicant (Pacific Gas and Electric Company, 2003a) for the Cascadia subduction interface and the Little Salmon fault zone and conducted a deterministic analysis for synchronous rupture using total earthquake moment and SRSS approaches. In the total moment approach, the $\mathbf{M_W}$ relationship of Hanks and Kanamori (1979) was used to calculate the earthquake moment for each subsource based on the PG&E characteristic magnitude distribution and assigned weight distributions. The moments from the two subsources were added to obtain total moment for synchronous rupture. The Little Salmon fault zone and the subduction interface were then treated as one single fault zone. The crustal attenuation relations of Abrahamson and Silva (1997), Sadigh (1997), and Campbell and Bozorgnia (2003) were used with equal weight. In the SRSS approach, the response spectrum for the Little Salmon fault zone was calculated using the attenuation relations of Abrahamson and Silva (1997), Sadigh (1997), and Campbell and Bozorgnia (2003) with equal weight. The spectrum for the Little Salmon fault zone was combined with the spectrum for the Cascadia subduction interface calculated using the attenuation relations of Youngs, et al. (1997) and Gregor, et al. (2002), respectively. These analyses show that the higher ground motion from the Cascadia interface predicted by Gregor, et al. (2002) causes notable increase in the spectrum for synchronous rupture.

In addition to spectral analyses, the applicant considered the effect of synchronous rupture in the development of ground motion time histories. Based on the assumption of random differences in the phase angles between the two subsources, time histories for synchronous rupture were obtained by adding time histories from individual sources in the time domain. In combining the time histories from individual sources, the applicant selected four different relative time shifts between the motions from individual sources to constrain the relative timing to reflect the uncertainty in rupture initiation locations on the main Cascadia interface. The time histories were combined such that the strong shaking from the Little Salmon fault source occurs during the strong shaking from the main Cascadia interface source. This approach for developing ground motion produced by synchronous rupture is new in earthquake engineering practice related to nuclear facilities. Although synchronous rupture had occurred in past subduction earthquakes (e.g., 1964 Alaska earthquake), there are no available strong motion recordings from such synchronous rupture that could be used to verify the approach.

To gain confidence and better understanding, the staff independently combined the time histories from individual sources following the applicant's approach, but with varying time shifts to account for uncertainties in the source-to-site travel times. The staff evaluation shows that the main effect of adding the subsource time histories is a slight increase in short period ground motions. The occurrence of constructive and destructive interferences appears to be random. An important aspect of the applicant's approach is that the resulting time history spectra are rematched to the soil spectra for synchronous rupture (i.e., the design spectra) to ensure that all spectral frequencies are fully represented in the resulting time history. With spectral rematching, the staff finds that the applicant's results are conservative.

Near Source Effects

Near source effects, including directivity and fling, were considered in the applicant's ground motion analyses because (i) the proposed ISFSI site is close to the earthquake sources and (ii) the existing empirical ground attenuation models do not include such effects. The methodology and scaling factors of Somerville, et al. (1997) were used to account for directivity effects. Fling is caused by permanent tectonic deformation and affects the long-period ground motions at sites near causative faults. Fling was accounted for by adding a fling acceleration time history to the fault normal and vertical directions of the design ground motion time histories. The development of fling parameters is documented in Pacific Gas and Electric Company (2002b, GEO.HBIP.02.05).

Site Response Analyses

The site for the proposed ISFSI at the HBPP consists of 122 to 183 m [400 to 600 ft] of medium dense to very dense alluvial soils, including clayey sand, silt, sandy and silty clay, clay, silty sand, sand, and gravel. The shear wave velocity increases from about 213.4 m/s [700 ft/sec] in the upper 6 m [20 ft] to about 609.6 m/s [2,000 ft/sec] near the base of the sediments. The applicant considered the effect of site soil responses using an equivalent linear procedure. Selected empirical ground motion time histories were propagated through three soil profiles, representing the median, upper bound, and lower bound soil properties, to develop site specific soil amplification factors (Pacific Gas and Electric Company, 2002a, 2003b). Two sets of site response analyses were conducted to calculate amplification factors for deterministic and probabilistic motions, respectively, using different characteristic earthquake magnitudes. It was observed that the equivalent linear procedure analysis tends to overdamp large input motions at high frequencies. Consequently, the applicant used large amplitude ground motions recorded during the 1994 Northridge, California, earthquake on seven soil sites to constrain the spectral shape of the site specific PSHA and DSHA spectra.

Deterministic Seismic Hazard

In the deterministic seismic hazard analysis (Pacific Gas and Electric Company, 2002c, GEO.HBIP.02.04), the applicant assumed that the deterministic ground motion at the site results from the synchronous rupture of the Cascadia subduction zone and Little Salmon fault. Specifically, the applicant considers a earthquake with a $\mathbf{M_W}$ of 7.7 on the Little Salmon fault zone with zero site-to-source distance (because the Little Salmon fault is located directly beneath the site) combined with an earthquake with a $\mathbf{M_W}$ of 8.8 on the main Cascadia interface with 7 km [4.3 mi] site-to-source distance. The analysis procedure included (i) calculating response spectra for each of the two controlling earthquakes using the applicable attenuation models discussed earlier; (ii) applying directivity effects to Little Salmon spectra, resulting in separated spectra for fault normal and fault parallel components; (iii) obtaining response spectra for synchronous rupture by combining response spectra of the two individual earthquakes using SRSS; (iv) obtaining soil surface spectra by multiplying the horizontal rock acceleration response spectra for synchronous rupture by the site-specific soil amplification factors; and (v) modifying the soil response spectra to expand the spectral range and to add constraints based on the 1994 Northridge earthquake. The deterministic analyses yielded a peak horizontal ground acceleration of 1.316 g for both fault normal and fault parallel components and a peak vertical ground acceleration of 1.673 g. The applicant's PSHA is based on well established methodologies and includes calculations of the seismic hazard from individual sources and calculations of total hazard from all potential seismic sources. The PSHA was performed generally in accordance with Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a); however, the mean spectral ground motion levels were computed specifically at frequencies of 0, 0.33, 1.0, and 5.0 Hz, which are different from the Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) values of 1.0 and 10.0 Hz. The applicant's use of the revised frequencies is acceptable for use at the Humboldt Bay site because earthquake response at frequencies beyond 5 Hz will not be significant.

Probabilistic Seismic Hazard

The applicant's PSHA (Pacific Gas and Electric Company, 2003a) is based on well established methodologies and includes calculations of the seismic hazard from individual sources and calculations of total hazard from all potential seismic sources. Such calculations produce hazard curves that depict the relationship between levels of ground motion and probabilities at which the levels of ground motion are exceeded. The mean total hazard curves and hazard curves by source were calculated at 15 spectral ordinates. The final uniform hazard spectra were generated for fault normal, fault parallel, and vertical directions for a number of return periods. For the 2,000-year return period (5×10^{-4} annual exceedence probability), the mean peak horizontal ground acceleration is 0.967 g for both the fault normal and fault parallel directions. The mean peak vertical ground acceleration is 0.731 g.

In the PSHA, the applicant tracked both aleatory variability and epistemic uncertainty in the source models, ground motion attenuation, and site response models, consistent with recommendations in the Senior Seismic Hazard Analysis Committee (SSHAC) guidelines (Budnitz, et al., 1997). Aleatory variability was considered using appropriate distribution functions in rock ground motion, earthquake magnitude, rupture dimension, rupture location, and hypocenter location. Epistemic uncertainty was modeled using a logic tree structure. Because only one attenuation relation was used for the subduction sources, there was no epistemic uncertainty modeled for the rock ground motions for these sources. At both short and long periods, the hazard for the 2,000-year return period is dominated by the Little Salmon/Cascadia synchronous rupture. The epistemic uncertainty in these hazard curves is dominated by the uncertainty in the rock ground motion models for the Little Salmon fault source (i.e., different ground motions predicted using the different crustal ground motion models discussed previously) and by the uncertainty in the site response (because of different ground motions predicted using different site specific soil profiles discussed previously). At short periods (e.g., 0.2 seconds), the hazard is dominated by the offshore Gorda sources, and the epistemic uncertainty is dominated by the uncertainty in the recurrence rates of these sources and the site response uncertainty.

Design Basis Ground Motion and Spectrum Compatible Time Histories

The applicant chose the 84th percentile deterministic soil acceleration spectra at 5 percent damping as the design spectra for the proposed ISFSI. The regulatory basis for choosing the deterministic spectra as design spectra is that the horizontal and vertical deterministic soil spectra envelop the corresponding uniform hazard spectra at a 2,000-year return period. A comparison of the deterministic design spectra and the 2,000-year return period uniform hazard spectra is presented in the SAR (Figure 2.6-72). This figure shows that the design spectra envelop the 2,000-year return period uniform hazard spectra at all spectral periods. The applicant also shows that the design spectra have a much broader shape than the 2,000-year return period uniform hazard spectra.

Four sets of three component time histories that match the corresponding deterministic design spectra were developed for design and analyses (Pacific Gas and Electric Company, 2002b, GEO.HBIP.02.05). The development of time histories involved the following process: (i) selecting empirical time histories for individual subsources (i.e., Little Salmon and Cascadia main subduction interface sources), (ii) spectrally matching the empirical time histories to the corresponding soil spectra for individual sources, (iii) combining time histories for individual sources in the time domain to account for synchronous rupture, (iv) adding fling time histories to the fault normal and vertical directions to account for the permanent tectonic displacement, and (v) rematching the combined time histories with fling to the soil spectra for synchronous rupture to obtain final time histories. The spectral matching used the 75 frequencies recommended in Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) and an additional 29 frequencies to cover a broader frequency range. In all of the spectral matching processes, the following requirements were applied to the average of the spectra at multiple damping values from the multiple time histories: (i) no more than 5 of the 75 recommended ordinate frequencies fall below the target spectrum and (ii) no ordinates fall below 0.9 times the target spectrum.

Based on review of the SAR, the staff concludes that the design spectra are conservative because (i) the DSHA-based design spectra exceed corresponding uniform hazard spectra at the 2,000-year return period specified in Regulatory Guidance 3.73 (U.S. Nuclear Regulatory Commission, 2003a); (ii) uncertainties in ground motions were addressed using a PSHA, consistent with the guidelines of SSHAC (Budnitz, et al., 1997) and the requirements of 10 CFR §72.103; (iii) the PSHA is consistent with 10 CFR §72.103, the Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a) procedure, and the state of practice; (iv) the DSHA uses conservative parameters for controlling earthquakes and is consistent with 10 CFR Part 100, Appendix A; and (v) the response spectra of time histories for the design analyses envelop the deterministic design spectra. The staff concludes, therefore, that the design spectra and their compatible time histories are acceptable for use in ISFSI design analyses. The earthquake information is also acceptable for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analyses, and demonstrate compliance with regulatory requirements in 10 CFR §72.92(a–b), §72.103(b), §72.103(f), and §72.122(b) with respect to this topic.

Design Basis Ground Motions For Transient Activities

Section 3.2.4 of the SAR concludes that the risk-scaled DEs for transient activities related to movement of the loaded casks along the transporter route and cask handling activities at the storage vault are significantly less than the 2,000-year return DEs used for the storage vault design. For cask transfer, the applicant uses the 50-year return period uniform hazard spectrum, which has a peak horizontal ground acceleration of 0.4 g. For the cask handling activities at the storage vault, the applicant uses the 25-year return period uniform hazard spectrum, which has a peak ground acceleration of 0.3 g. The staff assessment of the applicability of these risk-modified DEs is provided in Section 4.1.3.2 of this SER.

The staff reviewed the seismic information and concludes that the proposed levels of ground acceleration are sufficient to represent the 25- and 50-year return ground motions. The staff performed an independent check using the earthquake information provided in Tables 2.6-4 and 2.6-5 of the SAR and determined that the 0.3 g and 0.4 g peak horizontal ground accelerations are consistent with the nearly 150-year historical earthquake record. Thus, the staff concludes that the transient design spectra are acceptable for use in the ISFSI design analyses and for use in other sections of the SAR to develop the design bases of the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.92(a–b), §72.103 (b), §72.103(f), and §72.122(b) with respect to this topic.

2.1.6.3 Surface Faulting

Section 2.6.8 of the SAR describes the fault displacement hazard assessment performed by the applicant. Site investigations related to the potential for fault-displacement damage of the HBPP have been conducted by the applicant throughout the past 50 years related to the construction of the HBPP Unit 3 in 1962 and the ISFSI site. In the SAR, the applicant summarizes the geological information used to develop a technical basis to support the applicant's conclusion that surface faulting will not disrupt the ISFSI. In addition to site-specific information, the applicant examined surface fault damage from the recent 1999 earthquake with a $\mathbf{M}_W$ of 7.6 in Taiwan on the Chelungpu fault as an appropriate analog to the potential for surface faulting damage at the HBPP site.

The ISFSI site is situated on the hanging wall of the Little Salmon fault zone. At the HBPP, this fault zone is mapped as having four fault traces at the surface: the Little Salmon, Bay Entrance, Buhne Point, and Discharge Canal faults. The Little Salmon fault itself is a top-to-the-southwest thrust fault that projects to the surface about 2.2 km [1.4 mi] southwest of the site. The Bay Entrance and Buhne Point faults are synthetic splays of the Little Salmon fault. The surface projection of the Bay Entrance fault is no closer than 410 m [1,345 ft] southwest of the ISFSI site. The Buhne Point fault projects to the surface approximately 200 m [656 ft] southwest of the ISFSI site. The Discharge Canal fault is a small-displacement southwest dipping backthrust off the Buhne Point fault that projects to the surface no closer that 125 m [410 ft] from the ISFSI.

All four of these faults are considered active. Slip rates on the Little Salmon fault are in the range of 3 to 12 mm/yr [0.12 to 0.47 in/yr]. Slip rates on the Bay Entrance fault are estimated at 1 to 2 mm/yr [0.04 to 0.08 in/yr]. Given displacements of 1 to 3 m [3.3 to 9.8 ft], these slip rates suggest repeat times for large-magnitude earthquakes of 100 to 1,000 years on the Little Salmon fault and 500 to 1,000 years for the Bay Entrance fault, consistent with paleoseismic evidence. Nevertheless, geologic observations from surface observations and borings at the site indicate that deformation associated with repeated earthquakes on these faults is largely restricted to narrow fault-damage zones or on the slip surface. For example, the applicant shows that late Quaternary strata beneath the site are continuous and largely undisturbed by faulting between the Discharge Canal and Bay Entrance faults. Trenches reveal no evidence of surface faulting within 30 m [98 ft] of the ISFSI. The applicant supports these conclusions with trenching observations of fault deformation across nearby fault scarps, especially those at the College of the Redwoods, and with similarities to the style of deformation that resulted from the 1999 Chi-Chi earthquake on the Chelungpu thrust fault in Taiwan.

The staff reviewed the information in the SAR concerning surface faulting and finds it acceptable because the applicant adequately considered all necessary and relevant information in their assessment. Consistent with 10 CFR §72.92(a–b) and §72.98(a), the information in the SAR is sufficient to identify and assess potential surface faulting hazard with respect to the safe operation of the ISFSI site. The information in the SAR provides a comprehensive evaluation of the surface faulting potential. The staff finds that there is no credible radiological threat to safety from surface faulting at the site. The staff, therefore, has determined that this information is acceptable to use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analyses, and demonstrate compliance with the regulatory requirements of 10 CFR §72.24(a), §72.90(b–d), §72.92(a–c), §72.98(b), §72.98(c)(3), and §72.122(b) with respect to this topic.

2.1.6.4 Stability of Subsurface Materials

The staff reviewed information presented by the applicant in Sections 2.6.7, 4.1, and 4.2 of the SAR. In addition, the staff reviewed supporting data reports: Data Report B (Pacific Gas and Electric Company, 2002d), Data Report C (Pacific Gas and Electric Company, 2002e), Data Report D (Pacific Gas and Electric 2002f), and Data Report E (Pacific Gas and Electric Company, 2002g). The staff also reviewed documents provided by the applicant in response to a request for additional information related to the stability of subsurface materials (Pacific Gas and Electric Company, 2004c).

<u>Geotechnical Site Characterization</u>

The applicant provided subsurface information from several boreholes drilled in the general area of the proposed ISFSI: 13 boreholes in 1973 by Dames and Moore, 5 boreholes in 1980 by Woodward-Clyde, and 5 boreholes in 1999 by Geomatrix (Pacific Gas and Electric Company, 2004c). Only 5 boreholes (GMX99-1-GMX99-5) were used for soil sampling or standard penetration testing. One of the sampled boreholes (GMX99-3) is located within the footprint of the proposed ISFSI pad, three (GMX99-2, GMX99-4, and GMX99-5) are close enough to rely on for site characterization of the pad foundation, but the other sampled borehole (GMX99-1) is too far from the pad. The depth of the boreholes GMX99-3 to GMX99-5 ranged from 19 to 22 m [62 to 72 ft], and GMX99-1 and GMX99-2 were drilled to depths of 29 m [95 ft] and 122 m [402 ft], respectively. None of the boreholes were continuously sampled. The applicant excavated two exploratory trenches with a total length of approximately 70 m [225 ft], and trenches were up to 4.8 m [16 ft] deep at the ISFSI site (Pacific Gas and Electric Company, 2002f, Data Report D). The trenches are shallow and, therefore, provide information only for the near-surface soil stratigraphy.

All boreholes were drilled by mud rotary drilling. Soil samples were collected using a modified California drive sampler, a standard penetration test (SPT) sampler, or a Shelby tube sampler advanced by pushing or Pitcher drilling. Samples at greater depths {61 m below [200 ft]} were obtained by coring. The SPT samplers in the GMX99-1 and GMX99-2 boreholes were driven using a rope and a cathead system with a 63.5 kg [140 pound] hammer and a 76.3 cm [30 in] drop height. An automatic trip hammer was used to drive the SPT sampler in GMX99-3, GMX99-4, and GMX99-5. The SPT resistance number, N, was determined by driving the sampler 45 cm [18 in] into the soil. SPT blowcount N was set to the number of blows needed to drive the sampler through the last 30 cm [12 in]. The approach used to perform the SPT is consistent with standard practice.

The soil samples were tested in the laboratory to evaluate physical, engineering, and index properties. The following laboratory tests were performed: moisture content and unit weight, Atterberg limits (liquid limit and plastic limit), consolidation, grain-size distribution, consolidated-undrained and unconsolidated-undrained triaxial compression, and unconfined compression. The applicant presented the soil laboratory test data and borehole logs for the five sampled boreholes in two data reports (Pacific Gas and Electric Company (2002g and 2002d, respectively).

The applicant also provided geophysical measurements from two boreholes (GMX99-1 and GMX99-2) consisting of compressional wave (P-wave) and horizontally polarized shear wave (S_H-wave) velocities (Pacific Gas and Electric Company, 2002e, Data Report C). The wave velocities are provided as functions of depth to a maximum depth of 26.5 m [87 ft] in GMX99-1 and 125.6 m [412 ft] in GMX99-2.

The applicant estimated the groundwater table to be approximately 1.8 m [6 ft] above MLLW. The groundwater level is approximately 11.3 m [37 ft] below the ground surface or about 6.7 m [22 ft] below the base of the ISFSI vault. Water table location was estimated based on P-wave velocity profiles as shown in Figures 4 and 5 of the calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c). The water table location is consistent with measurements in the monitoring wells, as discussed in the calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d).

The applicant classified the soils at the ISFSI site based on the laboratory and field investigations and visual observation of exposed soil stratigraphy in the exploratory trenches. The soil stratigraphy and approximate thickness of strata, as described in the calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d), is as follows (downward from the ground surface): (i) medium dense clayey sand and stiff sandy clay {2.4 to 3.7 m [8 to 12 ft]}, (ii) very stiff silt and clays {2.4 to 3.4 m [8 to 11 ft]}, (iii) hard silty clay

{0.9 to 1.8 m [3 to 6 ft]}, (iv) very dense and silty sand {7.3 to 7.9 [24 to 26 ft]}, and (v) hard silt and silty clay with thin stratum of very stiff peat {3 m [10 ft]}. The soil below this layer is dense to very dense sand and gravel.

The staff reviewed the geotechnical site characterization information provided in the SAR and concluded that (i) the depth and thicknesses of soil layers and the water table depth at the site were determined using standard methods and procedures consistent with the staff guidance in Regulatory Guide 1.132 (U.S. Nuclear Regulatory Commission, 2003b), and (ii) the index properties and strength and compressibility of the soil layers were determined using an appropriate combination of field and laboratory testing consistent with regulatory guidance in Regulatory Guide 1.138 (U.S. Nuclear Regulatory Commission, 1978).

The staff finds that the small number of relevant boreholes and soil samples and the lack of a continuously sampled borehole leave some uncertainty regarding the subsurface conditions (e.g., such as depth, thickness, and lateral extent of soil layers) at the ISFSI site. The staff considered the applicant's information indicating that the reinforced concrete storage vault will be very stiff relative to the underlying soil and that there will not be any important-to-safety external connections to the vault. As discussed in more detail in Section 2.1.6.5 of this SER, potential deformation of the storage-vault soil foundation, owing to compression or shear failure of the soil, will likely cause a rigid rotation of the vault, but the capability of the vault to perform its safety functions is not likely to be impaired by such potential soil deformation. The staff also considered the regulatory guidance in Regulatory Guide 1.132 (U.S. Nuclear Regulatory Commission, 2003b, p. 1.132-8), which states that, "... foundation requirements should be considered in choosing the actual distribution, number, and depth of borings and other excavations for a site." Based on these considerations, the staff determined that, despite some uncertainty in the subsurface conditions, the information provided by the applicant is sufficient to assess the capability of the storage vault to perform its safety functions as required under 10 CFR §72.122(b).

The staff reviewed the information presented in the SAR and determined that the geotechnical site characterization has been adequately described and assessed. The staff, therefore, concludes that the geotechnical site characterization information presented in the SAR is adequate for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI, perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

<u>Liquefaction Potential</u>

The staff reviewed the information provided in Section 2.6.7 of the SAR and the calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c) regarding liquefaction potential at the ISFSI site. The staff also reviewed information provided by the applicant in response to a request for additional information regarding liquefaction potential (Pacific Gas and Electric Company, 2004c–e).

The applicant addressed the safety of the proposed facility with respect to liquefaction by concluding that the subsurface soils are not susceptible to liquefaction. The applicant cited SPT and geophysical data from the site to support this conclusion.

As discussed previously, four of the boreholes (GMX99-2–GMX99-5) are in the vicinity of the proposed storage vault, and the SPTs in these borings were performed at reasonable depths below the vault. The other borings are located too far from the footprint of the vault to be relevant in this analysis. The staff considered only the data from the four boreholes above in assessing the applicant's SPT information regarding liquefaction potential.

The applicant evaluated the liquefaction potential of the ISFSI based on SPT blow counts (i.e., SPT resistance, N) and the empirical relationship presented by Youd, et al. (2001) between the blow count and seismically induced stress. This method outlined in Youd, et al. (2001) is a modification of the procedure proposed by Seed, et al. (1985). The method is based on a relationship between cyclic stress ratio (CSR) and the normalized blow count $(N_1)_{60}$ [e.g., calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c), Figure 3], where $(N_1)_{60}$ is the SPT blow count normalized to an overburden pressure of approximately 100 kPa (1 ton/ft^2) and a hammer efficiency of 60 percent. The applicant determined the clean sand equivalent of the normalized blow count, $(N_1)_{60\text{-}CS}$ using the following equation:

$$(N_1)_{60\text{-}CS} = (N_1)_{60} + \Delta(N_1)_{60} \qquad (2\text{-}1)$$

Where $\Delta(N_1)_{60}$ is the correction for the fine-particle content and is defined by the following equation:

$$\Delta(N_1)_{60} = \alpha + (\beta - 1)(N_1)_{60} \qquad (2\text{-}2)$$

where α and β are coefficients related to the fine-particle content of the soil. The two equations used by the applicant are consistent with equations provided by Youd, et al. (2001). The applicant also applied other corrections suggested by Youd, et al. (2001) (e.g., for borehole diameter, rod length, and sampling method), as appropriate. The staff finds that the approach used by the applicant is based on standard methodology in accordance with the guidance in Regulatory Guide 1.198 (U.S. Nuclear Regulatory Commission, 2003c).

The applicant provided values of $(N_1)_{60\text{-}CS}$ plotted against depth below the ground surface in Figure 2 of calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c) and assessed the liquefaction potential for soil layers based on the value of $(N_1)_{60\text{-}CS}$ relative to a threshold value of 30. The applicant concluded that a soil layer with a value of $(N_1)_{60\text{-}CS}$ greater than 30 blows per foot is not susceptible to liquefaction considering the relationships provided by Youd, et al. (2001) and reproduced in Figure 3 of the calculation package GEO.HBIP.02.02 (Pacific Gas and Electric Company, 2003c). As indicated in Figure 3, the value of CSR that may cause liquefaction approaches infinity asymptotically at approximately $(N_1)_{60\text{-}CS} = 30$. The value of CSR ($\tau_{av}/\sigma r_{vo}$), which represents the seismic demand induced in the soil from earthquake ground motion, is evaluated using the following equation given by Youd, et al. (2001)

$$\tau_{av}/\sigma r_{vo} = 0.65(a_{max}/g)(\sigma_{vo}/\sigma r_{vo})r_d \qquad (2\text{-}3)$$

where a_{max} is the peak horizontal acceleration at the ground surface; g is the gravitational acceleration; σ_{vo} and σr_{vo} are total and effective vertical stresses, respectively; and r_d is the stress reduction coefficient, based on an empirical relationship provided in Youd, et al. (2001).

The design basis ground motion at the ISFSI site gives an a_{max} of 1.3 g, based on Figure 2.6-72 of the SAR. The value of CSR for the soil layers below the groundwater table to a depth of approximately 18.3 m [60 ft] is estimated to be approximately 0.7 or greater. The relationship provided by Youd, et al. (2001) indicates that liquefaction susceptibility is likely insensitive to CSR for values of $(N_1)_{60\text{-cs}}$ \$ 30. The empirical data supporting the Youd, et al. (2001) relationship, however, is limited to the values of CSR smaller than 0.6.

The applicant relied on the Youd, et al. (2001) relationship to conclude in Section 2.6.7 of the SAR that the ISFSI site is not susceptible to liquefaction because the majority of the $(N_1)_{60\text{-CS}}$ values for the site soils are greater than 30. Even if the Youd, et al. (2001) relationship were applicable, the applicant's data (Pacific Gas and Electric Company, 2003c; calculation package GEO.HBIP.02.02) indicate two $(N_1)_{60\text{-CS}}$ values smaller than 30. The two values appear to be significant because they suggest the occurrence of an approximately 3-m [10-ft] thick soil layer that is potentially susceptible to liquefaction. The potentially liquefiable soil layer was apparently encountered at a depth of approximately 14 m [46 ft] {elevation of 1.2 m [4 ft] below MLLW} in borehole GMX99-2 and approximately 16 m [53 ft] in borehole GMX99-3. The second borehole (GMX99-3) is the only borehole located within the footprint of the proposed storage vault foundation.

In response to the staff's request for additional information (Pacific Gas and Electric Company, 2004c), the applicant provided information indicating the occurrence of a relatively thin, silty soil layer at a depth of approximately 15 m [50 ft] below the ground surface at the ISFSI site. The thin layer encountered in the four boreholes (GMX99-2–GMX99-5) is approximately 1.5 m [5 ft] thick and varies in characteristics from low-plastic inorganic clay (CL) to low-plastic silt (ML). The thin layer is overlain by a thick stiff clay and underlain by dense sand and gravel with silt and clay lenses. The applicant also provided information to support the conclusion that the relatively low $(N_1)_{60\text{-CS}}$ values determined for the silty soil layer in boreholes GMX99-2 and GMX99-3 do not indicate a susceptibility to liquefaction. First, the applicant stated that the $(N_1)_{60\text{-CS}}$ value of 24 originally obtained for the silty soil layer in borehole GMX99-2 resulted from an incorrect interpretation of the measured SPT blow count. The applicant explained that the error occurred because the sampler was blocked by gravel during the attempted penetration of the gravel and sand layer. As a result, the underlying silty clay (or silt) layer was not reached, nor sampled. The applicant reinterpreted the $(N_1)_{60\text{-CS}}$ value as 32. Second, the applicant cited Regulatory Guide 1.198 (U.S. Nuclear Regulatory Commission, 2003c) to support the supposition that a low SPT blow count for a plastic fine-grained soil does not necessarily indicate liquefaction susceptibility because the low blow count is typically more indicative of the plasticity than the relative density of the soil. Third, the applicant provided analysis of shear wave velocities measured in borehole GMX99-2 that indicated soils encountered in the borehole are not susceptible to liquefaction. The analysis was performed based on procedures described in National Center for Earthquake Engineering Research (1997), Youd, et al. (2001), and Andrus and Stokoe (2000, 2004). Fourth, the applicant provided an external expert analysis (Pacific Gas and Electric Company, 2004e), which concluded that the two relatively low $(N_1)_{60\text{-CS}}$ values do not represent any appreciable liquefaction susceptibility for the site. The analysis indicated that the thin soil layers indicated by the low $(N_1)_{60\text{-CS}}$ values are surrounded by much thicker layers not susceptible to liquefaction, such that any liquefaction of the thin layers would be isolated and cause no detrimental effects to the site (Pacific Gas and Electric Company, 2004e).

The staff did not accept the first two arguments presented by the applicant; however, the staff does accept the third and fourth arguments presented. First, the data provided by the applicant were deemed insufficient to support the argument that a subset of the data was incorrect, especially since the data being judged as incorrect by the applicant indicate the potential occurrence of undesirable material behavior. Second, the information cited from Regulatory Guide 1.198 (U.S. Nuclear Regulatory Commission, 2003c) applies to plastic clays, whereas the applicant's data indicate that the soil layer of concern varies in characteristics from low-plastic CL to low-plastic ML. However, the applicant's geophysical and SPT data indicate that the preponderance of soils at the site are not susceptible to liquefaction. Even if lenses or thin layers of liquefaction-susceptible soil were present, any liquefaction of such lenses or thin layers will likely be isolated. Deformation resulting from such liquefaction may cause differential settlement of the ISFSI vault. The magnitude of such differential settlement will likely be negligible considering the small thickness of the silty soil layer relative to the total thickness of soil that may affect the behavior of the storage vault.

The staff reviewed the information presented in the SAR and determined that the liquefaction potential has been adequately described and assessed. The staff, therefore, concludes that the information presented in the SAR regarding the liquefaction potential of the storage vault foundation is adequate for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI and perform additional safety analysis, and demonstrate compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

2.1.6.5 Slope Stability

The staff reviewed Section 2.6.7 of the SAR, which provides an evaluation of the stability of natural slopes. The staff also reviewed applicant responses to the staff's request for additional information (Pacific Gas and Electric Company, 2004c).

The proposed ISFSI storage vault is located on a low and relatively flat terrain referred to as Buhne Point Hill. The hill has a maximum elevation of approximately 23 m [75.5 ft], but based on contour maps provided by the applicant, the elevation at the proposed location of the storage vault is 13.4 m [44 ft]. Buhne Point Hill extends approximately 480 m [1,575 ft] east-west and varies in width from 50 to 180 m [164 to 591 ft]. Buhne Point Hill is bordered on the north by a coastal bluff that drops off steeply (slope ratio of approximately 1:1) to the shore of Humboldt Bay. The hill is bordered on the east and south by the gentle slopes of a tidal marsh. The west side of the hill rises gently to the village of King Salmon, which is built on fill over tidal marsh and beach deposits.

Given these site conditions, potential slope stability problems at the facility are (i) landward retreat of the bluff toward the storage vault, (ii) rotational sliding along a surface that daylights at the bluff, (iii) a slide eastward or southward from the vault, or (iv) failure of the discharge-canal slope near the transporter route. Information provided by the applicant indicates that the retreat of the bluff toward the site is unlikely because such retreat was arrested by the placement of riprap along the base of the bluff in early 1950. The applicant analyzed the potential for a northward slide (bluff-side slope) or a southward slide (plant-side slope) considering static loading from the storage vault and dynamic loading from the design-basis ground motion. The potential for an eastward slide is bounded by the analysis for southward sliding. Although the east and south slopes have similar inclinations of 2- to 6-percent grade [based on Figure 7.1 in GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d)], the south slope daylights into an existing excavation for fuel oil storage tanks, which makes failure of the east slope less likely than the south slope. The applicant also provided an analysis to evaluate the potential for the instability of the slope along this transporter route sliding toward the discharge reservoir. The staff reviewed these analyses to assess the safety of the proposed facility with respect to slope stability.

The applicant used information from one borehole (GMX99-4) to develop the soil stratigraphy and strength parameters for stability analysis of the bluff-side and plant-side slopes. To extrapolate the borehole information through the domain of the stability analysis, the applicant assumed that the soils encountered in the borehole extend laterally as horizontal layers, as depicted in Figures 7-6 and 7-7 of calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). This assumption that soil layers are horizontally continuous is inconsistent with the reasoning provided by the applicant to support its analysis of liquefaction potential. To address the staff's concerns regarding liquefaction, the applicant had previously asserted that a zone of relatively low SPT blow count encountered in boreholes GMX99-2 and GMX99-3 likely represents a laterally discontinuous and weak soil layer. The applicant did not account for the potential occurrence of such soil layers in choosing a model for its slope stability analysis. The occurrence of weak and laterally discontinuous layers is a consideration for slope stability analysis because such relatively weak soil may form a preferential path for a potential failure surface, which would result in an average shear resistance smaller than the shear resistance used in the applicant's analysis. The applicant based its soil strength parameters on standard laboratory testing, such as unconsolidated, undrained triaxial testing for cohesive soils and consolidated, undrained triaxial testing for dense sand [Figures 7-6 and 7-7, calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d)]. To characterize the dynamic behavior of the soils, the applicant used measured shear wave velocities from boreholes GMX99-1 and GMX99-2 and used modulus reduction and damping data from the literature to determine the variation of shear modulus and damping with shear strain during a potential earthquake. The approach used by the applicant to determine values of soil parameters for static and dynamic analysis is consistent with standard practice, but the use of soil specimens from only one borehole for strength data results in some uncertainties in the strength parameter values and shapes of potential failure surfaces used for stability analysis. The potential impacts of such uncertainties are discussed in this section of the SER under "Potential Effects of Slope Instability on the Storage Vault."

The applicant considered a groundwater level at 1.8 m [6 ft] above MLLW {i.e., approximately 11.6 m [38 ft] below the ground surface} in its slope stability analysis. This assumed elevation is conservative with respect to the groundwater information reviewed previously in this section. Potential short-term increase in the groundwater level (e.g., during a tsunami event) was not accounted for in the applicant's slope stability analysis and is evaluated further in this section of the SER under "Stability of Slopes under Tsunami Conditions."

<u>Retreat of the Humboldt Bay Bluff toward the ISFSI</u>

The ISFSI site faces the entrance to Humboldt Bay and is located on Buhne Hill approximately 20 m [65 ft] from the edge of Red Bluff. The SAR notes that Red Bluff experienced 379 to 468 m [1,244 to 1,535 ft] of shoreline retreat between 1858 and 1952. The shoreline was reinforced in the 1950s with a riprap berm along the beach. The riprap berm was later reconstructed with larger riprap in 1989. The current riprap consists of four layers of 9 ton stones and is designed to withstand 3.7 to 4.0 m [12 to 14 ft] high waves. In response to the staff's request for additional information, the applicant provided a detailed analysis of the stabilization of the bluff since riprap was installed along the beach (Pacific Gas and Electric Company, 2004c). In the analysis, the applicant demonstrates that shoreline retreat was essentially abated by the riprap berm. The applicant concludes that the riprap is sufficient to withstand storm damage and even tsunami wave damage to the bluff (Pacific Gas and Electric Company, 2004c). The applicant also indicates it will monitor erosion of the bluff and take corrective measures if necessary (Pacific Gas and Electric Company, 2004c).

The staff concludes that the information provided in the SAR regarding the potential retreat of the Humboldt Bay bluff is adequate for use in other sections of the SAR to perform additional safety analysis and to demonstrate compliance with the regulatory requirements in 10 CFR §72.103(d) and §72.122(b).

<u>Long-Term Stability of Slopes</u>

The applicant evaluated the long-term stability of the plant-side and bluff-side slopes considering the self weight of soil layers and additional static loading from the storage vault [SAR Section 2.6.7.4 and calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d)]. The evaluation was based on a two-dimensional limit-equilibrium analysis of the slopes using cross sections identified in Figure 7-1 of calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The analysis consisted of numerically searching for a sliding mass with a minimum factor of safety from randomly selected circular slip surfaces. The analysis was performed using a method of slices based on the Spencer approach of satisfying force and moment equilibria (Abramson, et al., 2002). The analysis approach used by the applicant is consistent with standard practice.

The applicant calculated the values of the safety factor in the range of 2.7 to 4.9 from the limit equilibrium analysis. Values of the safety factor in the range of 1.25 to 1.5 indicate a stable slope based on accepted practice and NRC staff guidance (National Research Council Transportation Research Board, 1978, p. 172; Hoek and Bray, 1977; U.S. Nuclear Regulatory Commission, 1977). The values of the safety factor calculated by the applicant are significantly greater than this range. However, the representative values of long-term safety factor for the slopes at the ISFSI site may be smaller than those calculated by the applicant because of the potential existence of weak soil layers and the effect of such layers on the potential failure surfaces, as discussed earlier. Therefore, the staff's assessment of the capability of the storage vault to perform its safety functions included a consideration of potential instability of the ISFSI hill slopes under long-term static loading conditions. As discussed later in this section of the SER (under "Potential Effects of Slope Instability on the Storage Vault"), the staff finds that the capability of the storage vault to perform its safety functions would not be impaired because of potential slope instabilities.

The staff, therefore, concludes that the information provided in the SAR regarding slope stability under long-term static-loading conditions is adequate for use in other sections of the SAR to perform additional safety analysis and demonstrate compliance with regulatory requirements in 10 CFR §72.103(d) and §72.122(b).

Stability of Slopes under Tsunami Conditions

The staff's review of the applicant's information, as discussed in Section 2.1.4.6 of this SER, indicates that water levels at the ISFSI site can rise to 6.4 to 11 m [21 to 36 ft] above MLLW during a tsunami event. Such a water level rise can increase groundwater pressure head by 4.6 to 9.1 m [15 to 30 ft] above the groundwater pressure used in the applicant's slope stability analysis. The increased groundwater pressure would persist after the tsunami for a length of time that depends on the permeability and subsurface geometry of the soil layers. Therefore the staff's assessment of the capability of the storage vault to perform its safety functions includes a consideration of the potential instability of the ISFSI hill slopes under elevated water pressures due to a tsunami event. Despite this consideration, as discussed later in this SER (under "Potential Effects of Slope Instability on the Storage Vault"), the staff finds that the capability of the storage vault to perform its safety functions would not be impaired.

The staff, therefore, concludes that the information provided in the SAR is adequate for considering the potential effects of a tsunami on slope stability and for use in other sections of the SAR to perform additional safety analysis and demonstrate compliance with the regulatory requirements in 10 CFR §72.103(d) and §72.122(b).

Stability of Slopes under Seismic Loading Conditions

The applicant evaluated the stability of slopes under seismic loading conditions using an analysis based on the Newmark (1965) approach. The Newmark approach consists of calculating potential seismically induced displacements, which are interpreted as an instability index, using guidelines based on empirical data. The applicant's calculation of seismically induced displacements is provided in Section 2.6.7.5 of the SAR and calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The applicant provided additional information in response to the staff's requests for additional information (Pacific Gas and Electric Company, 2004c, Attachment 2-7). The applicant concluded that potential seismically induced slope displacements indicate that the slopes would be stable during potential seismic events. The applicant also concluded that the potential seismically induced displacement would not cause radiological consequences to the public and that the resulting potential rotation of the storage vault would not impair cask retrievability.

The applicant analyzed slope displacement using two sets of ground motion time histories that produced the largest displacements in a rigid block Newmark-type analysis. The time histories are consistent with the design-basis ground motion as reviewed by the staff in Section 2.1.6.2 of this SER. The applicant transformed the ground motion time histories twice to obtain the input for the analysis. First, the horizontal component of the surface ground motion was rotated to the direction of the slope cross section. Second, the rotated time histories were transformed by deconvolution to obtain input time histories applied at the base of the slope cross-section in a dynamic finite element model (Pacific Gas and Electric Company, 2003a). The seismically induced displacements were calculated through a series of analyses based on an approach proposed by Newmark (1965). The calculation consists of three steps for a selected potentially unstable mass.

First, the value of yield acceleration, k_y, was calculated through a limit-equilibrium analysis similar to the analysis described previously in this section (under "Long Term Stability of Slopes"). The parameter k_y is the horizontal acceleration that would cause the value of the safety factor against sliding of the potentially unstable mass to decrease to 1.0 from the value calculated for the long-term static condition. The yield acceleration is represented in the analysis as a static horizontal force k_yM, where M is the mass of the potentially unstable mass. The calculation of k_y is documented in calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The calculated values of k_y are 0.69 g for the bluff-side slope and 0.66 g for the plant-side slope.

Second, the seismic coefficient time history (i.e., an average horizontal acceleration time history, a_{ht}) for the potentially unstable mass was evaluated in calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The average acceleration time history is typically based on the ratio F_t/M where F_t is the resultant down-slope force along the potential failure surface (e.g., Kramer, 1996, p. 446). The applicant conducted two-dimensional dynamic finite element analysis using equivalent linear approach for calculating seismic coefficient time histories. The seismic coefficient time histories for the bluff-side and plant-side slopes for two seismic motions are provided in Figures 7-14 through 7-17 of calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d).

Third, the difference a_{ht} ! k_y for $a_{ht} > k_y$ was integrated twice with respect to time to obtain a displacement, referred to as the Newmark displacement. This evaluation is documented in Section 2.6.7.5 of the SAR and in calculation package GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d). The calculated displacements, as documented in Table 7-6 of GEO.HBIP.02.07 (Pacific Gas and Electric Company, 2003d) are 6.1 to 15.2 cm [0.2 to 0.5 ft] for the bluff-side slope and 9.1 to 143.3 cm [0.3 to 4.7 ft] for the plant-side slope (Pacific Gas and Electric Company, 2003d, Table 7-6).

The applicant interpreted the calculated displacements using a guideline recommended by the California Department of Water Resources, Division of Safety of Dams (Babbit and Verigin, 1996). The guideline recommends three stability levels for earth dams based on displacements calculated using the Newmark approach (Babbit and Verigin, 1996): (i) a displacement of 0 to 1.52 m [0 to 5 ft] is considered sustainable; (ii) a displacement of 1.52 to 3.05 m [5 to 10 ft] is considered serious, and any related structural behavior is less predictable as the displacement approaches 3.05 m [10 ft]; and (iii) displacements greater than 3.05 m [10 ft] indicate continuing (post seismic) instability. The applicant concluded based on the dam safety guideline that ISFSI hill slopes will be stable even if subjected to ground motion from a design-basis earthquake. The applicant's conclusion relies on the calculated maximum displacement being equal to 1.4 m [4.7 ft], which in the applicant's view implies that the slopes belong to the first stability level based on the California dam safety guideline (Babbit and Verigin, 1996).

The applicant interpreted its calculated Newmark displacements as an absolute measure of potential seismically induced displacements of the slope material. However, in the staff's view, the calculated displacements should be considered order of magnitude estimates of potential seismically induced displacements because of uncertainties in soil properties, subsurface geometry of potential failure surfaces, and approximate representation of the distribution of seismically induced ground motion within the soil. Abramson, et al. (2002) for example, suggest that the Newmark displacement should be treated only as a qualitative indication of stability. The applicant's calculated displacements, interpreted as an order of magnitude estimate, indicate that the slopes could potentially experience several feet of soil deformation during a design-basis earthquake. Several feet of deformation would imply the second stability level (i.e., serious conditions with structural behavior increasingly less predictable) based on the California dam safety guideline chosen by the applicant (Babbit and Verigin, 1996). Another guideline proposed by the State of California for interpreting Newmark slope displacements (State of California Division of Mines and Geology, 1997, Chapter 5) recommends the following stability levels based on the Newmark displacements: (i) displacements of 0 to 10 cm [0 to 3.94 in] are unlikely to correspond to serious landslide movement or damage; (ii) for displacements of 10 to 100 cm [3.94 to 39.4-in] slope deformation may be sufficient to cause serious ground cracking or enough strength loss to result in continuing (post seismic) failure; and (iii) displacements greater than 100 cm [39.4 in] are very likely to correspond to damaging landslide movement, and such slopes should be considered unstable. The applicant argued that the State of California guideline is not applicable to the ISFSI slopes. Although the two guidelines differ in their definition of the stability categories, they both lead to the same conclusion that the several feet of slope displacement estimated based on the applicant’s analysis indicates that the ISFSI slopes will likely be unstable during the design basis seismic events. Based on these considerations, the staff concludes that potential instability of slopes at the ISFSI site during a design-basis earthquake needs to be accounted for in assessing the capability of the storage vault to perform its safety functions, as required under 10 CFR §72.122(b). The staff’s assessment of the capability of the storage vault to perform its safety functions, therefore, includes a consideration of the potential instability of the ISFSI hill slopes under seismic loading conditions. Even with consideration of the potential slope instability, the staff finds that the capability of the storage vault to perform its safety functions would not be impaired, as discussed in this section of the SER (under “Potential Effects of Slope Instability on the Storage Vault”).

The staff, therefore, concludes that the information provided in the SAR regarding slope stability under seismic loading conditions is acceptable for use in other sections of the SAR to perform additional safety analysis and demonstrate compliance with regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

Potential Effects of Slope Instability on the Storage Vault

Any deformation of the subsurface material at the ISFSI site, such as may be associated with slope instability, will likely cause a rigid-body rotation of the below-grade storage vault. The vault is expected to behave in a rigid manner because it is stiff relative to the soil. There are no important-to-safety connections to the vault that may rupture or be misaligned if the vault were to experience a rigid rotation. Such rotation of the vault is of concern only because of its potential impact on the retrievability of the casks.

The applicant estimated a maximum vault rotation of 0.67E owing to a slope displacement of 1.4 m [4.7 ft]. The applicant based its calculation of the rotation on the vault being rigid compared to the surrounding soil and soil deformation being localized in a narrow zone along the potential slip surface. The vault rotation was calculated with respect to the vertical axis of the vault and corresponds to a tilt of approximately 5 cm [1.96 in]. The calculated tilt is smaller than the cask-to-vault clearance of 14.0 cm [5.5 in]. The applicant concluded that such a tilt would not interfere with cask retrieval. The staff considered the effects of a slope displacement of 3.05 m [10 ft] using the applicant’s approach, which indicates a vault rotation of 1.4E and tilt of 10.7 cm [4.2 in]. The vault rotation under such a condition would be smaller than the tolerable rotation considering cask retrievability.

The potential rotation and tilt of the vault, however, may exceed the values calculated using this approach because the soil in contact with the vault may not rotate in a rigid manner as assumed in the calculation. The applicant acknowledged that potential rotation of the vault could be larger because of this reason (Pacific Gas and Electric Company, 2004c). Any soil deformation associated with slope instability will likely be distributed among several slip surfaces instead of being localized on one slip surface as assumed in the applicant's calculation. Slip surfaces may develop close to the vault in association with more deep-seated slip surfaces. Such a deformation mode could cause a rotation of the vault that exceeds the rotation calculated with reference to one deep-seated slip surface. A rotation of the vault large enough to interfere with the vertical extraction of the cask can potentially result from slope instability. The vault also can potentially be submerged in mud due to soil deformation associated with slope instability. The applicant indicated that the capability of the vault to perform its safety functions would not be impaired even if the vault rotation were large enough to cause the casks to lie in a horizontal position (Pacific Gas and Electric Company, 2004c). The applicant also suggested that a crane could be used to remove the casks from the vault, if necessary. The staff finds that the capability of the storage vault to perform its safety functions would not be impaired even if the vault were to rotate or be submerged in mud due to potential slope instability.

The staff, therefore, concludes that the information provided in the SAR regarding slope stability at the ISFSI site is adequate for use in other sections of the SAR to perform additional safety analysis and demonstrate compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

Stability of Slope Along Transporter Route

The staff reviewed the information presented by the applicant in Section 2.6.7.6 of the SAR on the stability of the slope along the critical location where the transporter route is closest to the discharge canal. The staff also reviewed the information provided by the applicant in response to its request for additional information (Pacific Gas and Electric Company, 2004c). The applicant discussed the static slope stability and slope displacement during a seismic event in calculation package GEO.HBIP.02.08 (Pacific Gas and Electric Company, 2003e). The applicant used a 50-year return period uniform hazard spectrum to assess the stability of the slope. As discussed in Section 2.1.6.2 of this SER, the staff finds that a 50-year return period ground motion with peak horizontal ground acceleration of 0.4 g is appropriate during the transporter movement. Since the yield acceleration (0.84 g) of the slope evaluated in GEO.HBIP.02.08 (Pacific Gas and Electric Company, 2003e) is higher than the peak ground acceleration, the applicant concluded that permanent slope deformation resulting from the seismic ground motion commensurate with the return period during transit along the critical section is negligible. The staff concludes that the stability of the slope at the critical location close to the discharge canal along the transporter route will not be impaired by a seismic event during cask transfer.

The staff, therefore, concludes that the information provided in the SAR regarding slope stability along the transporter route during cask transfer is adequate and demonstrates compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

2.2 Evaluation Findings

Based on review of the information in the SAR, the staff makes the following findings regarding site characteristics of the Humboldt Bay ISFSI:

- The SAR adequately describes the site location, site description, population distribution and trends, and land and water use in compliance with 10 CFR §72.24(a), §72.90(a–f), §72.98(a–c), and §72.100(a).

- The SAR adequately describes and assesses nearby industrial, transportation, and military facilities with sufficient identification of the facilities that may pose a hazard to the ISFSI in compliance with 10 CFR §72.24(a) and §72.94(a). Potential hazards from these facilities are more fully evaluated in Chapter 15 of this SER.

- Regional climatology and local meteorology have been sufficiently characterized in compliance with 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), and §72.122(b), including the application of meteorological descriptions previously accepted by the staff for the co-located HBPP as allowed in §72.40(c). The staff finds that an onsite meteorological program is not necessary because of the applicability of the information available from the National Weather Service station on Woodley Island, due to its proximity to the HB ISFSI site.

- Surface hydrologic conditions, including assessment of dam failure, stream flooding, surge and seiche flooding, tsunami inundation, and ice flooding, were adequately characterized and evaluated in compliance with the regulatory requirements in 10 CFR §72.24(a), §72.90(a–f), §72.92(a–c), §72.98(a–c), §72.100(b), §72.120(a), and §72.122(b). The staff finds that significant flooding will not occur at the ISFSI site. Even in the event of severe flooding, the HI-STAR HB casks can be temporarily wetted without harm, and will retain their ability to contain the waste without radioactive effluents.

- The SAR and Environmental Report provided an adequate description of the subsurface hydrology in compliance with the regulatory requirements in 10 CFR §72.98(a–c),§72.100(b), and §72.122(b)(4). The staff finds that groundwater quality at the site will not be adversely affected by the ISFSI, nor will groundwater conditions at the HBPP site impact construction and operation of the ISFSI.

- Geology and seismology of the site have been adequately characterized and assessed in compliance with the regulatory requirements in 10 CFR §72.90(a–d), §72.92(a–c), §72.94(a–c), §72.98(a–c), §72.103 (b–f), §72.120(a), and §72.122(b)(4). The DE for the ISFSI is conservatively based on the 84th percentile deterministic acceleration spectra that would result from coseismic rupture of the Cascadia subduction megathrust and nearby Little Salmon Fault system. The DE spectra envelops the 2,000-year return period probabilistic uniform hazard spectra specified in Regulatory Guide 3.73 (U.S. Nuclear Regulatory Commission, 2003a). The 25- and 50-year DE spectra that are used for transient operations, which include cask movement and vault loading operations, are appropriate and consistent with the historical earthquake record. The SAR also demonstrates that despite the presence of nearby thrust faults, the ISFSI is not likely to be disrupted by surface faulting.

- The geotechnical site characterization has been adequately described and assessed in compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b). The staff concludes that the geotechnical site characterization information presented in the SAR is acceptable for use in other sections of the SAR to develop the design bases for the Humboldt Bay ISFSI and perform additional safety analysis. The staff determined that the liquefaction potential has been adequately described and assessed in compliance with the regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b).

- The stability of the slopes at the ISFSI site and transporter route has been adequately described and assessed in compliance with regulatory requirements in 10 CFR §72.103(c–d) and §72.122(b). The applicant provided sufficient information for the staff to conclude that the capability of the storage vault and the HI-STAR HB overpack to perform their safety functions will not be impaired during cask transfer to the ISFSI and during interim storage at the ISFSI.

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