DIABLO CANYON ISFSI
SAFETY ANALYSIS REPORT

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## GLOSSARY

A glossary of most of the terms and acronyms used in this safety analysis report, including their frequently used variations, is presented in this section as an aid to readers and reviewers.

**Accident Events** means events that are considered to occur infrequently, if ever, during the lifetime of the facility. Natural phenomena, such as earthquakes, tornadoes, floods, and tsunami, are considered to be accident events.

**ALARA** means as low as is reasonably achievable.

**Boral** is a generic term to denote an aluminum-boron carbide cermet manufactured in accordance with U.S. Patent No. 4027377. The individual material supplier may use another trade name to refer to the same product.

**BPRA** means burnable poison rod assembly.

**Cask Transporter (or Transporter)** is a U-shaped tracked vehicle used for lifting, handling, and onsite transport of loaded overpacks and the transfer cask.

**CEDE** means committed effective dose equivalent.

**CFR** means Code of Federal Regulations.

**CIMIS** means the California Irrigation Management Information System.

**CoC** means a certificate of compliance issued by the NRC that approves the design of a spent fuel storage cask design in accordance with Subpart L of 10 CFR 72.

**Confinement Boundary** means the outline formed by the sealed, cylindrical enclosure of the multi-purpose canister (MPC) shell welded to a solid baseplate, a lid welded around the top circumference of the shell wall, the port cover plates welded to the lid, and the closure ring welded to the lid and MPC shell providing the redundant sealing.

**Confinement System** means the MPC that encloses and confines the spent nuclear fuel and associated nonfuel hardware during storage.

**Consolidated Fuel** means a fuel assembly that contains more than 264 fuel rods.

**Controlled Area (or Owner-Controlled Area)** means the area, outside the restricted area but inside the site boundary, for which access can be limited by PG&E.

**Cooling Time** is the time between discharging a spent fuel assembly and associated nonfuel hardware from the reactor (reactor shutdown) and the time the spent fuel assembly and associated nonfuel hardware are loaded into the MPC.

## GLOSSARY

**CTF** means the cask transfer facility. The CTF is used to transfer an MPC from the transfer cask to an overpack, following transport from the FHB/AB and prior to moving the loaded overpack to the storage pad. The CTF can also be used to transfer an MPC from a loaded overpack to the transfer cask for transport back to the FHB/AB.

**Damaged Fuel Assembly** is a fuel assembly with known or suspected cladding defects, as determined by review of records, greater than pinhole leaks or hairline cracks; empty fuel rod locations that are not replaced with dummy fuel rods; or those that cannot be handled by normal means. Fuel assemblies that cannot be handled by normal means due to fuel cladding damage are considered fuel debris.

**Damaged Fuel Container (or DFC)** means a specially designed enclosure for damaged fuel or fuel debris that permits gaseous and liquid media to escape while minimizing dispersal of gross particulates. The DFC features a lifting location that is suitable for remote handling of a loaded or unloaded DFC.

**DBE** means design-basis earthquake.

**DCPP** means Diablo Canyon Power Plant.

**DCPP FSAR Update** means the FSAR for DCPP that is maintained up-to-date in accordance with 10 CFR 51.71(e).

**DCSS** means dry cask storage system.

**DDE** means double design earthquake or deep dose equivalent.

**DE** means design earthquake.

**Design Life** is the minimum duration for which the component is engineered to perform its intended function as set forth in this SAR, if operated and maintained in accordance with this SAR.

**Diablo Canyon ISFSI (or ISFSI)** means the total Diablo Canyon storage system and includes the HI-STORM 100 System, transporter, CTF, storage pads, and ancillary equipment.

**Diablo Canyon ISFSI Technical Specifications (or Diablo Canyon ISFSI TS or DC ISFSI TS)** means the Technical Specifications issued as part of the license for PG&E to operate the Diablo Canyon ISFSI.

**DOE** means the US Department of Energy.

## GLOSSARY

**FHB/AB** means the DCPP fuel handling building/auxiliary building.

**Fracture Toughness** is a property that is a measure of the ability of a material to limit crack propagation under a suddenly applied load.

**FSAR** means final safety analysis report.

**Fuel Basket** means a honeycombed structural weldment with square openings that can accept a fuel assembly of the type for which it is designed.

**Fuel Debris** refers to ruptured fuel rods, severed rods, loose fuel pellets, or fuel assemblies with known or suspected defects that cannot be handled by normal means.

**HE** means Hosgri earthquake.

**High Burnup Fuel** is a spent fuel assembly with an average burnup greater than 45,000 MWD/MTU.

**HI-STORM 100 Overpack (or Loaded Overpack or Storage Cask)** means the cask that receives and contains the sealed MPCs (containing spent nuclear fuel and nonfuel hardware) for final storage on the storage pads. It provides the gamma and neutron shielding, ventilation passages, missile protection, and protection against natural phenomena and accidents for the MPC.

**HI-STORM 100SA Overpack** is a variant of the HI-STORM 100 overpack that is shorter, has a redesigned top lid, and is outfitted with an extended baseplate and gussets to enable the overpack to be anchored to the storage pad. The HI-STORM 100SA overpack is designed for high-seismic applications and is used at the Diablo Canyon ISFSI.

**HI-STORM 100 System** consists of the Holtec International MPC, HI-STORM 100SA overpack, and HI-TRAC transfer cask. For Diablo Canyon, the HI-STORM 100SA overpack replaces the HI-STORM 100 overpack.

**HI-TRAC 125 Transfer Cask (or HI-TRAC Transfer Cask or HI-TRAC or Transfer Cask)** means the cask used to house the MPC during MPC fuel loading, unloading, drying, sealing, and onsite transfer operations to an overpack. The HI-TRAC shields the loaded MPC allowing loading operations to be performed while limiting radiation exposure to personnel. The HI-TRAC is equipped with a pair of lifting trunnions to lift and downend/upend the HI-TRAC with a loaded MPC. HI-TRAC is an acronym for Holtec International Transfer Cask. The transfer cask used at the Diablo Canyon ISFSI is the standard HI-TRAC 125 with some optional features.

## GLOSSARY

**Holtite** is a trademarked Holtec International neutron shield material.

**IFBA** means integral fuel burnable absorber.

**Important to Safety (ITS)** means a function or condition required to store spent nuclear fuel safely; to prevent damage to spent nuclear fuel during handling and storage; and to provide reasonable assurance that spent nuclear fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. This definition is used to classify structures, systems, and components of the ISFSI as important to safety (ITS) or not important to safety (NITS).

**Independent Spent Fuel Storage Installation (ISFSI)** means a facility designed, constructed, and licensed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage in accordance with 10 CFR 72. For Diablo Canyon, this term is clarified to mean the total storage system and includes the HI-STORM 100 System, transporter, CTF, storage pads, and ancillary equipment.

**Insolation** means incident solar radiation.

**Intact Fuel Assembly** means a fuel assembly without known or suspected cladding defects greater than pinhole leaks and hairline cracks, and which can be handled by normal means. Partial fuel assemblies, that is fuel assemblies from which fuel rods are missing, shall not be classified as intact fuel assemblies unless dummy fuel rods are used to displace an amount of water greater than or equal to that displaced by the original fuel rod(s).

**ISFSI Site** means the ISFSI storage site and CTF.

**ISFSI Storage Site (or Storage Site)** means the area contained within the restricted area fence that circumscribes the ISFSI protected area fence and storage pads.

**LAR** means license amendment request.

**LCO** means limiting condition for operation.

**LDE** means lens dose equivalent.

**License Life** means the duration that the HI-STORM 100 System and the Diablo Canyon ISFSI are authorized by virtue of certification by the US NRC.

**Lowest Service Temperature (LST)** is the minimum metal temperature of a part for the specified service condition.

**LPZ** means low population zone.

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**LTSP** means long-term seismic program.

**Maximum Reactivity** means the highest possible k-effective including bias, uncertainties, and calculational statistics evaluated for the worst-case combination of fuel basket manufacturing tolerances.

**MCNP** means Monte Carlo N-Particle transport computer code.

**Moderate Burnup Fuel** is a spent fuel assembly with an average burnup less than or equal to 45,000 MWD/MTU.

**MPC-24** means the Holtec MPC designed to store up to 24 intact PWR fuel assemblies and associated nonfuel hardware.

**MPC-24E** means the Holtec MPC designed to store up to 24 PWR fuel assemblies and associated nonfuel hardware, 4 of which can be DFCs containing damaged fuel assemblies in designated fuel basket locations, and the balance being intact fuel assemblies.

**MPC-24EF** means the Holtec MPC designed to store up to 24 PWR fuel assemblies and associated nonfuel hardware, 4 of which can be DFCs containing damaged fuel assemblies or fuel debris in designated fuel basket locations, and the balance being intact fuel assemblies.

**MPC-32** means the Holtec MPC designed to store up to 32 intact PWR fuel assemblies and associated nonfuel hardware.

**MSL** means mean sea level.

**MTU** means metric tons of uranium.

**Multi-Purpose Canister (MPC)** means the sealed canister that consists of a honeycombed fuel basket contained in a cylindrical canister shell that is welded to a baseplate, lid with welded port cover plates, and closure ring. The MPC is the confinement boundary for storage conditions.

**MWD/MTU** means megawatt-days per metric ton of uranium.

**Neutron Shielding** means a material used to thermalize and capture neutrons emanating from the radioactive spent nuclear fuel.

**NFPA** means National Fire Protection Association.

## GLOSSARY

**Nonfuel Hardware** is defined as burnable poison rod assemblies (BPRAs), thimble plug devices (TPDs), control rod assemblies (CRAs), and other similarly designed devices with different names.

**NRC** means the US Nuclear Regulatory Commission.

**NSOC** means the DCPP Nuclear Safety Oversight Committee.

**NWPA** means the Nuclear Waste Policy Act of 1982 and any amendments thereto.

**OBE** means operating basis earthquake.

**PMF** means probable maximum flood.

**Post-Core Decay time (PCDT)** is synonymous with cooling time.

**Preferential Fuel Loading** is a requirement in the Diablo Canyon ISFSI Technical Specifications applicable to uniform fuel loading whenever fuel assemblies with significantly different post-irradiation cooling times ($\geq$ 1 year) are to be loaded in the same MPC. Fuel assemblies with the longest post-irradiation cooling time are loaded into fuel storage locations at the periphery of the basket. Fuel assemblies with shorter post-irradiation cooling times are placed toward the center of the basket. Regionalized fuel loading meets the intent of preferential fuel loading. The preferential fuel loading requirement is in addition to other fuel loading restrictions in the Diablo Canyon ISFSI Technical Specifications, such as those for nonfuel hardware and damaged fuel containers.

**Protected Area (or ISFSI Protected Area)** means the area within the security fence that circumscribes the storage pads.

**Protected Area Boundary** means the security fence that circumscribes the storage pads.

**PSRC** means the DCPP Plant Staff Review Committee.

**PWR** means pressurized water reactor.

**RCCA** means rod cluster control assembly.

**Reactivity** is used synonymously with effective neutron multiplication factor or k-effective.

**Regionalized Fuel Loading** is a term used to describe an optional fuel loading strategy used in lieu of uniform fuel loading. Regionalized fuel loading allows high-heat-emitting fuel assemblies to be stored in fuel storage locations in the center of the fuel basket provided

## GLOSSARY

lower-heat-emitting fuel assemblies are stored in the peripheral fuel storage locations. When choosing regionalized fuel loading, other restrictions in the Diablo Canyon ISFSI Technical Specifications must be considered also, such as those for nonfuel hardware and damaged fuel containers. Regionalized fuel loading meets the intent of preferential fuel loading.

**Restricted Area** means the area within the second fence circumscribing the storage pads, access to which is limited by PG&E for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials.

**Restricted Area Fence** means the second fence that circumscribes the storage pads. It is located to ensure the dose rate at this boundary will be less than 2 mrem/hr in compliance with 10 CFR 20 requirements for a restricted area boundary.

**SAR** means Diablo Canyon ISFSI Safety Analysis Report.

**SAT** means systematic approach to training.

**Security Fence** is the first fence circumscribing the storage pads.

**SDE** means shallow dose equivalent.

**Service Life** means the duration for which the component is reasonably expected to perform its intended function, if operated and maintained in accordance with the provisions of the CoC. Service life may be much longer than the design life because of the conservatism inherent in the codes, standards, and procedures used to design, fabricate, operate, and maintain the component.

**SFP** means spent fuel pool.

**Single Failure Proof Handling System** means that the handling system is designed so that all directly-loaded tension and compression members are engineered to satisfy the enhanced safety criteria of paragraphs 5.1.6(1)(a) and (b) of NUREG-0612.

**SNF** means spent nuclear fuel.
**SR** means surveillance requirement.

**SSC** means structures, systems, and components.

**SSE** means safe shutdown earthquake.

**STP** means standard temperature and pressure conditions.

## GLOSSARY

**TEDE** means total effective dose equivalent.

**Thermosiphon** is the term used to describe the buoyancy-driven natural convection circulation of helium within the MPC.

**TLD** means thermoluminescent dosimeter.

**TODE** means total organ dose equivalent.

**TPD** means thimble plug device.

**Transport Route** means the route used by the transporter for onsite movement of the loaded transfer cask from the FHB/AB to the CTF.

**Uniform Fuel Loading** is a fuel loading strategy where any authorized fuel assembly may be stored in any fuel storage location, subject to other restrictions in the Diablo Canyon ISFSI Technical Specifications, such as preferential fuel loading, and those restrictions applicable to nonfuel hardware and damaged fuel containers.

**USGS** means the US Geological Survey.

**UTM** means Universal Transverse Mecator and is used to define topographic locations in metric coordinates.

**Westinghouse LOPAR fuel assemblies** have been used at DCPP and are one of the types of spent fuel assemblies that will be stored at the ISFSI.

**Westinghouse VANTAGE 5 fuel assemblies** have been used at DCPP and are one of the types of spent fuel assemblies that will be stored at the ISFSI.

$\chi/Q$ means site-specific atmospheric dispersion factors used in radiological dose calculations for routine and accidental releases.

**ZPA** means zero period acceleration.

**Zr** means fuel cladding material with the trade names Zircaloy-2, Zircaloy-4, or ZIRLO, unless otherwise specified. Any discussion of Zircaloy fuel cladding material in this SAR applies to any of these variants of zirconium-based fuel cladding material for low burnup fuel. High burnup fuel is limited to Zircaloy-2 or Zircaloy-4 cladding material.

CHAPTER 1

# INTRODUCTION AND GENERAL DESCRIPTION

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CHAPTER 1

# INTRODUCTION AND GENERAL DESCRIPTION

## TABLES

## 1.2 GENERAL DESCRIPTION OF LOCATION

The DCPP site consists of approximately 750 acres of land located in San Luis Obispo County, California, adjacent to the Pacific Ocean and roughly equidistant from San Francisco and Los Angeles. The site is located directly southeast of Montana de Oro State park, which is located along the coast of California in San Luis Obispo County. This site area is approximately 12 miles west-southwest of the city of San Luis Obispo, the county seat and nearest significant population center.

The nearest residential community is Los Osos, approximately 8 miles north of the plant site. The township of Avila Beach is located along the coast at a distance of approximately 6 miles southeast of the plant site. The city of Morro Bay is located along the coast approximately 10 miles northwest of the plant site. A number of other cities, as well as some unincorporated residential areas, exist along the coast and inland. However, these are at distances greater than 8 miles from the plant site. Only a few individuals reside within 5 miles of the plant site.

Access to the plant site is controlled by security fencing that defines the plant-protected area within the owner-controlled area, which is surrounded by a farm-type fence. The plant site is located near the mouth of Diablo Creek, and a portion of the site is bounded by the Pacific Ocean. All coastal properties located north of Diablo Creek, extending north to the southerly boundary of Montana de Oro State Park and reaching inland approximately 0.5 miles are owned by PG&E. Coastal properties located south of Diablo Creek and reaching inland approximately 0.5 miles are owned by Eureka Energy Company, a wholly owned subsidiary of PG&E. Except for the DCPP site, the 4,500 acres of this owner-controlled area are encumbered by two grazing leases.

PG&E has complete authority to control all activities within the site boundary and this authority extends to the mean high water line along the ocean. On land, there are no activities unrelated to plant operation within the owner-controlled area. The plant site is not traversed by public highway or railroad. Normal access to the site is from the south by private road through the owner-controlled area, which is fenced and posted by PG&E. The offshore area is not under PG&E control and is at times entered by commercial or sports fishing boats.

The plant site occupies a coastal terrace that ranges in elevation from 60 to 150 ft above mean sea level (MSL) and is approximately 1,000 ft wide. Plant grade, determined at the turbine building main floor, is at elevation 85 ft above MSL. The seaward edge of the terrace is a near-vertical cliff. Back from the terrace and extending for several miles inland are the rugged Irish hills, an area of steep, brush-covered hillsides and deep canyons that are part of the San Luis Mountains, which attain an elevation of 1,500 ft within about a mile of the site.

The reactors and ancillary structures are situated on top of bedrock. The coastal areas surrounding the plant are well drained, primarily via Diablo Creek, and groundwater is at a depth of at least 170 ft below the surface of the ISFSI pad. The climate of the site area is typical of that along the central California coast. The winter comprises the rainy season, with more than 80 percent of the average annual rainfall of approximately 16 inches. The average annual temperature of the site area is about 55°F, with a variation between approximately 32°F minimum and 97°F maximum, which reflects the strong marine influence.

The ISFSI is located within the PG&E owner-controlled area at DCPP. Figure 2.1-1 shows the location of the plant and ISFSI sites on a map of western San Luis Obispo County. Figure 2.1-2 shows a plan drawing of the ISFSI site. There are no important to safety structures, systems or components that are shared between the ISFSI and DCPP. A more detailed description of the ISFSI site is provided in SAR Section 2.1.

TABLE 1.1-1

DIABLO CANYON ISFSI LICENSE APPLICATION
EXEMPTION REQUESTS

| Code of Federal Regulations Reference | Exemption Request |
|---|---|
| 10 CFR 72.72(d) | PG&E is requesting an exemption from storing spent fuel and high-level radioactive waste records in duplicate. Refer to Diablo Canyon ISFSI SAR, Section 9.4.2. |
| 10 CFR 72.124(c) | On November 12, 1997, the NRC granted PG&E an exemption from the requirements of 10 CFR 70.24 concerning criticality monitors. PG&E requested an exemption from the 10 CFR 72.124(c) criticality monitoring requirements by requesting an extension of the NRC's November 12, 1997, exemption for the FHB/AB to envelop the activities associated with the Diablo Canyon ISFSI SAR, in its letter DCL-02-044, "License Amendment Request 02-03, Spent Fuel Cask Handling," dated April 15, 2002. DCL-02-044 is PG&E's 10 CFR 50 LAR in support of ISFSI licensing, and included the exemption extension request<br><br>In PG&E letter DCL-02-117, "Change in Licensing Basis Compliance from 10 CFR 70.24 to 10 CFR 50.68(b)," dated October 2, 2002, PG&E informed the NRC that PG&E will revise the DCPP licensing basis to reflect compliance with 10 CFR 50.68(b) in lieu of 10 CFR 70.24 and that the exemption request in DCL-02-044 will be revised to request a similar exemption from 10 CFR 50.68(b) in lieu of 10 CFR 70.24. |
| 10 CFR 73.55 | PG&E is requesting an exemption from four 10 CFR 73.55 requirements, as described in the Security Program license amendment request (LAR) 01-09. Refer to PG&E letter DCL-01-127, dated December 21, 2001. |

CHAPTER 2

# SITE CHARACTERISTICS

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# SITE CHARACTERISTICS

## FIGURES (Continued)

CHAPTER 2

# SITE CHARACTERISTICS

FIGURES (Continued)

## 2.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

### 2.2.1 OFFSITE POTENTIAL HAZARDS

#### 2.2.1.1 Description of Location and Routes

Industry in the vicinity of the Diablo Canyon ISFSI site is mainly light and of a local nature, serving the needs of agriculture in the area. Food processing and refining of crude oil are the major industries in the area, although the numbers employed are not large. Less than 8 percent of the work force in San Luis Obispo County is engaged in manufacturing. The largest industrial complex is Vandenberg Air Force Base, located approximately 35 miles south-southeast of the DCPP site in Santa Barbara County.

Port San Luis Harbor and the Point San Luis Lighthouse property are located approximately 6 miles south-southeast of the DCPP site. The Point San Luis Lighthouse is located on a 30-acre parcel of land. Until 1990, the US Coast Guard owned the lighthouse property. In 1990 the Port San Luis Harbor District, owners and operators of the Port San Luis Harbor, were granted ownership of the lighthouse and the 30 acres, except for approximately 3 acres of land, in 3 parcels, which the Coast Guard retained as owners in order to operate and maintain the modern light station and navigating equipment located on those 3 acres.

Located approximately 6 miles east-southeast of the DCPP site is the Port San Luis tanker-loading pier. The pier is located on property that is owned by the Port San Luis Harbor District and leased by UNOCAL, which built and owns the pier. However, this pier is no longer active as tanker traffic into Port San Luis has been discontinued.

US Highway 101 is the main arterial road serving the coastal region in this portion of California. It passes approximately 9 miles east of the site, separated from it by the Irish Hills. US Highway 1 passes approximately 10 miles to the north and carries moderate traffic between San Luis Obispo and the coast. The nearest public access from a US highway is by county roads in Clark Valley, 5 miles north, and See Canyon, 5 miles east. Access to the site is by Avila Beach Drive, a county road, to the entrance of the PG&E private road system.

The Southern Pacific Transportation Company provides rail service to the county by a route that essentially parallels US Highway 101. It passes approximately 9 miles east of the site, separated from it by the Irish Hills. There is no spur track into the DCPP site.

Coastal shipping lanes are approximately 20 miles offshore. Prior to 1998, there were local tankers coming into and out of Estero Bay, which is north of the DCPP site. There is no further tanker traffic in either Port San Luis or Estero Bay. The local tanker terminal at Estero Bay closed in 1994, and Avila Pier ceased operation in 1998. Petroleum products and crude oil are no longer stored at Avila Beach since the storage tanks there were removed in 1999. However, some petroleum products and crude oil continue to be stored at Estero Bay, approximately 10 miles from the DCPP site.

The San Luis Obispo County Airport is located 12 miles east of the DCPP site. The airport serves approximately 52 scheduled landings and departures per day of commercial commuter flights, provided primarily by turbo-prop aircraft that seat no more than 41 people with a gross weight of no more than 30,000 pounds. The airport also serves approximately 10,000 total landings and departures of private aircraft per month. These consist mostly of aircraft that seat no more than 8 people, with an average gross weight of less than 12,500 pounds. Although there are no specific air traffic restrictions over DCPP, most air traffic into and out of the San Luis Obispo Airport does not approach within 5 miles of the ISFSI site because of the mountainous terrain.

There is a federal flight corridor (V-27) approximately 5 miles east of the ISFSI that is used for aircraft flying between Santa Barbara and Big Sur areas, with an estimated 20 flights per day. The majority of the aircraft using this route is above 10,000 ft. Sometimes this corridor is used also for traffic in to San Luis Obispo Airport and, in this case, has traffic that passes as close as 1 mile of the ISFSI site at an elevation of 3,000 ft. However, this portion of the route is normally only used for aircraft to align for instrument landing. The more commonly used approach route for visual landings passes 8 miles from the Diablo Canyon ISFSI site on the far side of the San Luis Range.

There is also a military training route (VR-249), which runs parallel to the site and its center is approximately 2 miles off shore. This training route is not frequently used. (Estimated at less then 60 flights per year). Its use requires a minimum of 5 miles visibility, and the flights are to maintain their altitude between sea level and 10,000 ft.

There is a municipal airport near Oceano, located 15 miles east-southeast of the DCPP site, which accommodates only small (12,500 pounds or less) private planes. The traffic at this airport is estimated to be no more than 2,200 flights per month. The Camp San Luis Obispo airfield is located 8 miles northeast of the DCPP site, but is now shown as helicopter use only.

The peak Vandenberg Air Force Base employment is approximately 4,400 people, including 3,200 military and 1,200 civilian personnel. Missiles fired to the Western Pacific Missile Range are not directed north or northwest, and are thus away from the DCPP site. Missile launch sites are approximately 25 miles south of DCPP. Polar orbit launches are in a southerly direction. Vandenberg Air Force Base is a designated alternate landing site for the space shuttles, but has not been used for that purpose to date. The landing approach is normally west to east, and does not bring the shuttles within 30 miles of the ISFSI site.

The nearest US Army installation is the Hunter-Liggett Military Reservation located in Monterey County, approximately 45 miles north of the DCPP site. The California National Guard (CNG) maintains Camp Roberts, located on the border of Monterey County and San Luis Obispo County, southeast of the Hunter-Liggett Military Reservation and approximately 30 miles north of the DCPP site. The CNG also maintains Camp San Luis Obispo, located in San Luis Obispo County, approximately 10 miles northeast of the DCPP site. In addition, as noted earlier, a US Coast Guard Light station is located in Avila Beach on property commonly known as the Point San Luis Lighthouse property.

No significant amounts of any hazardous products are commercially manufactured, stored, or transported within 5 miles of the DCPP site. Within 6 to 10 miles of the site, up to 1998, 1 to 2 local tankers per month offloaded oil for storage at Avila Beach. However, such shipments no longer occur and oil is no longer transported through or stored at Avila Beach. Due to very limited industry within San Luis Obispo County and the distances involved, any hazardous products or materials commercially manufactured, stored, or transported in the areas between 5 and 10 miles from the site are not considered to be a significant hazard to the ISFSI.

### 2.2.1.2 Hazards from Facilities and Ground Transportation

The ISFSI is located in a remote, sparsely populated, undeveloped area. The ISFSI site is in a canyon, which is east and above DCPP Units 1 and 2, and is directly protected on two sides by hillsides. There are no industrial facilities (other than DCPP), public transportation routes, or military bases within 5 miles of the ISFSI. Therefore, activities related to such facilities do not occur near the ISFSI and, thus, do not pose any hazard to the ISFSI.

Local shipping tankers may come within 10 miles of the DCPP site, but will remain outside of a 5-mile range. Coastal shipping lanes are approximately 20 miles offshore. Therefore, shipping does not pose a hazard to the ISFSI.

No commercial explosive or combustible materials are stored within 5 miles of the site, and no natural gas or other pipelines pass within 5 miles of the site. Therefore, there is no potential hazard to the ISFSI from any explosions or fires involving such materials.

Since there are no rail lines or public transportation routes within 5 miles of the ISFSI location, no credible explosions involving truck or rail transportation events need to be considered, pursuant to Regulatory Guide 1.91 (Reference 1). Similarly, explosions involving shipping events offshore at the DCPP site are unlikely. Although the shortest distance from the ISFSI location to the ocean is approximately 1/2-mile, there is no shipping traffic within 5 miles of this location. Therefore, consistent with the guidance of Regulatory Guide 1.91, explosions involving shipping events are not considered credible accidents for the ISFSI.

### 2.2.1.3 Hazards from Air Crashes

Aircraft crashes were assessed in accordance with the guidance of NUREG-0800, Section 3.5.1.6, Aircraft Hazards (Reference 2). Although this guidance applies to power reactor sites, the analysis of aircraft crash probabilities on the site is not dependent on the nature of the site other than size of the facility involved and, thus, the guidance of NUREG-0800 can be applied to the Diablo Canyon ISFSI site.

As specified in NUREG-0800, the probability of aircraft crashes is considered to be negligibly low by inspection and does not require further analysis if the three criteria specified in Item II.1 of Section 3.5.1.6 are met. In particular, Criterion 1 of Section 3.5.1.6 specifies that the plant-to-airport distance, D, must be greater than 10 statute miles, and the projected annual number of operations must be less than $1000D^2$. San Luis Obispo Airport is at a distance of 12 miles, with annual flight totals of approximately 139,000, which is less than $1000(12)^2$ or 144,000. The airport at Oceano is 15 miles away, with flight totals of no more than approximately 26,400 per year, which is less than $1000(15)^2$ or 225,000. Vandenberg Air Force Base is 35 miles away and flight totals there are not expected to be more than $1000(35)^2$ or 1,225,000 per year (or more than 3300 each day). Therefore, based on current data, Criterion 1 is met. However, the airways that are in the vicinity of the Diablo Canyon ISFSI have been analyzed below.

Criterion 2 specifies that the facility must be at least 5 statute miles from the edge of military training routes. There is a military training flight corridor (VR-249) that is within approximately 2 miles of the Diablo Canyon ISFSI site. This route is evaluated below.

Criterion 3 specifies that the facility must be at least 2 statute miles beyond the nearest edge of a federal airway, holding pattern, or approach pattern. There is a federal airway (V-27) whose edge is within approximately 1 mile east of the ISFSI site. As a result, this route is evaluated below.

Evaluation of Airways

For situations where federal airways or aviation corridors pass through the vicinity of the ISFSI site, the probability per year of an aircraft crashing into the site ($P_{fa}$) is estimated in accordance with NUREG-0800. The probability depends on factors such as altitude, frequency, and width of the corridor and corresponding distribution of past accidents. Per NUREG-0800, the following expression is used to calculate the probability:

$$P_{fa} = C \times N \times A/w$$

Where:

C = Inflight crash rate per mile for aircraft using airway

w = Width of airway (plus twice the distance from the airway edge to the site when the site is outside the airway) in miles

N = Number of flights per year along airway

A = Effective area of the site in square miles

The following analysis was completed per DOE-STD 3014-96 (Reference 5) to determine effective crash area. In this analysis conservative factors have been used for maximum skid distance and maximum wingspan. Based on the available information on aircraft type, size, and the location of the site these factors are very conservative.

In DOE-STD-3014-96:

The effective crash area is: $A_{eff} = A_f + A_s$

where:

$A_f = (WS + R)(H\cot\Phi) + (2*L*W*WS)/R + (L*W)$

and

$A_s = (WS + R)*S$

where:

| | | |
|---|---|---|
| $A_f$ | = | effective fly-in area; |
| $A_s$ | = | effective skid area; |
| WS | = | aircraft wingspan; (reference Table B-16 of DOE Std) |
| R | = | length of diagonal of the facility, |
| H | = | facility height; |
| $\cot\Phi$ | = | mean on the cotangent of the aircraft impact angle; (reference Table B-17 of DOE Std) |
| L | = | length of facility; |
| W | = | width of facility; |
| S | = | aircraft skid distance; (reference Table B-18 of DOE Std) |

$A_f = (223 + 511)(20)(10.2) + (2*500*105*223)/511 + (500*105)$
$A_f = 248058 ft^2/(5280\ ft/mile)^2 = 0.0089$ sq miles

and

$A_s = (WS + R)*S = (223 + 511)(700) = 0.0184$ sq miles

For calculating $A_s$ the skid distance is based on the layout of the facility which is surrounded on three sides by hills and is actually up against one of these hills, which limits the potential crash angle and limits the possible skid distance. The fourth side is protected by a drop off in terrain with a slope of greater than 1:1. The maximum distance on the unprotected side is estimated at less than 700 ft. Since the site is protected and limited from skidding aircraft on three sides, the use of the 700 ft is conservative.

$A_{eff} = A_f + A_s = 0.0089 + 0.0184 = 0.0273$ sq miles

For local traffic on V-27:

V-27 use for local aircraft is usually limited to a instrument landings for aircraft arriving from the south and instrument departures to the south from runway 19 at the San Luis Obispo Airport. As stated above, there are approximately 52 scheduled commercial aircraft landings and takeoffs per day. It is estimated that 50 percent of the commercial traffic is coming from or departing to the south and 10 percent of the commercial aircraft are using this routeunder instrument conditions. For the private aircraft usage, there are approximately 10,000 total landings and takeoffs per month at the San Luis Obispo Airport of which 50 percent are from or to the south. Because of limited instrument landing capability and qualification, conservatively only about 5 percent would be flying under instrument conditions and on this route. As a result, N for commercial aircraft would be equal to approximately 949 flights per year (52 x 0.5 x 0.1 x 365) and for general aviation to 3,000 flights per year (10,000 x 0.5 x 0.05 x 12).

Published holding patterns exist for arrivals a CREPE and CADAB intersections and for missed approaches, at Morro Bay VOR. The CREPE Intersection is 11 miles and the CADAB Intersection 21 miles from the ISFSI site. Both holding patterns place the aircraft further from the ISFSI site and therefore do not need to be considered. The ISFSI site distance to the Morro Bay VOR is approximately 6 miles and the holding pattern places the aircraft closer to the ISFSI. Since the Morro Bay VOR holding pattern is used for missed approaches, it is conservatively estimated that 5 percent of all instrument landing approaches are missed and each aircraft remains in the holding pattern for ten passes. For commercial traffic N is increased by 237 flights (949/2 x 0.05 x 10) and general aviation by 750 flights (3,000/2 x 0.05 x10).

Per NUREG-0800, C for commercial aircraft is provided as $4 \times 10^{-10}$. For general aviation, there are no data provided in NUREG-0800 and a conservative value of $1 \times 10^{-8}$ was used in this analysis. Per federal guidelines, the width of the airway is 8 miles and the center is approximately 5 miles from the site. As a result, (w) is conservatively taken to equal 10 miles.

For commercial flights:

$$P1_{fa} = CxNxA/w = (4 \times 10^{-10}) \times (949 + 237) \times (0.0273)/(10) = 1.30 \times 10^{-9}$$

For general aviation flights:

$$P1b_{fa} = CxNxA/w = (1 \times 10^{-8}) \times (3{,}000 + 750) \times (0.0273)/10 = 1.02 \times 10^{-7}$$

Total local aircraft crash potential:

$$P1_{fa} = P1a_{f} + P1b_{f} = 1.30 \times 10^{-10} + 1.02 \times 10^{-7} = 1.033 \times 10^{-7}$$

For commercial traffic flying on V-27 and not landing locally:

V-27 is a federal flight route from the Santa Barbara area northwest to the Big Sur area.. Most of the aircraft on this route are normally flying at altitudes above 10,000 ft, with some smaller aircraft at elevations as low as 3,500 ft. Per the FAA Standards Office, the number of aircraft on this route is conservatively estimated at 20 per day or 7,300 per year. Using the same data as above and adjusting for the number of flights:

$$P2_{fa} = CxNxA/w = (4 \times 10^{-10}) \times (7300) \times (0.0273)/(10) = 7.97 \times 10^{-9}$$

For military aircraft flying on VR-249:

VR-249 is a military training route, which requires 5 miles visibility and the ceilings above 3,000 ft. The aircraft may be traveling between sea level and 10,000 ft. The route is used very infrequently and is estimated to have approximately 50 flights a year. In the area of the DC ISFSI this route is provided for normal flight modes and is not expected to include any high-stress maneuvers. The majority of the aircraft flying this route over the past 12 months were F-18s. In addition, there have been a limited number of C-130, F-16 and EA6B aircraft and some helicopters using this route. For this calculation, N is conservatively taken to be 75 flights. The center of the route is approximately 2 miles off shore; therefore, (w) is conservatively set at 1 mile in this calculation. There was no data provided in the NUREG for military aircraft that would support this route and as a result the in flight crash probability for F-16s accepted in the Private Fuels SER of $2.736 \times 10^{-8}$ was used.

$$P3_{fa} = CxNxA/w = (2.736 \times 10^{-8}) \times (75) \times (0.0273)/(1) = 5.60 \times 10^{-8}$$

Military ordinance on aircraft on VR-249

Based on information provided by the Naval Air Station at Lenore, which flies a majority of the flight on VR-249, aerial bombs are not carried. . However, because of recent events, other ordinance such as air-to-air missiles and cannon/machine guns might be carried on a very small number of the military aircraft on this route. Accidental firings of air-to-air missiles or aircraft guns have not been reported. In addition, air-to-air ordinance does not have a large explosive charge and would not be expected to cause major damage to non-aircraft targets.

VR-249 is a visual route, which requires a minimum of 5 miles of visibility and minimum ceilings of 3,000 ft. Aircraft using this route normally remain offshore and do not fly directly over the Diablo Canyon Power Plant or the Diablo Canyon ISFSI. Based on the type of ordinance the miniscule probability of an accidental discharge, and the visual requirements of the route the potential for any possible interaction between the ordinance and the ISFSI is not credible.

Summary of aircraft hazards

As stated above, and with the exception of the traffic related to VR-249, Morro Bay VOR and from V-27, the landing patterns and distance to the local airports would not significantly increase the probability of a crash at the ISFSI site. In addition, there are no designated airspaces, which are within the limits of Criterion 2 of NUREG-0800. As result, the total aircraft hazard probability at the Diablo Canyon ISFSI site is equal to the sum of the individual probabilities calculated above.

$$\text{Total} = P1_{fa} + P2_{fa} + P3_{fa} = (1.033 \times 10^{-7}) + (7.97 \times 10^{-9}) + (5.60 \times 10^{-8}) = 1.67 \times 10^{-7}$$

Based on the above calculation, the total aircraft hazard probability is determined to be approximately $1.67 \times 10^{-7}$, which is less than the threshold of $1 \times 10^{-6}$ specified in DOE-STD-3014-96 for acceptable frequency of aircraft impact into a facility from all types of aircraft.

PG&E is aware the NRC is considering revising security regulations which may affect aircraft hazard requirements relating to aircraft hazards. Following adoption of any new security regulations by the NRC, PG&E will comply with any such revised requirements as appropriate.

## 2.2.2 ONSITE POTENTIAL HAZARDS

### 2.2.2.1 Structures and Facilities

At the DCPP site, including the ISFSI storage site, there are no cooling towers or stacks with a potential for collapse. Therefore, such hazards need not be considered for any potential effects on the ISFSI.

There are 500-kV transmission lines that run in close proximity of the ISFSI storage site and on the hill above it (Figure 2.2-1). A 500-kV transmission line drop is postulated as a result of a transmission tower collapse or transmission line hardware failure near the ISFSI storage site and the cask transfer facility (CTF), as discussed on Section 8.2.8. The worst-case fault condition for a cask is that which places a cask in the conduction path for the largest current. This condition is the line drop of a single conductor of one phase with resulting single line-to-ground fault current and voltage-induced arc at the point of contact.

It is concluded that the postulated transmission line break will not cause the affected cask components to exceed either normal or accident condition temperature limits and that localized material damage at the point of arc on the shell of the overpack and transfer cask water jacket is bounded by accident conditions discussed in Sections 8.2.2 (tornado missile) and 8.2.11 (loss of shielding, HI-TRAC transfer cask water jacket). As a result of the considerations, it is apparent that the postulated transmission line break does not adversely affect the thermal performance of either system.

In addition to the 500-kV lines, the towers that support these lines were evaluated for any potential effect (Figure 2.2-1). They have been evaluated, and although the towers could fail as a result of a severe wind event, there would be no separation of the towers from their foundations, and the towers on the hillside would not have credible contact with the ISFSI storage site. However, the towers, which are located near the ISFSI storage site could, in these events, collapse and strike either the MPC while at the CTF or the loaded overpacks stored on the pads. As a result, as discussed in Section 8.2.16, this impact potential has been evaluated, and it does not adversely affect the MPC or the loaded overpacks.

### 2.2.2.2 Hazards from Fires

The ISFSI or the fuel storage systems have no credible exposure to fires caused by offsite transportation accidents, pipelines, or manufacturing facilities because of the distance to these transportation routes and the lack of facilities in the proximity of the site. However, there are onsite sources that were evaluated.

Fires are classified as human-induced or natural phenomena design events in accordance with ANSI/ANS 57.9, Design Events III and IV (Reference 3). To identify sources and to establish a conservative design basis for onsite exposure, a walkdown was performed of the CTF, ISFSI storage site, and the complete transportation route from the FHB/AB to the CTF and ISFSI storage site. Based on that walkdown, the following fire events are postulated:

(1) Onsite transporter fuel tank fire

(2) Other onsite vehicle fuel tank fires

(3) Combustion of other local stationary fuel tanks

(4) Combustion of other local combustible materials

(5) Fire in the surrounding vegetation

The potential for fire is addressed for both the HI-STORM 100 overpack and the HI-TRAC transfer cask. Locations where the potential for fire is addressed include the ISFSI storage pad; the area immediately surrounding the ISFSI storage pad, including the CTF; and along the transport route between DCPP and the ISFSI storage pad. These design-bases fires and their evaluations are detailed in Section 8.2.5.

For the evaluation of the onsite transporter and other onsite vehicle fuel tank fires (Events 1 and 2), it is postulated that the fuel tank is ruptured, spilling all the contained fuel, and the fuel is ignited. The fuel tank capacity of the onsite transporter is limited to a maximum of 50 gallons of fuel. The maximum fuel tank capacity for other onsite vehicles in proximity to the transport route and the ISFSI storage pads is assumed to be 30 gallons. Any transient sources of fuel in larger volumes, such as tanker trucks, will be administratively controlled to provide a sufficient distance from the ISFSI storage pads (at all times), the CTF (while transferring an MPC), and the transport route during the cask transport. As discussed in Section 8.2.5, the results of analyses indicate that neither the storage cask nor the transfer cask undergoes any structural degradation and that only a small amount of shielding material (concrete and water) is damaged or lost. This analysis bounds the 30-gallon onsite vehicle fuel tank fire (Event 2).

All onsite stationary fuel tanks (Event 3) are at least 100 ft from the nearest storage cask, the transport route, and the CTF (Figure 2.2-1). Therefore, there is at least a 100-ft clearance between combustible fuel tanks and the nearest cask in transport, at the CTF, or on the ISFSI storage pads. These existing stationary tanks have been evaluated, but due to their distances to the transport route or the storage pads, the total energy received by the storage cask or the transporter is insignificant compared to the design basis fire event.

No combustible materials will be stored within the security fence around the ISFSI storage pads at any time. In addition, prior to any cask operation involving fuel transport, a walkdown of the general area and transportation route will be performed to assure all local combustible materials (Event 4), including all transient combustibles, are controlled in accordance with administrative procedures.

The native vegetation surrounding the ISFSI storage pad is primarily grass, with no significant brush and no trees. Maintenance programs will prevent uncontrolled growth of the surrounding vegetation. As discussed in Section 8.2.5, a conservative fire model was established for evaluation of grass fires, which has demonstrated that grass fires are bounded by the 50-gallon transporter fuel tank fire evaluation.

In summary, as discussed in Section 8.2.5, the potential effects of any of these postulated fires have been found to be insignificant or acceptable. The physical layout of the Diablo Canyon ISFSI and the administrative controls on fuel sources ensure that the general design criteria related to fire protection specified in 10 CFR 72.122(c) are met (Reference 4).

#### 2.2.2.3 Onsite Explosion Hazards

The storage site has no credible exposure to explosion caused by transportation accidents, pipelines, or manufacturing facilities because of the distance to these transportation routes and the lack of facilities in the proximity of the site. However, there are potential onsite hazards that must be evaluated.

Explosions are classified as human-induced or natural phenomena design events in accordance with ANSI/ANS 57.9 Design Events III and IV. To determine the potential explosive hazards, which could affect the ISFSI or the fuel transportation system, a walkdown of the ISFSI storage area and the transportation route from the FHB/AB was completed. The following explosion sources and event categories have been identified and evaluated in Section 8.2.6:

(1) Detonation of a transporter or an onsite vehicle fuel tank

(2) Detonation of a propane bottle transported past the ISFSI storage pad

(3) Detonation of an acetylene bottle transported past the ISFSI storage pad

(4) Detonation of large stationary fuel tanks in the vicinity of the transport route

(5) Detonation of mineral oil from the Unit 2 main bank transformers

(6) Explosive decompression of a compressed gas cylinder

(7) Detonation of the bulk hydrogen storage facility

(8) Detonation of acetylene bottles stored on the east side of the cold machine shop

Figure 2.2-1 shows the location of the stationary potential sources (sources 4, 5, 7, and 8). Events 1, 2, 3, and 6 are assumed to occur in the vicinity of the ISFSI storage pads, CTF, or transport route and potentially affect both the loaded overpack and the transfer cask. The assumed distance between the source of detonation and the nearest loaded overpack is 50 ft. This is based on: (a) no gasoline-powered vehicles being allowed within the ISFSI protected area, and (b) the minimum distance between the storage casks and the north side of the ISFSI protected area fence (where the road is) being 50 ft. Detonation sources in the vicinity of the CTF or transporter during fuel transportation or storage operations will be controlled by administrative procedures to provide sufficient distance. Events 4 through 8 occur in the vicinity of the transport route and affect only the transfer cask.

In all of the above evaluations, the effect on the loaded overpacks or transport cask is minimal, and there will be no loss of function. For Events 1 through 3, the size of the fuel tanks, number of cylinders, how they are transported, when they are transported, and the physical distance to the storage pads, CTF, or transporter are controlled by administrative procedures. For Event 4, the distance of the existing fuel tanks from the transportation route precludes any effect on the transportation of the spent fuel to the storage pads or CTF. Event 5 involves the mineral oil in the Unit 2 main bank transformers. The detonation of this oil is normally not considered credible because of its flash point. However, there is some potential for an electrical short or other ignition source to be the cause of ignition. As a result, this was evaluated as discussed in Section 8.2.6 and found to be risk insignificant based on Regulatory Guide 1.91 acceptance criteria. Event 6 concerns decompression of gas cylinders and the possible missile damage to the transfer cask and overpack. The evaluation performed in Section 8.2.6 shows that there would be no significant damage or loss of function by this event. Event 7 involves the transportation of the transfer cask past a potential hydrogen explosion hazard (Figure 2.2-1). Section 8.2.6 discusses the evaluation that was performed for this event. The evaluation shows that the probability of a detonation at the moment the transporter is in the vicinity is so small that it is not credible per the guidelines of Regulatory

Guide 1.91. Event 8 was evaluated, as discussed in Section 8.2.6, where it is shown that the number of acetylene bottles that would have to be stored on the east side of the cold machine shop and detonate to degrade the structural integrity of the transfer cask far exceeds the available bottle storage space.

The Cask Transportation Evaluation Program will be developed, implemented, and maintained to ensure that no additional hazards are introduced either at the storage pads, CTF, or on the transportation route during onsite transport of the loaded overpacks or transfer cask. That program will include limitation on hazards and will require a transportation route walkdown prior to any movement of the transporter with nuclear fuel between the FHB/AB and the CTF, and between the CTF and the storage pads. The walkdown will require the evaluation or removal of any identified hazards prior to the movement of the transporter. The program will also control all movement of vehicles or activities during onsite transport that could have an adverse effect on the loaded overpacks or transfer cask.

#### 2.2.2.4 Chemical Hazards

A walkdown of all chemical hazards was performed in the ISFSI storage pad and CTF areas, and along the transportation route. Chemical hazards were identified that could have an effect on the ISFSI or the transportation system. To ensure minimum potential for chemical hazards, the administrative program provided to control fire and explosive hazards will also include identification, control, and evaluation of hazardous chemicals.

### 2.2.3 SUMMARY

In summary, there are no credible accident scenarios involving any offsite industrial, transportation, or military facilities in the area around the DCPP site that will have any significant adverse impact on the ISFSI. In addition, there are no potential onsite fires, explosions, or chemical hazards that would have a significant impact on the ISFSI.

### 2.2.4 REFERENCES

1. Regulatory Guide 1.91, Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants, US Nuclear Regulatory Commission, February 1978.

2. Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, USNRC, NUREG-0800, July 1981.

3. ANSI/ANS 57.9, 1992, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type), American National Standards Institute.

4. 10 CFR 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.

5. DOE-STD-3014-96 Accident Analysis for Aircraft Crash Into Hazardous Facilities, US Department of Energy, October 1996.

## 2.3 METEOROLOGY

The meteorology of the Diablo Canyon area is described in Section 2.3 of the DCPP FSAR Update. Information in the FSAR Update includes discussion of the regional climatology, local meteorology, topographical information, onsite meteorological measurement program, and diffusion estimates for the Diablo Canyon owner-controlled area, which includes the ISFSI site. Relevant tables and figures supporting the discussion are included in the FSAR Update.

Meteorological conditions for the ISFSI site are expected to be the same as for DCPP since the ISFSI site is located approximately 0.22 miles and slightly uphill from the DCPP facilities. No significant changes in climate or meteorological characteristics can occur within such a short distance and, thus, existing meteorological measurements for DCPP are expected to be equally applicable to the ISFSI. Diffusion estimates at the ISFSI site are provided in Section 2.3.4.

The FSAR Update is maintained up to date by PG&E through periodic revisions made in accordance with 10 CFR 50.71(e). Hence, the information contained in the FSAR Update is current, and no further revision is necessary for applicability to the ISFSI. Therefore, in accordance with the guidance of Regulatory Guide 3.62, material from Section 2.3 of the FSAR Update is incorporated herein by reference in support of the ISFSI license application. The following paragraphs provide a brief summary of various discussions from Section 2.3 of the FSAR Update.

### 2.3.1 REGIONAL CLIMATOLOGY

The climate of the area is typical of the central California coastal region and is characterized by small diurnal and seasonal temperature variations and scanty summer precipitation. The prevailing wind direction is from the northwest, and the annual average wind speed is about 10 mph. In the dry season, which extends from May through September, the Pacific high-pressure area is located off the California coast, and the Pacific storm track is located far to the north. Moderate to strong sea breezes are common during the afternoon hours of this season while, at night, weak offshore drainage winds (land breezes) are prevalent. There is a high frequency of fog and low stratus clouds during the dry season, associated with a strong low-level temperature inversion.

The mountains that extend in a general northwest-to-southeast direction along the coastline affect the general circulation patterns. This range of mountains is indented by numerous canyons and valleys, each of which has its own land-sea breeze regime. As the air flows along this barrier, it is dispersed inland by the valleys and canyons that indent the coastal range. Once the air enters these valleys and canyons, it is controlled by the local terrain features.

The annual mean number of days with severe weather conditions, such as tornadoes and ice storms at west coast sites, is zero. Thunderstorms and hail are also rare phenomena, the average occurrence being less than 3 days per year. The maximum-recorded precipitation in the San Luis Obispo region is 5.98 inches in 24 hours at San Luis Obispo. The 24-hour maximum occurred on March 4, 1978.

The maximum-recorded annual precipitation at San Luis Obispo was 54.53 inches during 1969. The average annual precipitation at San Luis Obispo is 21.53 inches. There are no fastest mile wind speed records in the general area of Diablo Canyon, surface peak gusts at 46 mph have been reported at Santa Maria, California, and peak gusts of 84 mph have been recorded at the 250 ft level at the Diablo Canyon site.

## 2.3.2 LOCAL METEOROLOGY

The average annual temperature at the ISFSI site is approximately 55°F (based on measurements made at the DCPP primary meteorological tower). Generally, the warmest mean monthly temperature occurs in October, and the coldest mean monthly temperature occurs in December. The highest hourly temperature, as recorded at one of the recording stations, is 97°F in October 1987, and Diablo Canyon experienced below-freezing temperatures in December 1990 for several hours. Essentially no snow or ice occurs at the ISFSI site.

Solar radiation data considered representative of the Diablo Canyon ISFSI site is collected by the California Irrigation Management Information System (CIMIS), Department of Water Resources, at the California Polytechnic State University in San Luis Obispo, California. The CIMIS collection site is about 12 miles northeast of the Diablo Canyon ISFSI site. For a period of record between May 1, 1986 and December 31, 1999, the maximum measured incident solar radiation (insolation) values at the CIMIS site were 766 g-cal/cm$^2$ per day for a 24-hour period and 754 g-cal/cm$^2$ per day for a 12-hour period, both on June 1, 1989. The daily (24-hour) average for the period of record was 430 g-cal/cm$^2$ per day. For the Diablo Canyon ISFSI site, the insolation values would likely be lower than the CIMIS values because of more frequent fog in the ISFSI area.

The average annual precipitation at the DCPP site is approximately 16 inches. The highest monthly total recorded between 1967 and 1981 was 11.26 inches. The greatest amount of precipitation received in a 24-hour period was 3 28 inches. These maxima were recorded in January 1969 and March 1978, respectively. The maximum hourly amount recorded in the Diablo Canyon area during the same period is 2.35 inches.

The highest recorded peak wind gust at the primary meteorological tower is 84 mph, and the maximum-recorded hourly mean wind speed is 54 mph. Persistence analysis of wind directions in the Diablo Canyon area shows that, despite the prevalence of the marine inversion and the northwesterly wind flow gradient along the California coast, the long-term accumulation of emissions in any particular geographical area downwind is virtually impossible. Pollutants injected into the marine inversion layer of the coastal wind regime are transported and dispersed by a complex array of land-sea breeze regimes that exist all along the coast wherever canyons or valleys indent the coastal range.

Topographical influences on both short-term and long-term diffusion estimates are pronounced in that the ridge lines east of the ISFSI location extend at least to the average height of the marine inversion base. The implications of this barrier are:

(1) Any material released that is diverted along the coastline will be diluted and dispersed by the natural valleys and canyons, which indent the coastline.

(2) Any material released that is transported over the ridgeline will be distributed through a deep layer because of the enhanced vertical mixing due to topographic features.

### 2.3.3 ONSITE METEOROLOGICAL MEASUREMENT PROGRAM

The current onsite meteorological monitoring system supporting DCPP operation will serve as the onsite meteorological measurement program for the ISFSI. The system consists of two independent subsystems that measure meteorological conditions and process the information into useable data. The measurement subsystems consist of a primary meteorological tower and a backup meteorological tower. The program has been designed and continually updated to conform with Regulatory Guide 1.23.

A supplemental meteorological measurement system is also located in the vicinity of DCPP. The supplemental system consists of two Doppler acoustic sounders and six tower sites. Data from the supplemental system are used for emergency response purposes to access the location and movement of any radioactive plume.

### 2.3.4 DIFFUSION ESTIMATES

For ISFSI dose calculations required by 10 CFR 72.104, (normal operations and anticipated occurrences), site boundary $\chi/Q$ values range from $9.2 \times 10^{-8}$ to $3.4 \times 10^{-6}$ sec/m$^3$ and nearest residence $\chi/Q$ values range from $2.0 \times 10^{-8}$ to $4.2 \times 10^{-7}$ sec/m$^3$. These values are taken from Table 11.6-13 of the DCPP FSAR Update and have been determined to be applicable to the ISFSI site. They will be used, as appropriate, for dose calculations related to normal operations and anticipated occurrences.

Compliance with 10 CFR 72.106 requires calculation of design basis accident doses at the controlled area boundary (site boundary for the Diablo Canyon ISFSI), which is about 400 meters from the ISFSI at its closest point. Based on information from the DCPP FSAR Update, Section 2.3.4 and Table 2.3-41, a $\chi/Q$ of $4.5 \times 10^{-4}$ sec/m$^3$ has been determined to be a conservative estimate applicable to the ISFSI site and will be used for accident dose calculations.

## 2.6 GEOLOGY AND SEISMOLOGY

The Diablo Canyon Independent Spent Fuel Storage Installation (ISFSI) will be located directly inland from the power plant on a graded bedrock hillslope adjacent to the DCPP raw water reservoir (Figure 2.6-1). It was desirable to select a site having bedrock properties and earthquake response characteristics comparable to those of the bedrock beneath the Diablo Canyon power block, such that existing DCPP design-basis ground motions could be used in the design of the ISFSI.

In this section, the geologic and seismologic conditions in the region are described and evaluated. Detailed information is provided regarding the earthquake vibratory ground motions, foundation characteristics, and slope stability at the ISFSI and CTF sites. Information regarding foundation characteristics and slope stability also is provided for the transport route between the power block and the CTF. The information is in compliance with the criteria in Appendix A of 10 CFR 100, and 10 CFR 72.102, and meets the format and content recommendations of Regulatory Guide 3.62. Several commercial technical computer software programs were used to assist in the analyses performed for Section 2.6.

An external, independent Seismic Hazards Review Board advised on the studies carried out for this section of the licensing submittal. A letter summarizing the conclusions of the consulting board is provided in Reference 1, as are the names and affiliations of the project team responsible for preparation of this section.

**Definitions**

For the purposes of Section 2.6, the following definitions and boundaries were used to describe the ISFSI study area and plant site region, as illustrated on Figure 2.6-1 (definitions of other terms used in this report are in the glossary at the front of the report):

- plant site region: the area of the Irish Hills and vicinity within a 10-mile radius of the Diablo Canyon ISFSI
- plant site area: the area within the DCPP boundary
- ISFSI study area: the area extending along the nose of the ridge behind the power plant and encompassing the ISFSI site and CTF site

**Conclusions**

Geologic, seismologic, and geotechnical investigations for the ISFSI yielded the following conclusions:

- The ISFSI will be founded on bedrock that is part of the same continuous, thick sequence of sandstone and dolomite beds upon which the DCPP power block is sited. The shear wave velocity characteristics of the rock at the ISFSI and CTF sites are within the same range as those at the power block. Additionally, the ISFSI and CTF sites are approximately the same distance from the Hosgri fault zone, the controlling earthquake source for the DCPP. Thus, the foundation conditions and ground-motion response characteristics are the same as those at the DCPP (discussed in Section 2.6.1.10).

- Because the ground-motion response characteristics at the ISFSI are the same as those at the DCPP, the DCPP earthquake ground motions are appropriate for use in the licensing of the ISFSI, in accordance with 10 CFR 72.102(f) (discussed in Section 2.6.2).

- Because ISFSI pad sliding, slope stability, and the stability of the transporter are affected by longer-period ground motions than those characterized by the DCPP ground motions, response spectra having a longer-period component were developed. The longer-period component conservatively incorporates the near-fault effects of fault rupture directivity and fling. These spectra, referred to as the ISFSI long-period ground motions (ILP), and associated time histories, were used to analyze elements that may be affected by longer-period ground motions (discussed in Section 2.6.2.5).

- Several minor bedrock faults were observed at the ISFSI and CTF sites. These minor faults are not capable; hence, there is no potential for surface faulting at the ISFSI or CTF sites (discussed in Section 2 6.3).

- The sandstone and dolomite bedrock, including zones of friable rock, that underlies the ISFSI and CTF sites area is stable, and has sufficient capacity to support the loads imposed by the ISFSI pads and casks and the CTF without settlement or differential movement (discussed in Section 2.6.4).

- There are no active landslides or other evidence of existing ground instability at the ISFSI and CTF sites, or on the hillslope above the ISFSI site (discussed in Section 2.6.1.12).

- The stability of the hillslope and the slopes associated with the pads, CTF, and transport route under static and seismic conditions was analyzed using conservative assumptions regarding slope geometry, material properties, seismic inputs, and analytical procedures (discussed in Section 2.6.5). The analyses show that the slopes have ample factors of safety under static conditions. The cutslope above the ISFSI site may experience local wedge movements or small displacements if exposed to the design-basis earthquakes Mitigation measures to address these movements are described in Sections 4.2.1.1.9.1 and 4.2.1.1.9.2.

- The transport route follows existing paved roads, except for a portion of the route that will be constructed to avoid a landslide at Patton Cove along the coast. The route will have foundation conditions satisfactory for the transporter (discussed in Section 4.3.3). Small debris flows could potentially close portions of the road during or immediately following severe weather (discussed in Section 2.6.5.4). Because the transport route will not be used during severe weather, the flows will not be a hazard to the transporter.

## 2.6.1 GEOLOGIC, SEISMOLOGIC AND GEOTECHNICAL INVESTIGATIONS

Extensive geologic, seismologic and geotechnical investigations were performed to characterize the ISFSI and CTF sites. These investigations included compilation and review of pre-existing information developed for construction of the power plant, the raw water reservoir, and the 230-kV and 500-kV switchyards; as well as extensive detailed investigations performed in the ISFSI study area. These investigations are described in References 2 and 3. The investigations focused on collecting information to address four primary objectives:

- to evaluate foundation properties beneath the ISFSI pads, the CTF facility, and the transport route
- to evaluate the stability of the proposed cutslopes and existing hillslope above the ISFSI pads and along the transport route
- to identify and characterize bedrock faults at the site
- to compare bedrock conditions at the ISFSI site with bedrock conditions beneath the DCPP power block for the purpose of characterizing earthquake ground motions

Investigations in the plant site area included interpretation of aerial photography, review of existing data and literature, and field reconnaissance. In particular, borehole and trench data collected in the 1960s and 1970s for the power plant were compiled, reviewed, and used to evaluate stratigraphic conditions beneath the power block and between the power block and the ISFSI site.

Investigations in the ISFSI study area and along the transport route were conducted to develop detailed information on the lithology, structure, geometry, and physical properties of bedrock beneath the ISFSI and CTF sites, and beneath the transport route. Investigations of the ISFSI and CTF site geology included 17 borings at 14 locations, 22 trenches and test pits, a seismic refraction survey, down-hole geophysics and televiewer surveys, petrographic analysis of rock samples, laboratory analysis of soil and rock properties, and detailed surface mapping (Reference 3). These data were used to develop a detailed geologic map of the plant site area, the ISFSI study area and transport route, and 12 geologic cross sections to illustrate the subsurface distribution of bedrock lithology and structure (Reference 2, Attachment 16).

### 2.6.1.1 Existing Geologic, Seismologic, and Geotechnical Information

Existing geologic, seismologic, and geotechnical information includes that collected for licensing the operating DCPP, construction of the raw water reservoir, and construction of the

230-kV and 500-kV switchyards. Regional and site-specific geologic, seismologic and geotechnical investigations at the DCPP site are documented in Sections 2.5.1 and 2.5.2 of the DCPP Final Safety Analysis Report (FSAR) Update, submitted in support of continued operation of Units 1 and 2 (Reference 4). In response to License Condition Item 2.C.(7) of the Unit 1 Operating License DPR-80, issued in 1980, PG&E was required to reevaluate the seismic design bases for the DCPP. This reevaluation became known as the Long Term Seismic Program (LTSP). The program was conducted between 1985 and 1991. In June 1991, the Nuclear Regulatory Commission (NRC) issued Supplement Number 34 to the Diablo Canyon Safety Evaluation Report (Reference 5), in which the NRC concluded that PG&E had satisfied License Condition Item 2.C.(7). The LTSP evaluations are docketed in the LTSP Final Report (Reference 6) and the Addendum to the Final Report (Reference 7). The information presented herein summarizes and refers to the DCPP FSAR Update and LTSP reports.

Existing regional and site-specific geologic, seismologic and geotechnical information for the ISFSI is discussed in the following docketed references:

| | |
|---|---|
| Regional physiography: | DCPP FSAR Update, Section 2.5.1.1.1 |
| Geologic setting: | DCPP FSAR Update, Section 2.5.1.1.2.1<br>LTSP Final Report, Chapter 2 |
| Tectonic features. | DCPP FSAR Update, Sections 2.5.1.1.2.2 and 2.5.1.1.2.3<br>LTSP Final Report, Chapter 2 |
| Geologic history: | DCPP FSAR Update, Section 2.5.1.1.3<br>LTSP Final Report, Chapter 2 |
| Regional geologic structure and stratigraphy: | DCPP FSAR Update, Sections 2.5.1.1.4 and 2.5.1.1.5<br>LTSP Final Report, Chapter 2 |
| Geologic structure and stratigraphy of the plant site area: | DCPP FSAR Update, Section 2.5.1.2<br>LTSP Final Report, Chapter 2 |
| Slope stability of the plant site area: | Slope Stability Report |
| Earthquake history and association of earthquakes with geologic structures: | DCPP FSAR Update, Sections 2.5.2.5 and 2.5.2.6<br>LTSP Final Report, Chapter 2 |

| | |
|---|---|
| Maximum earthquakes affecting the plant site area: | DCPP FSAR Update, Section 2.5.2.9<br>LTSP Final Report, Chapter 3 |
| Earthquake ground accelerations and response spectra: | DCPP FSAR Update, 2.5.2.10 and 3.71<br>LTSP Final Report, Chapter 4 |

The ISFSI is sited on a bedrock slope that was previously used as a source of fill materials for construction of the 500-kV and 230-kV switchyards. The first geologic and geotechnical studies in the area were performed by Harding Miller Lawson & Associates (HML) (Reference 8). The study was conducted prior to the borrow excavation to obtain information regarding the excavatability and suitability of the site materials for switchyard fills. Their investigations included borings, test pits, and refraction surveys. The depth of their explorations, however, was limited to the depth of the planned (and as-built) borrow excavation, and did not extend below the present post-excavation site elevations. All the material investigated by HML was removed during the borrow excavation and used for construction of the switchyard fills.

In addition, an assessment of slope stability near the DCPP was performed following the heavy winter storms of 1996-1997 (Reference 9). This report includes a map of landslides in the plant site area, and a slope stability analysis of the natural hillslope and cutslope between the power plant and the ISFSI.

### 2.6.1.2 Detailed ISFSI Study Area Investigations

Additional detailed geologic, seismic, and geotechnical studies were performed in the ISFSI study area. References 2 and 3 further describe the method, technical approach, and results of the detailed studies. The following field, office, and laboratory investigations were performed:

| Activity | Documented in |
|---|---|
| Interpretation of 1968 aerial photography, by PG&E Geosciences Department (Geosciences) and William Lettis & Associates, Inc. (WLA) | Reference 2, Attachment 16 |
| Evaluation of previous geologic investigations in the power plant area, including borings by HML and others, by Geosciences and WLA | Reference 2, Attachment 16 |
| Detailed geologic mapping of structures and lithology, by Geosciences and WLA | Reference 2, Attachment 16 |
| **ACTIVITY** | **Documented in** |
| Analysis of rock mass strength, by Geosciences and WLA | Reference 2, Attachment 16 |

| | |
|---|---|
| Evaluation of rock fractures, by Geosciences and WLA | Reference 2, Attachment 16 |
| Analysis of potential rock slope stability, by Geosciences, WLA, and Geomatrix Consultants | Reference 2, Attachments 17, 18, 20, 21, 23 |
| Geologic mapping of the power plant site and ISFSI study area, by WLA | Reference 3, Data Report A |
| Drilling and logging of 17 exploratory diamond-core borings at 14 locations at and near the ISFSI and CTF sites, by WLA | Reference 3, Data Report B |
| Implementation of two surface seismic refraction lines to measure compressional wave and shear wave velocities of shallow bedrock across the ISFSI site, by GeoVision | Reference 3, Data Report C |
| Suspension logging of compression and shear wave velocities from boreholes 98BA-1, -3 and -4, by GeoVision | Reference 3, Data Report C |
| Excavation and logging of 22 exploratory trenches at 14 locations to expose bedrock structures and lithology at the ISFSI site, by WLA | Reference 3, Data Report D |
| Natural gamma and caliper logging of borings 00BA-1 and -2, and optical televiewer imaging of all borings drilled in 2000 and 2001, by NORCAL Geophysical Consultants | Reference 3, Data Report E |
| Compilation of discontinuity data, by WLA | Reference 3, Data Report F |
| Soil testing of clay beds, by Cooper Testing Laboratories | Reference 3, Data Report G |
| Characterization of rock mass strength, by WLA | Reference 3, Data Report H |
| Rock strength testing of representative core samples, by GeoTest Unlimited | Reference 3, Data Report I |
| Petrographic analyses and x-ray diffraction testing of rock samples, by Spectrum Petrographics, Inc. | Reference 3, Data Report J |
| X-ray diffraction testing and petrographic analysis of clay beds, by Schwein/Christensen Laboratories, Inc. | Reference 3, Data Report K |

### 2.6.1.3 General Description of the ISFSI Study Area

The location and topography of the ISFSI and CTF sites and the transport route are shown in Figures 2.6-1, 2.6-2, and 2.6-3. Detailed investigations of the seismotectonic setting performed for the LTSP (LTSP Final Report, Chapter 2) show that the plant site area lies along the active tectonic boundary between the Pacific and North American plates in coastal Central California. It is located within the San Andreas fault system, about 48 miles west of the main San Andreas fault, and about 3 miles east of the offshore Hosgri fault zone. Current tectonic activity in the region is dominated by active strike-slip faulting along the Hosgri fault zone; and reverse faulting within the Los Osos/Santa Maria domain. The plant site area is on a structural subblock of the San Luis Range (the Irish Hills subblock, Figure 2.6-4), bordered on the northeast and southwest by the Los Osos and southwestern boundary zone reverse faults, respectively, and on the west by the Hosgri fault zone (LTSP Final Report, Chapter 2, Figure 2-50). Since the end of the early Quaternary, the Irish Hills subblock has been slowly elevated along these bounding faults. Detailed mapping and paleoseismic investigations performed for the LTSP (LTSP Final Report) and the DCPP FSAR Update, Section 2.5.1 show that no capable faults are present within the plant site area.

Within the Irish Hills structural subblock, the principal geologic structure is the northwest-trending Pismo syncline (termed the San Luis-Pismo syncline in the DCPP FSAR Update, Section 2.5.1.1.5.2). This 20-mile-long regional structure deforms rocks of the Miocene Monterey and Obispo formations, and the Pliocene Pismo Formation. Fold deformation occurred primarily during the Pliocene, and ceased sometime in the late Pliocene or early Quaternary. Detailed mapping of Quaternary marine terraces across the axis and flanks of the syncline during the LTSP (LTSP Final Report, Plates 10 and 12) documents the absence of fold deformation and associated faulting within the Irish Hills structural subblock for at least the past 500,000 to 1,000,000 years (LTSP Final Report, page 2-34).

The plant site area is situated on the eroded southwestern limb of the Pismo syncline (Figure 2.6-4), within Miocene bedrock of the Obispo Formation (Figure 2.6-5). This regional structure has subsidiary folds that are hundreds to 10,000 ft long and hundreds of feet wide (DCPP FSAR Update, Section 2.5.1.1.5.2, p. 2.5-19, -20). One of these structures, a small northwest-trending syncline, is located directly northeast of the power block (DCPP FSAR Update, Section 2.5.1.2.4.2, p. 2.5-32, -33, Figure 2.5-8). This is the same small syncline that extends across the western part of the ISFSI site (Figures 2.6-5, 2.6-6, and 2.6-7).

Along the coast, the Obispo and Monterey formations have been eroded and incised by former high stands of sea level, leaving a preserved sequence of marine terraces and terrace remnants (Figures 2.6-2 and 2.6-7). The foundation for the power block was excavated into rock below the lower two marine terraces, which are approximately 80,000 and 120,000 years old, respectively (LTSP Final Report, Chapter 2). The power block is founded on competent sandstone and siltstone of the Obispo Formation, the same stratigraphic unit that underlies the ISFSI site.

The ISFSI will be on a prominent ridge directly south of the raw water reservoir and east of the DCPP (Figures 2.6-7 and 2.6-8). The ridge area was used formerly as a borrow source to derive fill material for construction of the 230-kV and 500-kV switchyards. The borrow excavation, completed in 1971, removed up to 100 ft of material from the ISFSI site area and extended deep into bedrock (Figures -2.6-2, 2.6-3, and 2.6-9 through 2.6-12). As a result, the ISFSI and CTF facilities will be founded on bedrock, and the foundation stability and seismic response will be controlled by the bedrock properties. The borrow area cutslope is 900 by 600 ft in plan view, and 300 ft high. The slope of the cut face varies between 2.5:1 and 4:1 (22 to 14 degrees). The former borrow activity at the site stripped surficial soil and weathered rock from the hillside above the ISFSI site, leaving a bedrock slope covered with a veneer of rock rubble. The proposed cutslopes south of the ISFSI pads will be cut entirely in bedrock.

The ISFSI site will be accessed via the transport route, which will follow existing paved roads, except where the road is routed inland from Patton Cove. The transport route starts at the power block, and ends at the ISFSI (Figures 2.6-1, 2.6-3, and 2.6-7).

### 2.6.1.4 Stratigraphy

#### 2.6.1.4.1 Plant Site Area Stratigraphy

The plant site area is underlain by bedrock of the early and middle Miocene Obispo Formation, and middle Miocene diabase intrusions (References 10 and 6, Chapter 2). Geologic studies for the original DCPP FSAR Update classified bedrock at the power plant site as strata from the middle and late Miocene Monterey Formation. Subsequent studies published by the U.S. Geological Survey (Reference 10), and conducted during the LTSP (LTSP Final Report, Chapter 2) and this ISFSI study reclassified most of the bedrock in the plant site area as part of the Obispo Formation.

Hall and others (Reference 10) divided the Obispo Formation into two members: a fine-grained, massively bedded, resistant zeolitized tuff (mapped as Tor), and a thick sequence of interbedded marine sandstone, siltstone, and dolomite (mapped as Tof) (Figures 2.6-6 and 2.6-7). During the current geologic investigations, the marine sedimentary deposits were further divided into three units, a, b, and c, based on distinct changes in lithology. Unit $Tof_a$ occurs in the eastern part of the plant site area (entirely east of the ISFSI study area) and consists primarily of thick to massively bedded diatomaceous siltstone and tuffaceous sandstone. Unit $Tof_b$ occurs in the central and west-central part of the plant site area, including the entire ISFSI study area and beneath the power block, and consists primarily of medium to thickly bedded dolomite, dolomitic siltstone, dolomitic sandstone, and sandstone. Unit $Tof_c$ occurs in the western part of the plant site area and consists of thin to medium bedded, extensively sheared shale, claystone and siltstone.

Diabase and gabbro sills and dikes intrude the Obispo Formation in the plant site area. These intrusive rocks originally were mapped as a member of the Obispo Formation (Tod) by Hall

(Reference 11), but later were reclassified as a separate volcanic formation (Tvr) by Hall and others (Reference 10), because the rocks intrude several different formations, and are not confined to the Obispo Formation. The nomenclature of Hall and others (Reference 10) has been adopted for this study, and these rocks are mapped as Tertiary volcanic rock (Tvr) in the plant site area. These intrusive rocks are well exposed in the north wall of Diablo Canyon, across from the ISFSI site (Reference 11). The diabase typically is a dark, highly weathered, low-hardness rock. It is altered and weak, has a fine crystalline structure, and weathers spheroidally. Petrographic analysis of hand samples shows the diabase is an altered cataclastic gabbro and diorite. The large diabase sill that intruded between dolomite and sandstone beds in the raw water reservoir area was entirely removed during borrow area excavation (Figures 2.6-10 and 2.6-11). There are no exposures of diabase remaining on the borrow area cutslope and no diabase was encountered in any of the boreholes or trenches excavated at the ISFSI study area. Deeper parts of the original intrusion are still exposed in the roadcut along Tribar Road east of and below the raw water reservoir (Figure 2.6-6).

Quaternary deposits generally cover bedrock within the plant site area (Figure 2.6-7). These unconsolidated sediments are discussed in Section 2.6.1.5.

#### 2.6.1.4.2 ISFSI Study Area Stratigraphy

The ISFSI is sited on folded and faulted marine strata of unit $Tof_b$ of the Obispo Formation (Figures 2.6-7 and 2.6-8). Unit $Tof_b$ in the ISFSI study area has undergone a complex history of deposition, alteration, and deformation. Understanding the complexity of the geology and the various geologic processes giving rise to the current geologic conditions at the site is important for interpreting the stratigraphy and structural geology at the site. Based on analysis of surface and subsurface data, supplemented by petrographic analyses of rock lithology, mineralogy, and depositional history, the following events produced the current lithology and stratigraphic character of bedrock at the site (Figures 2.6-13 and 2.6-14). A detailed description of each of these processes is presented in Reference 2, Attachment 16.

1. Original marine deposition, including vertical and lateral facies changes within the dolomite and sandstone sequence

2. Burial and lithification, followed by diagenesis and dolomitization

3. Localized addition of petroliferous fluids

4. Diabase intrusion, hydrothermal alteration, and associated deformation

5. Tectonic deformation (folding and faulting)

6. Surface erosion and weathering (both chemical and mechanical)

7. Borrow excavation and stress unloading

Across the ISFSI site, unit $Tof_b$ is significantly influenced by a lateral and vertical facies change from dolomite to sandstone. In the ISFSI site area, therefore, unit $Tof_b$ has been further divided into a dolomite unit ($Tof_{b-1}$) and a sandstone unit ($Tof_{b-2}$). Figure 2.6-15 provides a generalized stratigraphic column illustrating the distribution of rock types within these two subunits. Unit $Tof_{b-1}$ consists primarily of dolomite, dolomitic siltstone, fine-grained dolomitic sandstone, and limestone. Unit $Tof_{b-2}$ consists primarily of fine- to medium-grained dolomitic sandstone and sandstone. Thin clay beds also are present in both units. The dolomite appears to be a diagenetic product of alteration from a limestone and/or calcareous siltstone and very fine sandstone parent rock. Primary deposition of limestone ($CaCO_3$) or calcareous siltstone occurred in a shallow to moderately deep marine environment. Following burial and lithification, the replacement of calcium by magnesium (dolomitization) during diagenesis of the limestone or siltstone formed dolomite ($CaMg(CO_3)_2$).

The contact between the dolomite and sandstone (units $Tof_{b-1}$ and $Tof_{b-2}$) marks a facies change from a deep marine dolomite sequence to a sandstone turbidite sequence. The contact varies from sharp to gradational, and bedding from one unit locally interfingers with bedding of the other unit. For purposes of mapping, the contact was arbitrarily defined as the first occurrence (proceeding down-section) of medium- to coarse-grained dolomitic sandstone below the dolomite. Surface and subsurface geologic data were used to construct 12 cross sections across the site and transport route (Reference 2, Attachment 16). The interfingering nature of the dolomite/sandstone contact beneath the ISFSI study area is illustrated on cross sections A-A', B-B''', D-D', F-F', I-I', and L-L' (Figures 2.6-10, 2.6-11, 2.6-16, 2.6-17, 2.6-18, and 2.6-19, respectively). Some of the thin, interfingering beds provide direct evidence for the lateral continuity and geometry (attitude) of bedding within the hillslope (for example, between boring 01-F and 00BA-1 on section I-I').

Analysis of the cross sections shows that the facies contact between the dolomite and sandstone (units Tofb-1 and Tofb-2) generally extends from northwest to southeast across the ISFSI study area, with sandstone of unit Tofb-2 primarily in the north and northeast part of the area, and dolomite of unit Tofb-1 primarily in the south and southwest part of the area. The three-dimensional distribution of the facies contact is well illustrated by comparing cross sections B-B''' and I-I' (Figures 2.6-11–and 2.6-18). This distribution of the two units reflects a cyclic transgressive/regressive/transgressive marine sequence during the Miocene.

The division of unit $Tof_b$ into two subunits also allows for a detailed interpretation of the geologic structure (folds and faults) in the ISFSI study area. This understanding provides the basis for evaluating the distribution of rock types in the area, and for selecting appropriate rock properties for foundation design and slope stability analyses at the ISFSI, as discussed in Sections 2.6.1.7, 2.6.1.8, 2.6.4.2, and 2 6.5.

#### 2.6.1.4.2.1 Dolomite (Unit $Tof_{b-1}$)

The slope above the ISFSI, including most of the borrow area excavation slope, is underlain by dolomite (Figure 2.6-8). The dolomite is exposed as scattered outcrops across the excavated slope, along the unpaved tower access road (Reference 3, Data Report A), in the upper part of most borings in the ISFSI study area (Reference 3, Data Report B), and in most exploratory trenches (Reference 3, Data Report D). The dolomite consists predominately of tan to yellowish-brown, competent, well-bedded dolomite, with subordinate dolomitic siltstone to fine-grained dolomitic sandstone, and limestone (Figure 2.6-20). Petrographic analyses of hand and core samples from, and adjacent to, the ISFSI study area show that the rock consists primarily of clayey dolomite, altered clayey carbonate and altered calcareous claystone, with lesser amounts of clayey fossiliferous, bioclastic and brecciated limestone, fossiliferous dolomite, and friable sandstone and siltstone (Reference 3, Data Report J, Tables J-1 and J-2). As described in the petrographic analysis, the carbonate component of these rocks is primarily dolomite; thus the general term dolomite and dolomitic sandstone is used to describe the rock.

The dolomite crops out on the excavated borrow area slope as flat to slightly undulating rock surfaces. The rock is moderately hard to hard, and typically medium strong to brittle, with locally well defined bedding that ranges between several inches to 10 ft thick in surface exposures and boreholes. Bedding planes are laterally continuous for several tens of feet, as observed in outcrops, and may extend for hundreds of feet based on the interpreted marine depositional environment. The bedding planes are generally tight and bonded. Unbonded bedding parting surfaces are rare and generally limited to less than several tens of feet, based on outcrop exposures.

#### 2.6.1.4.2.2 Sandstone (Unit $Tof_{b-2}$)

Sandstone of unit $Tof_{b-2}$ generally underlies the ISFSI study area below about elevation 330 ft (Figure 2.6-8). Typically, the rocks in this subunit are well-cemented, hard sandstone and dolomitic sandstone, and lesser dolomite beds.

The well-cemented sandstone encountered in the borings and trenches is tan to gray, moderately to thickly bedded, and competent (Figure 2.6-21). The rock is well sorted, fine- to coarse-grained, and is typically well cemented with dolomite. Petrographic analyses show that the sandstone is altered, and that its composition varies from arkosic to arenitic, with individual grains consisting of quartz, feldspar, dolomite, and volcanic rock fragments (Reference 3, Data Report J). The rock is of low to medium hardness, is moderately to well cemented, and is medium strong. The matrix of some samples contains a significant percentage of carbonate and calcareous silt to clay matrix (probably from alteration). Petrographic analyses show that the carbonate is primarily dolomite. Thus, these rocks are referred to as sandstone and dolomitic sandstone. Bedding in places is well defined, and bedding plane contacts are tight and well bonded. Similar to the dolomite beds, unbonded bedding surfaces within the sandstone are rare and generally limited to less than several tens of feet, based on limited outcrop exposure.

#### 2.6.1.4.2.3 Friable Bedrock

Distinct zones of friable bedrock are present within the generally more cemented sandstone and dolomite (Figures 2.6-8, 2.6-15, and 2.6-22). In some cases, the friable bedrock appears to reflect the original deposit, with no subsequent dolomitization. In other cases, the friable bedrock appears to be related to subsequent chemical weathering or hydrothermal alteration. The friable beds within units $Tof_{b-1}$ and $Tof_{b-2}$ have been designated with the subscript (a). Unit $Tof_{b-1a}$ consists primarily of altered or weathered dolomite or dolomitic siltstone that has a block-in-matrix friable consistency, or simply a silt and clay matrix with friable consistency. The friable rock is of low hardness and is very weak to weak Unit $Tof_{b-2a}$ consists primarily of friable sandstone, is of low hardness, and is very weak to weak. In many cases, the friable sandstone is the original sandstone that has been chemically weathered or altered to a clayey sand (plagioclase and lithics altered to clay). In other cases, the friable sandstone simply lacks dolomite cementation and retains its original friable nature.

The vertical thickness of the friable rock encountered in borings ranges from less than 1 ft to 32 ft. The friable zones extend laterally for tens of feet in trench exposures, and up to about 200 ft were assumed to correlate between borings (Reference 2, Attachment 16). As illustrated on cross section I-I' (Figure 2.6-18), the zones of friable rock are more common, and possibly more laterally continuous, in the sandstone than in the dolomite.

#### 2.6.1.4.2.4 Clay Beds

Clay beds are present within both the sandstone and dolomite units. Clay beds were observed in several trenches (Figures 2.6-23 and 2.6-24) and in many of the borings (Figures 2.6-25 and 2.6-26). Because clay beds are potential layers of weakness in the hillslope above the ISFSI site, they were investigated in detail, (Reference 2, Attachment 16). The clay beds generally are bedding-parallel, and commonly range in thickness from thin partings (less than 1/16 inch thick) to beds 2 to 4 inches thick; the maximum thickness encountered was about 8.5 inches. The clay beds are yellow-brown, orange-brown, and dark brown, sandy and silty, and stiff to hard. Petrographic analyses show that the clay contains marine microfossils and small rock inclusions; the rock inclusions are angular pieces of dolomite that are matrix-supported, and have no preferred orientation or shear fabric (Reference 3, Data Report K). In the trenches, the clay beds locally have slickensides and polished surfaces The clay beds typically are overconsolidated (due to original burial), as supported by laboratory test data (Reference 3, Data Report G), and, where thick, have a blocky structure.

The clay beds encountered in the borings were recorded on the boring logs (Reference 3, Data Report B). In addition, in most of the borings, the clay beds also were documented in situ by a borehole televiewer. The televiewer logs show that the clay beds generally are in tight contact with the bounding rock, and are bedding-parallel (Reference 3, Data Report E). The clay beds range from massive having no preferred shear fabric, to laminated having clear shear fabric. The shear fabric is interpreted to be the result of tectonic shearing during folding and flexural slip of the bedding surfaces. The shear fabric does not reflect gravitational sliding, because features indicative of sliding, such as disarticulation of the rock mass, tensional fissures, and geomorphic expression of a landslide on pre-construction aerial photographs, are not present.

**Clay Beds in Dolomite**

Clay beds are more common, thicker, and more laterally continuous in the dolomite (unit $Tof_{b-1}$). Examination of the continuity of clay beds within and between adjacent trenches, roadcuts, and borings provided data on the lateral continuity (persistence) of the clay beds (Reference 2, Attachment 16). Individual clay beds exposed in the trenches and roadcuts appear to be persistent over distances of between tens of feet to more than 160 ft, extending beyond the length of the exposures. The exposed clay beds are wavy and have significant variations in thickness along the bed. Thinner clay beds (less than about 1/4 inch thick) typically contain areas where asperities on the surfaces of the bounding adjacent hard rock project through or into the thin clay. The bedding surfaces are all irregular and undulating, with the height (amplitude) of the undulation greater than the thickness of the clay beds, such that the clay beds likely will have rock-to-rock contact locally during potential sliding, producing an overall increase in the average shear strength of the clay bed surface. A correlation of clay beds within the slope above the ISFSI site is shown on cross section I-I' (Figure 2.6-18). These correlations indicate that at least some clay beds extend over several hundred feet into the hillslope. However, some beds clearly do not correlate: for example, the clay beds exposed in trenches T-14 and T-15 are not found in nearby boring 01-I.

**Clay Beds in Sandstone**

Clay beds are less common, generally thinner, and less laterally continuous in the sandstone (unit $Tof_{b-2}$). Clay beds observed in the sandstone generally are less than 1/4 inch thick. These thinner clay beds are difficult to correlate laterally between borings and, at least locally, are less than 50 to 100 ft in lateral extent. For example, as shown on cross sections B-B' and I-I' (Figures 2.6-11 and 2.6-18), clay beds were not encountered in boring 01-B, but were encountered in borings 01-A and 01-H, 50 to 100 ft away.

**Clay Moisture Content**

The clay beds encountered in the borings and trench excavations in both the dolomite and sandstone were moist. Clay beds uncovered in the trenches dried out after exposure during the dry season, and became hard and desiccated. When wetted during the rainy season, the clay in the trenches became soft and sticky (Reference 3, Data Report D, Trench T-11). Possible local perched water tables, as observed in boring 01-F and evident elsewhere in the plant site area (Section 2.5, Subsurface Hydrology), also may soften the upper portions of the clay beds during the rainy season in the ISFSI study area.

**Clay Composition**

X-ray diffraction analyses (Reference 3, Data Report K) show that the clay-size fraction of the clay beds consists of three primary minerals: kaolinite (a clay), ganophyllite (a zeolite), and sepiolite (a clay). The silt-size fraction of the sample consists primarily of rock and mineral fragments of quartz, dolomite/ankerite, and calcite. Petrographic examination of the clay (Reference 3, Data Report K) shows a clay matrix having matrix-supported angular rock fragments and no shear fabric. Included rock fragments have evidence of secondary dolomitization of original calcite (limestone), and localized post-depositional contact alteration. Some samples contain microfossils (benthic foraminifera). The ganophyllite minerals appear to be expansive, as evidenced by swelling of one sample (X-1 from trench T-14A) after thin-section mounting. Sample X-2 also had a significant percentage of ganophyllite, and a high plasticity index (PI) of 63 (Reference 3, Data Reports K and G).

The presence of microfossils confirms the clay is depositional in origin, and was not formed by alteration or weathering of a lithified host rock. The clay is interpreted to reflect pelagic deposition in a marine environment.

**2.6.1.4.2.5 Diabase (Tvr)**

Diabase is exposed in the roadcut along Tribar Road and probably underlies the eastern portion of the raw water reservoir area. The diabase is part of the Miocene diabase intrusive complex in Diablo Canyon near the switchyards (Reference 10). A large diabase body was removed during grading for the raw water reservoir pad and the borrow cut area. This body of diabase likely was continuous with the diabase exposed along Tribar Road. Currently, no diabase is exposed on the borrow cut slope, and diabase was not encountered in any of the borings or trenches in the ISFSI study area. The diabase exposed along Tribar Road has been altered to a friable rock, and is soft to dense and easily picked apart; it is judged to be similar in engineering properties to the friable sandstone and friable dolomite found in the ISFSI study area. Though diabase was not encountered elsewhere in the ISFSI study area during field investigations, it is possible that other small dikes or sills of diabase may be encountered during excavation for the ISFSI pads or cutslope.

**2.6.1.5 Geomorphology and Quaternary Geology**

The geomorphology and Quaternary geology of the plant site area is dominated by a flight of coastal marine terraces, deep fluvial incision along Diablo Creek, and deposition of alluvial and colluvial fans at the base of hillslopes. Quaternary deposits cover bedrock across most of the power plant property, except in the ISFSI study area, where extensive borrow excavation in the 1970s removed the Quaternary deposits. These deposits accumulated in distinctive geomorphic landforms that include coastal marine terrace platforms, debris and colluvial fans at the base of hills and swales, landslides on hillslopes and sea cliffs, and alluvium along the floor of Diablo Canyon. The distribution of Quaternary deposits and landforms are shown on Figures 2.6-7 and 2.6-8.

### 2.6.1.5.1 Marine Terraces

Several marine terraces form broad coastal platforms within the western part of the power plant property (Figure 2.6-7). The power plant and associated support facilities and buildings are constructed on these terraces (Figure 2.6-2). Discontinuous remnants of older and higher terraces also are present locally across the ISFSI study area. Each of these marine terraces consists of a relatively flat, wave-cut bedrock platform, a thin layer of marine sand and cobble sediments, and surficial deposits of colluvium, alluvium, and eolian sediments. The "staircase" of bedrock platforms resulted from a combination of regional uplift, sea level fluctuations, and wave erosion.

The locations and elevations of marine terraces along the coast from Avila Beach to Montaña de Oro and Morro Bay, including the area of the power plant, were initially characterized during studies for PG&E's Long Term Seismic Program (LTSP Final Report). Several terraces were mapped in more detail for the ISFSI studies, and the location of the inner edge (or shoreline angle) of the terraces was estimated (Figure 2.6-7). Well-developed, wave-cut bedrock platforms and their associated terraces exist in the plant site area at elevations of about 30 to 35 ft ($Q_1$ terrace), 100 to 105 ft ($Q_2$ terrace), and 140 to 150 ft ($Q_3$ terrace), and form relatively level bedrock surfaces under the surficial Quaternary deposits along the coast. The platforms slope gently seaward at angles from 2 degrees to 3 degrees, and are bordered landward by steep (50 degrees to 60 degrees, LTSP Final Report) former sea cliffs that are now largely covered by thick surficial deposits. A sequence of Pleistocene to Holocene colluvial fans covers the landward portion of the coastal terraces. These deposits consist of crudely bedded clay, clayey gravel, and sandy clay, and have distinct paleosol and carbonate horizons. The lower, Pleistocene fan deposits are very stiff and partly consolidated; they have highly weathered clasts, carbonate horizons, and an oxidized appearance. The upper, Holocene deposits are unconsolidated and have a higher organic contact; they do not have argillic or carbonate horizons.

Near the ISFSI site, discontinuous remnants of a higher marine terrace are present. The terrace has an approximate shoreline angle elevation of 290 ft ($Q_5$ terrace) (Figure 2.6-7). The terrace deposits consist of a basal layer of marine sand and gravel overlain by colluvial sandy clay and clayey gravel. This terrace may be coeval with an estuarine deposit of black clay having interfingering white shell hash that crops out beneath the edge of the 500-kV switchyard fill (Figure 2.6-7). The clay appears to have been deposited in an estuarine environment by an ancient marine embayment into Diablo Canyon. Most of the $Q_5$ terrace, however, has been eroded by incision along Diablo Creek, or is buried by younger stream terrace and landslide deposits, or switchyard and road fills.

The thickness of the terrace deposits (depth to bedrock) varies greatly, from less than 10 ft to greater than 80 ft. Extensive grading for the DCPP and related facilities and parking areas has substantially modified the morphology and thickness of terrace deposits in some locations. The current thickness of terrace deposits, therefore, is locally dependent on site-specific grading activities.

### 2.6.1.5.2 Inland Quaternary Deposits

Diablo Creek has carved a deep channel into bedrock, causing oversteepening of the slopes along the canyon walls. Some thin, narrow, channel deposits, and one locally preserved stream terrace veneered by colluvial deposits, are present in the canyon. The rate and extent of erosion, however, generally has been dominant over sedimentation in the canyon, and alluvial deposits are relatively thin and of limited extent. Substantial reaches along the lower part of the creek were artificially filled, channeled, and altered during development of the power plant and related facilities, particularly around the 230-kV and 500-kV switchyards, which are constructed on large fill pads across the bottom of the canyon.

Slopes in the Irish Hills are extensively modified by mass wasting processes, including landslides, debris flows, creep, gully and stream erosion, and sheet wash. Extensive grading to form level platforms for the power plant and related facilities along the back edge of the coastal terraces has greatly modified the lower portions of most slopes in the plant site area. Large, deep-seated landslide complexes are present on the slopes of Diablo Canyon south of the 230-kV and 500-kV switchyards (Figure 2.6-7). These features consist of large (exceeding 100 acres), deep-seated, coalescing, bedrock landslides. The dip of bedrock strata in the vicinity of these large slides is downslope, suggesting the failure planes for these slides probably occurred within the bedrock along clay beds and bedding contacts. Some slides may have occurred at the contact between bedrock and overlying weathered bedrock and colluvium, or along contacts between Obispo Formation bedrock and relatively weaker diabase.

The large landslide complexes have been considerably modified by erosion, and fluvial terraces and possible remnants of the $Q_5$ marine terrace appear to have been cut into the toes of some of the slides. These conditions suggest they are old features that likely formed prior to the Pleistocene-Holocene transition, during a wetter climate. These large slide complexes, therefore, appear to have a stable configuration under the present climatic conditions, which have persisted during the Holocene (past 10,000 years or so).

Debris-flow scars and deposits are found along some of the steeper slopes (Figure 2.6-7). The debris flows originate where colluvium collects in topographic swales or gullies on the upper and middle slopes. Debris flows usually are triggered by periods of severe weather that allow development of perched groundwater within hillside colluvial deposits. Following initial failure, the saturated mass flows rapidly down drainage channels, commonly scouring the bottom of the channel and increasing in volume as it travels downslope. The flow stops and leaves a deposit of poorly sorted debris at a point where the slope angle decreases. Debris fans formed by accumulation of successive debris flows are present at the mouths of the larger canyons and gullies in the area (Figure 2.6-7).

### 2.6.1.6 Structure

#### 2.6.1.6.1 Regional Structure

Bedrock structure in the plant site region is dominated by the northwest-trending Pismo syncline (Figure 2.6-4), which forms the core of the Irish Hills (References 10 and 11). The regional bedrock structure and tectonic setting are described in the DCPP FSAR Update, Section 2.5.1.1, and LTSP Final Report, Chapter 2, and are summarized in Section 2.6.2 of this report. The following sections describe the structural setting of the ISFSI study area, including the distribution of bedrock folds, faults, and joints in the area.

#### 2.6.1.6.2 ISFSI Study Area Structure

Bedrock in the ISFSI study area has been deformed by tectonic processes and possibly by the intrusion of diabase. The detailed stratigraphic framework described above provides the basis for analyzing the geologic structure in the site area.

Geologic structures in the ISFSI study area include folds, faults, and joints and fractures. The distribution and geometry of these structures is important for evaluating rock mass conditions and slope stability because (1) folds in the bedrock produce the inclination of bedding that is important for evaluating the potential for out-of-slope, bedding-plane slope failures; and (2) faults and, to a lesser extent, joints in the bedrock produce laterally continuous rock discontinuities along which potential rock failures may detach in the proposed cutslopes.

The distribution and geometry of folds and faults in the bedrock were evaluated through detailed surface geologic mapping, trenches, and borings (References 2 and 3). Data from these studies were integrated to produce geologic maps (Figures 2.6-6, 2.6-7, and 2.6-8) and geologic cross sections (for example, Figures 2.6-10, 2.6-11, and 2.6-16 through 2.6-19). The cross sections were prepared at various orientations to evaluate the three-dimensional distribution of structures. Bedding attitudes were obtained from surface mapping (including roadcut and trench exposures) and from boreholes (based on visual inspection of rock core integrated with oriented televiewer data). These bedding attitudes were used to constrain the distribution of bedrock lithologies and geometry of bedding shown on the cross sections.

##### 2.6.1.6.2.1 Folds

Similar to the power plant, the ISFSI is located on the southwestern limb of the regional Pismo syncline (Figure 2.6-4). As shown on the geologic maps (Figures 2.6-6, 2.6-7, and 2.6-8) and cross sections (Figures 2.6-10, 2.6-11, and 2.6-16 through 2.6-19), bedrock in the ISFSI study area is deformed into a small, northwest-trending syncline and anticline along the western limb of the larger regional Pismo syncline. On the ridge southeast of the ISFSI study area, nearly continuous outcrops of resistant beds expose the small anticline and an en echelon syncline (Figures 2.6-6, 2.6-7, and 2.6-17). These folds are relatively tight and sharp-crested, have steep limbs, and plunge to the northwest.

Within the ISFSI study area, the northwest-plunging anticline appears to be the northwestward continuation of the anticline that is exposed in the ridge top at the Skyview Road overlook area (Figure 2.6-1). The anticline varies from a tight chevron fold southeast of the ISFSI study area, to a very broad-crested open fold across the central part of the area. The northwestward shallowing of dips along the anticlinal trend appears to reflect a flattening of fold limbs up-section. In the ISFSI study area, the broad crest of the fold is disrupted by a series of fold-parallel, minor faults (Figure 2.6-11). The minor faults displace the fold axis, as well as produce local drag folding, which tends to disrupt and complicate the fold geometry. The axis of this broad-crested anticline is approximately located on the geologic map (Figure 2.6-8).

The en echelon syncline at the ridge crest along Skyview Road projects to the northwest along the southwestern margin of the ISFSI study area. From the southeast to the northwest, the syncline changes into a northwest-trending monocline, and then back into a syncline (Figures 2.6-6 and 2.6-7). In the ISFSI study area, the syncline opens into a broad, gently northwest plunging (generally less than 15 degrees) fold with gently sloping limbs (generally less than 20 degrees). Bedding generally dips downslope to the northwest in the upper part of the slope above the ISFSI site, and perpendicular to the slope to the southwest and west in the lower part of the slope. Small undulations in the bedding reflect the transition from a tight syncline to a relatively flat monocline, or "shoulder," and then back to a broad, northwest-plunging syncline. These localized interruptions to the northwestern plunge of the fold may be caused by the diabase intrusion and localized doming associated with the intrusion (compare diagrams C and D on Figure 2.6-13).

As discussed above and shown on cross sections B-B''', D-D', and F-F' (Figures 2.6-11, 2.6-16, and 2.6-17), the western limb of the small syncline varies from steeply dipping (approximately 70 degrees northwest) across the southern part of the plant site area, to gently dipping (approximately 30 degrees northwest) beneath the power block. This change in the dip of the syncline across the plant site area mirrors the change in dip described above across the ISFSI study area. Based on the geometry of the syncline, bedrock beneath the power block consists of sandstone (unit $Tof_{b-2}$), underlain by dolomite (unit $Tof_{b-1}$) (Figure 2.6-11). The power block is located on the same stratigraphic sequence exposed in the ISFSI study area; however, the sequence is approximately 400 ft lower in the stratigraphic section. As shown on cross section B-B''' (Figure 2.6-11), boreholes drilled during foundation exploration for the power block encountered calcareous siltstone having abundant foraminifera. This description of the rock is very similar to the dolomite of unit $Tof_{b-1}$; thus, the lower contact between units $Tof_{b-1}$ and $Tof_{b-2}$ is interpreted to be beneath the power block area.

Folding occurred during growth of the northwest-trending, regional Pismo syncline in the Pliocene to early Quaternary (LTSP Final Report). The smaller folds at and near the ISFSI study area are parasitic secondary folds along the southwestern limb of the larger Pismo syncline. Because of their structural association with the Pismo syncline, the folding in the area is interpreted to have occurred during the Pliocene to early Quaternary (Figure 2.6-8). Some localized fold deformation also may have accompanied the earlier Miocene diabase intrusions.

### 2.6.1.6.2.2 Faults

Numerous minor, bedrock faults occur within the ISFSI study area (Figures 2.6-27 and 2.6-28). Based on displaced lithologic and bedding contacts, most of the faults have vertical separations of a few inches to a few feet. At least five faults show vertical separation of several tens of feet. Slickensides and mullions on the fault surfaces generally show strike-slip to oblique strike-slip displacement.

The faults trend generally northwest, subparallel to the local fold axes (Figure 2.6-29). They dip steeply to near-vertical, generally 70 to 90 degrees, both northeast and southwest. They consist of interconnecting and anastomosing strands, in zones up to 5 ft wide. The faults have documented lengths of tens of feet to a few hundred feet, and are spaced from several tens of feet to hundreds of feet apart across the ISFSI study area, based on trench exposures and surface geologic mapping.

The fault surfaces within bedrock vary from tightly bonded or cemented rock/rock surfaces, to relatively soft slickensided clay/rock and clay film contacts. Individual faults are narrow, ranging in width from less than an inch to about 2 ft. Fault zones contain broken and slickensided rock, intermixed clay and rock, and locally soft, sheared, clayey gouge. The thickness of fault gouge and breccia is variable along the faults.

Cross section B-B''' (Figure 2.6-11) illustrates the subsurface stratigraphy and structure beneath the ISFSI pads. As shown on the map (Figure 2.6-8) and cross section, five minor faults clearly juxtapose dolomite ($Tof_{b-1}$) against sandstone ($Tof_{b-2}$), and truncate individual friable beds. Vertical separation across individual faults ranges from about 10 ft to greater than 50 ft, based on displacements of friable beds and the contact between units $Tof_{b-1}$ and $Tof_{b-2}$. Total vertical separation across the entire fault zone exceeds 50 ft; cumulative displacement is down on the northeast. As described previously, the contact between dolomite and sandstone (units $Tof_{b-1}$ and $Tof_{b-2}$) beneath the pads is based on the first occurrence of medium to coarse-grained sandstone, and there is no evidence of significant facies interfingering between the two units beneath the pads that would obscure the amount of displacement. Therefore, the interpretation of vertical separation of bedrock along the faults is given a relatively high degree of confidence.

Subhorizontal slickensides indicate that the minor faults in the ISFSI study area have predominantly strike-slip displacement (Figure 2.6-30). Using a typical range of a 10-degree to 20-degree rake on the slickensides and the vertical separation, total fault displacement is estimated to be several tens to several hundreds of feet. The faults trend subparallel to the axis of the Pismo syncline, and trend approximately 35 to 55 degrees more westward than the offshore Hosgri fault zone (Figure 2.6-29).

The faults in the ISFSI study area may be continuous with several other minor faults having similar characteristics exposed along strike in dolomite in the Diablo Creek roadcut about

800 ft to the north (Figures 2.6-6, 2.6-7, and 2.6-30). Given this correlation and the presence of several hundred feet of strike-slip displacement, the faults may be at least several thousand feet long. Interpretation of pre-borrow excavation aerial photography shows that the faults are not geomorphically expressed in the ISFSI study area (Figure 2.6-31) and there is no evidence of displaced Quaternary deposits along the fault traces.

In the analysis of slope stability (Section 2.6.5), the faults are assumed to form high-angle parting surfaces along the lateral margins of potential rock slides, rock wedges, and topple blocks. Fault-bounded structural blocks are shown on Figure 2.6-8, and on cross section B-B''' (Figure 2.6-11). The age and noncapability of the faults are discussed in Section 2.6.3.

**2.6.1.6.2.3 Bedrock Discontinuities**

Extensive data on bedrock discontinuities were collected from the borings and trenches within the ISFSI study area to assess their orientation, intensity, and spatial variability (Reference 3, Data Report F). The discontinuity data were used in the failure analysis of the ISFSI cutslopes (Section 2.6.5). Bedrock discontinuities include joints, faults, bedding, and fractures of unknown origin. These discontinuities, in particular joints, are pervasive throughout bedrock in the ISFSI study area (Figure 2.6-20) Steeply dipping faults and joint sets are the dominant discontinuities, giving the rock mass a subvertical fabric. Random and poorly developed low-angle joints also occur subparallel to bedding. The fault discontinuities are described in Section 2.6.1.6.2.2. Joint discontinuities are described below.

Joint contacts vary from tight to partially tight to slightly open; joint surfaces are slightly smooth to rough, and have thin iron oxide or manganese coatings (Reference 3, Data Report H). Joint lengths in trenches and outcrops typically range from a few feet to about 20 ft, and typical joint spacings range from about 6 inches to 4 ft, with an observed maximum spacing of about 14 ft (Reference 3, Data Report F, Table F-6). The intersections of various joints, faults, and bedding divide the bedrock into blocks generally 2 ft to 3 ft in dimension, up to a maximum of about 14 ft. Rock blocks formed by intersecting joints larger than those described above generally are keyed into the rock mass by intact rock bridges or asperity interlocking. The largest expected "free" block in the rock mass is, therefore, estimated to be on the order of about 14 ft in maximum dimension.

Both the well-cemented sandstone and the dolomite contain numerous joints. The jointing typically is confined to individual beds or groups of beds, giving the bedrock a blocky appearance in outcrop. Joints are less well developed and less common in the friable sandstone and friable dolomite. Linear zones of discoloration in the friable rock may represent former joints and small faults, but these zones are partially recemented, and not as frequent or obvious as joints in the harder rock.

The character of joints also differs between the upper, dilated zone of bedrock (generally within the upper 4 ft in the ISFSI study area, but conservatively estimated to extend to a maximum of 20 ft deep, particularly toward the edges of the old borrow cut where the amount of rock removed in 1971 is minimal) and the underlying zone of "tight" bedrock. Joints are generally tight to open in the upper zone. In the lower zone, the joints and other structures are tight and, in places, bonded and healed. This is well demonstrated in the borehole optical televiewer logs (Reference 3, Data Report E), which show the joints are typically tight and/or partly bonded throughout the borings. In both zones, the joints are locally clay-filled, and commonly contain thin fillings of clay, calcite, dolomite, and locally, gypsum. Joints and fractures in the borings are very closely to widely spaced (less than 1/16-inch to 3-ft spacing), with local crushed areas between joints.

In general, the joints group into two broad sets: a west- to west-northwest-striking set, and a north-northwest-striking set. In some trenches, fractures from both sets are present, whereas some show a scatter in orientation within a general northwest-southeast orientation. The variation in orientation and density of the joints with both strata and location across the ISFSI study area shows that the joints are limited in continuity.

The general northwest-southeast-trending character of the joints in the ISFSI study area is consistent with both the overall northwest-trending regional structural grain. Local variations in discontinuity orientations and intensity are attributed to rheological differences between dolomite and sandstone and their friable zones, as well as to proximity to the minor faults that cut across the area.

### 2.6.1.7 Stratigraphy and Structure of the ISFSI Pads Foundation

Figure 2.6-32 illustrates the expected bedrock conditions that will be encountered in the foundation excavation for the ISFSI pads at the assumed pad subgrade elevation of 302 ft (Reference 2, Attachment 16). The pads will be founded primarily on dolomitic sandstone of unit $Tof_{b-2}$ and dolomite of unit $Tof_{b-1}$. Dolomitic sandstone generally underlies most of the site; dolomite underlies the eastern end of the site. The proposed cutslopes above the site are generally underlain by dolomitic sandstone in the western and central parts of the cut, and by dolomite in the upper and eastern parts of the cut.

Locally, friable sandstone ($Tof_{b-2a}$) and friable dolomite ($Tof_{b-1a}$) underlie the foundation of the ISFSI pads and the proposed cutslopes (Figure 2.6-32). Because the zones are highly variable in thickness and continuity, their actual distribution likely will vary from that shown on Figure 2.6-32. In particular, a large body of friable dolomite underlies the southeastern portion of the proposed cutslope. Other smaller occurrences of friable sandstone and dolomite probably will be encountered in the excavation. These friable rocks locally have dense, soil-like properties; thus, specific analyses were performed to assess the foundation properties and slope stability of these friable rock zones (Reference 3, Data Report I). Small zones of friable diabase may be found in the excavation, as discussed in Section 2.6.1.4.2.5. This rock has properties similar to the friable sandstone.

In two places beneath the foundation of the ISFSI pads, clay beds within dolomite and sandstone are expected to daylight or occur within 5 ft of the base of the foundation

(Figure 2.6-32). Additional clay beds may be exposed in the foundation of the pads. Although available geologic data do not document the presence of clay beds that will daylight in the ISFSI cutslope, some may be encountered when the cuts are made.

In addition, a zone of minor noncapable faults trends northwest across the central and eastern part of the ISFSI pads (Figures 2.6-8 and 2.6-11) (Section 2.6.3). The faults have vertical separations of 10 ft to 30 ft, and locally juxtapose different bedrock units.

### 2.6.1.8 Stratigraphy and Structure of the CTF Foundation

The CTF site lies about 100 ft directly northwest of the northwest corner of the ISFSI site (Figure 2.6-8). The CTF site is on the same west limb of the small anticline that underlies the ISFSI site (Figure 2.6-8, Section 2.6.1.6.2.1). Borings 00BA-3 and 01-CTF-A show the CTF will be founded on sandstone (unit $Tof_{b-2}$) and friable sandstone (unit $Tof_{b-2a}$), similar to the rock at the ISFSI site (Figures 2.6-8 and 2.6-32). The CTF site is located along the northwestern projection of the small bedrock faults at the ISFSI site, and similar faults and joints are expected to be encountered in the excavation for the CTF. Although no clay beds were encountered in borings 00BA-3 and 01-CTF-A, clay beds may underlie the site at deeper elevations (Reference 2, Attachment 16). The dip of the bedrock at the CTF site appears to be near-horizontal. In the cutslope west of the CTF site, bedrock dips moderately to the northeast, into the slope (Figure 2.6-7).

### 2.6.1.9 Stratigraphy and Structure of the Transport Route

The transport route begins at the power block and ends at the ISFSI. The route will follow existing paved Plant View, Shore Cliff, and Reservoir roads (Figure 2.6-1), except where routed north of the intersection of Shore Cliff and Reservoir roads to avoid an existing landslide at Patton Cove. The lower two-thirds of the route traverses thick surficial deposits, including marine terrace, debris-flow, and colluvial deposits of varying thicknesses (Reference 2, Attachment 16). These surficial deposits overlie two units of the Obispo Formation bedrock: unit $Tof_b$ sandstone and dolomite, and unit $Tof_c$ thinly to thickly bedded claystone, siltstone, and shale. The upper third of the route is on engineered fill, directly above dolomite and sandstone bedrock (units $Tof_{b-1}$ and $Tof_{b-2}$) of the Obispo Formation (Figure 2.6-7). Locally, the road is on a cut-and-fill bench cut into the bedrock.

In the geologic description below, approximate stations have been assigned to assist in defining distances between locations, starting from the power block and ending at the ISFSI (Figure 2.6-7). Although not surveyed, this informal stationing is standard engineering format to represent the distance, in feet, from the beginning of the route outside the power block to the station location (for example, 21+00 is 2,100 ft from the beginning). The specific conditions along the route are discussed below.

Station 00+00 (south side of power block) to 20+00 (near Reservoir Road): The transport route generally follows Plant View Road and Shore Cliff Road. The route starts at the power block and crosses flat, graded topography on the lower coastal marine terrace ($Q_2$) (Figure 2.6-3). Behind the power block, the route is founded on sandstone ($Tof_b$) of the Obispo Formation. From there to near Reservoir Road, the transport route is founded on surficial deposits 10 to 40 ft thick, and engineered fill in excavations made during construction of the power plant. The surficial deposits consist primarily of debris-flow and colluvial deposits that overlie the marine bedrock terrace platform (Figures 2.6-7 and 2.6-16). These deposits range in age from middle Pleistocene to Holocene, and consist of overconsolidated to normally consolidated clayey sand and gravelly clay. The deposits contain some carbonate cementation and paleosols, and typically are stiff to very stiff (medium dense to dense). Bedrock below the marine terrace platform consists of east-dipping sandstone ($Tof_b$) from station 00+00 to about 07+00, and steeply dipping claystone and shale ($Tof_c$) from about 07+00 to 20+00. Because of the thickness of the overburden, bedrock structure will have no effect on the foundation stability of the road.

Station 20+00 to 34+00 (near Shore Cliff Road to Hillside Road): From station 20+00 to 26+00, the transport route will be on a new road north of the intersection of Shore Cliff Road and Reservoir Road to avoid an existing landslide at Patton Cove (Section 2.6.1.12.1.1; Figures 2.6-6, 2.6-7, and 2.6-19). A 5- to 50-ft-thick prism of engineered fill will be placed to achieve elevation from the lower part of the marine terrace to the upper part of the marine terrace as the road U-turns uphill. The engineered fill will overlie overconsolidated to normally consolidated Pleistocene debris-flow and colluvial deposits 20 to 80 ft thick that cover the marine bedrock platform (Q2), which in turn overlie steeply dipping claystone and shale of unit Tofc below the marine platform.

Along Reservoir Road, the route follows the higher part of this terrace, generally over the marine platforms $Q_2$ and $Q_3$. The surficial deposits consist of debris-flow and colluvial deposits up to 80 ft thick along the base of the ridge behind parking lot 8 (Figure 2.6-19). Bedrock below the marine terrace is claystone and shale (Tofc) from station 26+00 to 29+50, and sandstone ($Tof_b$) from station 29+50 to 34+00.

Station 34+00 (Reservoir Road at Hillside Road) to 49+00 (along Reservoir Road): The route follows Reservoir Road to the raw water reservoir area. The road traverses the west flank of the ridge on an engineered cut-and-fill bench constructed over unit $Tof_b$ dolomite and sandstone, and thin colluvium and debris-flow fan deposits. Bedding, as exposed in the roadcut, dips 30 to 50 degrees into the hillslope, away from the road. Engineered fill on sandstone and dolomite underlies the inboard edge of the road, and a wedge of engineered fill over colluvium generally underlies the outboard edge of the road (Figures 2.6-7, 2.6-11, and 2.6-19).

Bedrock joints exposed in this part of the route are similar to those at the ISFSI site. Joints are generally of low lateral persistence, confined to individual beds, and are tight to open. Joint-bounded blocks are typically well keyed into the slope, with the exception of a 1- to 3-foot-thick outer dilated zone. No large unstable blocks or adverse structures prone to large-scale sliding were observed.

Station 49+00 (along Reservoir Road) to 53+50 (ISFSI pads): The route leaves the existing Reservoir Road and crosses the power plant overview parking area. The route will be placed on new engineered fill up to 5 ft thick that will overlie thin engineered fill (up to 4 ft thick) that was placed over sandstone and friable sandstone ($Tof_{b-2}$ and $Tof_{b-2a}$), the same rock types that underlie the ISFSI pads and CTF site.

Bedrock structures beneath this part of the route are inferred to be joints and small faults, similar to those exposed at the ISFSI site (Figure 2.6-8). The faults would trend generally northwest, and dip steeply northeast and southeast, to vertical. The primary joint sets are near-vertical (Section 2.6.1.6.2.3). This part of the road is on flat topography, and bedrock structure will have no effect on the foundation stability of the road.

### 2.6.1.10 Comparison of Power Block and ISFSI Bedrock

Bedrock beneath the ISFSI was compared to bedrock beneath the power block based on stratigraphic position, lithology, and shear wave velocity. Based on these three independent lines of evidence, the bedrock beneath the ISFSI and the power block is interpreted to be part of the same stratigraphic sequence, and to have similar bedrock properties and lithology.

#### Stratigraphic Position

Cross section B-B''' illustrates the stratigraphic correlation of bedrock between the ISFSI site and the power block site (Figure 2.6-11). As shown on the cross section, the power block and ISFSI are located on the same continuous, stratigraphic sequence of sandstone and dolomite of unit $Tof_b$ of the Obispo Formation. As mentioned previously, the sequence at the power block is approximately 400 ft lower in the stratigraphic section.

The bedrock of the same continuous, stratigraphic sequence as that beneath the power block is exposed directly along strike in roadcuts along Reservoir Road (Figure 2.6-2). The bedrock exposed in the roadcut consists of dolomite, dolomitic siltstone, and dolomitic sandstone of unit $Tof_{b-1}$.

#### Lithology

As described in the DCPP FSAR Update, Section 2.5.1.2.5.6, p. 2.5-42, Figures 2.5-9 and 2.5-10) bedrock beneath the power block consists predominantly of sandstone, with subordinate thin- to thick-bedded slightly calcareous siltstone (for examples, see boring descriptions on Figures 2.6-11 and 2.6-19). The rocks are described as thin-bedded to platy and massive, hard to moderately soft and "slightly punky," but firm. These lithologic descriptions are similar to those for the rocks at the ISFSI site, and the rocks are interpreted to be the same lithologies.

The "calcareous siltstone" described in the DCPP FSAR Update is probably dolomite or dolomitic siltstone comparable to unit $Tof_{b-1}$. For example, based on the geologic descriptions of the rocks, the "siltstone" and "sandstone" encountered in 1977 in power block boring DDH-D is interpreted to be the dolomite and dolomitic sandstone of unit $Tof_{b-1}$ observed at the ISFSI site.

Boring logs from the hillslope between the power block and the ISFSI site, included in the DCPP FSAR Update (Figures 2.5-22 to 2.5-27; Appendix 2.5C, plates A-1 to A-19), describe bedrock as tan and gray silty sandstone and tuffaceous sandstone (Figures 2.6-11 and 2.6-19). These rocks are moderately hard and moderately strong. The rock strata underlying this slope dip into the hillside and correlate with the sandstone and dolomite strata exposed on the west flank of the ridge (and west limb of the syncline) that are exposed in roadcuts along Reservoir Road south of the ISFSI site (Figures 2.6-6, 2.6-7, and 2.6-20) and in the deeper part of the borings at the ISFSI site.

**Shear Wave Velocity**

Shear wave velocity data from the power block site and the ISFSI site are summarized on Figures 2.6-33 and 2.6-34. Velocity data in Figure 2.6-35 are from borehole surveys at the ISFSI site (Reference 3, Data Report C), and comparative velocities at the power block site are from the DCPP FSAR Update. As evident from the figures, shear-wave velocities from surface refraction and borehole geophysical surveys at the ISFSI site are within the same range as those obtained at the power block site. The velocity profiles at both sites are consistent with a classification of "rock" for purposes of characterizing ground-motions (Reference 12).

### 2.6.1.11 Groundwater

Refer to Section 2.5, Subsurface Hydrology.

### 2.6.1.12 Landslides

#### 2.6.1.12.1 Landslide Potential in the Plant Site Area

Slopes in the Irish Hills are subjected to mass-wasting processes, including landslides, debris flows, creep, gully and stream erosion, and sheet wash (Reference 9). Extensive grading in the plant site area to create level platforms for structures along Diablo Canyon and the coastal terraces has modified the lower portions of most of the slopes near the plant site.

Debris-flow scars and deposits occur on, and at the base of, slopes in the plant site area. The debris flows initiate where colluvium collects in topographic swales or gullies, and are usually triggered by periods of severe weather. Debris-flow fans, caused by the accumulation of successive debris flows, form at the mouths of the larger canyons and gullies in the area. Several typical gullies that have colluvium-filled swales, debris-flow chutes, and debris-flow fans at the bottom of the chutes are found on the slope above parking lots 7 and 8, south of the power plant (Figures 2.6-5 and 2.6-7).

During landslide investigations in 1997, PG&E identified a large, (exceeding 100 acres) ancient landslide complex on the slopes of Diablo Canyon, directly east of the 230- and 550-kV switchyards (Reference 9) (Figure 2.6-7). The dip of the bedrock in the vicinity of these large slides is downslope, contributing to slope instability (Reference 9, Figure 21). This structure suggests the failure planes for these slides are probably within the bedrock along bedding contacts, clay beds, and possibly along the intrusive contacts between Obispo Formation bedrock and the altered diabase.

The large landslide complex is subdued, and has been considerably modified by erosion. Thin stream-terrace deposits and remnants of the $Q_5$ 430,000-year-old marine terrace at elevation 290 ±5 ft appear to have been cut into the toes of some of the slides These relations indicate the landslides are old, and likely formed in a wetter climate during the middle to late Pleistocene. The landslides appear to be stable under the present climatic conditions. There is no geomorphic evidence of activity in the Holocene (past 10,000 years or so). Additionally, the 500-kV switchyard embankment fill in the canyon provides a partial buttress to the toe of the old landslide deposit, and serves to help stabilize the landslide. The switchyard shows evidence of no post-construction slope movement. The complex lies entirely east of the ISFSI, and does not encroach, undermine, or otherwise affect the ISFSI.

**Patton Cove Landslide**

The Patton Cove landslide (Figure 2.6-36) is a deep-seated rotational slump located at a small cove adjacent to Shore Cliff Road along the coast, about one-half mile east of the power plant (Figures 2.6-6, 2.6-7, and 2.6-17) (Reference 9, p. 78-83). Shore Cliff Road was constructed on engineered fill benched into marine-terrace and debris-flow fan deposits directly east of the slide. Cracks within Shore Cliff Road suggest that the landslide may be encroaching headward beneath the road The landslide is approximately 125 ft long, 400 ft wide, and 50 ft deep. The slide occupies nearly the full height of the bluff face, which is inclined about 1.3:1 (H:V).

Slide movement was first documented in 1970 by Harding Lawson Associates (HLA) (Reference 13). In 1970, the head scarp of the slide was approximately 15 ft south of the toe of the fill that supports Shore Cliff Road. In the 31 years since slide movement was first documented, the slide mass has been episodically reactivated by heavy rains and continued wave erosion at the toe of the slide along the base of the sea cliff.

Renewed activity of the landslide in the winter of 1996/1997 coincided with development of numerous en echelon cracks in the asphalt roadway and walkway along Shore Cliff Road. In the winter of 1999/2000, a water line separated beneath the paved roadway in the vicinity of the cracks. Comparison of pre- and post-construction topographic maps shows that the locations of these cracks coincide approximately with the contact between the road fill wedge and the underlying colluvium, suggesting that deformation in this area may be caused by fill settlement or creep. However, the arcuate pattern of the cracks and proximity to the Patton Cove landslide suggest that incipient landsliding is encroaching into the roadway. The cracks also are located in the general area of a crescent-shaped marine terrace riser mapped prior to road construction (DCPP FSAR Update, Figure 2.5-8). The mapped terrace riser is more likely a subdued landslide headscarp.

An inclinometer was installed on the road shoulder closest to the slide in November 2000 to monitor the depth and rate of future movements. The inclinometer has recorded small movements near the contact between the base of the fill and the underlying colluvium and debris-flow deposits.

To avoid the potential hazard of the landslide and unstable fill, the transport route will be constructed north of the existing road, where the Patton Cove slide will pose no hazard (Section 2.6.1.12.3). The closest approach of the transport route will be about 100 ft north of the cracks at the intersection of Shore Cliff and Reservoir roads.

#### 2.6.1.12.2 Landslide Potential at the ISFSI and CTF Sites

Detailed investigation of landslides in the plant site area (Reference 9) shows there are no existing deep-seated landslides or shallow slope failures at the ISFSI and CTF sites. Field mapping and interpretation of 1968 aerial photography (Figure 2.6-31) during the ISFSI site investigations confirmed the absence of deep-seated bedrock slides or shallow slope failures at the site.

Excavation of the existing slope at the ISFSI site was completed in 1971. No stability problems were encountered during excavation using bulldozers and scrapers, and the slope has been stable, with minimal surface erosion, since 1971. Prior to excavation of the slope, Harding Miller Lawson (HML) (Reference 8) described a shallow landslide in weathered bedrock (Figure 2.6-10) along a "shale seam" in their exploratory trench A (Reference 8, Plate D-3). This feature was less than 15 ft deep, and was removed entirely, along with underlying intact bedrock, to a depth of about 75 ft during excavation of the slope. Zones of "fractured, decomposed, and locally brecciated sandstone, siltstone, and shale" and "breccia and clay zones" described in HML trench A are interpreted to be friable dolomite zones and steep faults.

The Harding Miller Lawson landslide is apparent on 1968 black-and-white aerial photography, and is expressed by a subtle, arcuate headscarp, hummocky landscape, and locally thicker vegetation, probably reflecting high soil moisture within the slide debris (Figure 2.6-31). The slide was located along a slight swale in colluvial soils and possibly weathered bedrock that mantled the slope prior to excavation. The slide mass appears to have moved northeast along the axis of the swale, and not directly downslope. Because bedding is interpreted to dip to the northwest in this area, the landslide probably was not a bedrock-controlled failure. There is no evidence of deep-seated bedrock landslides on the 1968 aerial photographs; the ISFSI study area appears as a stable, resistant bedrock ridge in the photos.

Because surficial soils were removed from the ISFSI site area during past grading, there is no potential for surficial slides to adversely affect the site. There is no evidence of bedrock landslides below the ISFSI site or along the southern margin of Diablo Canyon near the raw water reservoir. Reservoir facilities (including the water treatment plant) and paved areas between the ISFSI and CTF sites and Diablo Canyon show no evidence of sliding or distress. Because the 290-foot $Q_5$ marine terrace is preserved locally across the ISFSI study area, it is apparent that no deep-seated bedrock slides have occurred since formation of the 430,000-year-old terrace, and the ridge is interpreted to be stable. Some shallow debris-flow failures and slumps were identified in surficial soil on the outermost 3 ft to 4 ft of weathered rock in the steep (45 to 65 degrees) slope below the raw water reservoir (Figure 2.6-7). These failures are shallow, and do not pose a stability hazard to the ISFSI or CTF sites, which are set more than 180 ft back from the top of the slope.

### 2.6.1.12.3 Landslide Potential Along the Transport Route

The transport route is located 100 ft north of the headscarp of the active Patton Cove landslide (Figure 2.6-7). Based on detailed mapping, borings, and an inclinometer, the landslide headscarp is defined by a series of cracks at the intersection of Shore Cliff and Reservoir Roads. A cross section through the landslide is shown in Figure 2.6-17. The geometry and depth of the slide plane indicate further headward encroachment of the landslide toward the transport route is not likely.

Where the transport route follows Reservoir Road at the base of the bedrock hillslope north from near Hillside Road, there are no bedrock landslides. Sandstone beds in the hillslope above the road dip obliquely into the slope at about 30 to 50 degrees (Figures 2.6-7, 2.6-11, and 2.6-19). These beds extend continuously across much of the hillside, providing direct evidence of the absence of bedrock slope failures (Figure 2.6-5). Small faults and joints in the rock mass do not appear to adversely affect potential slope stability, and the existing roadcut and natural slopes have no evidence of any slope failures.

Kinematic analyses of the bedding and fractures along the road were performed where the road borders the bedrock slope (Section 2.6.5.4.1). Two portions of the route were analyzed: a northern part from approximately station 43+00 to 49+00 (Figure 2.6-37), and a northwesterly stretch from approximately station 35+00 to 42+00 (Figure 2.6-38). The rock mass is stable against significant wedge or rock block failures; however, the analysis indicates that rock topple failure from the cutslope into the road is possible. Field evaluations indicate such failures would be localized and limited to small blocks. The existing drainage ditches on the inboard edge of the road would catch these small topple blocks.

Several colluvial or debris-flow swales are present above the transport route along Reservoir Road (Figures 2.6-5 and 2.6-7). These swales have been the source of past debris flows that primarily have built the large fans on the marine terraces over the past tens of thousands of years. Additional debris flows could develop within these swales during sever weather events, similar to those described elsewhere in the Irish Hills following the 1997 storms (Reference 9). Holocene debris-flow fan deposits extend to just below the road alignment, indicating that future debris flows could cross the road. However, large graded benches for an abandoned leach field system are present above a portion of the Reservoir Road, and concrete ditches and culverts are present in swale axes. These existing facilities will catch and divert much of the debris from future debris flows above the road. However, two debris-flow chutes are present above the road northwest of Hillside Road; this part of Reservoir Road is not protected from these potential debris flows. Based on the thickness of the colluvium in the swales (5 to 10 ft), and the slope profile, the maximum depth of debris on the road following severe weather is estimated to be less than 3 ft, which easily could be removed after the event.

### 2.6.1.13 Seismicity

A detailed analysis of the earthquake activity in south-central coastal California was presented in the LTSP Final Report. The report included the historical earthquake record in the region since 1800, instrumental locations from 1900 through May 1988, and selected focal mechanisms from 1952 to 1988. From October 1987 through May 1988, the earthquake catalog incorporated data recorded by the PG&E Central Coast Seismic Network (CCSN). This station network has operated continuously since then to monitor earthquake activity in the region.

The seismicity in the region is illustrated in two frames on Figure 2.6-39: (a) historical earthquakes of magnitude 5 and greater since 1830, and (b) instrumentally recorded seismicity of all magnitudes from 1973 through September 1987. Epicentral patterns of the microearthquakes (Figure 2.6-39) show that most of activity within the region occurs to the north, beneath the Santa Lucia Range and north of San Simeon, and in the southern onshore and offshore region south of Point Sal. Earthquakes in the southern offshore region extend westward to the Santa Lucia Bank area. Within about 15 miles of the ISFSI, small, scattered earthquakes occur between the Los Osos fault and faults of the Southwest Boundary fault zone (including the Irish Hills subblock (Section 2.6.1.3), in the nearshore region within Estero Bay, and along the Hosgri fault zone. Focal mechanisms along the Hosgri fault zone show right-slip displacement along nearly vertical fault planes (LTSP Final Report, Chapter 2, Figures 2-30 and 2-36).

McLaren and Savage (Reference 14) updated the earthquake record and present well-determined hypocenters and focal mechanisms for earthquakes recorded from October 1987 through January 1997 by the CCSN and by the U.S. Geological Survey, from north of San Simeon to the southern region near Point Arguello (Figure 2.6-40). No significant earthquakes occurred during this time period, and no significant change in the frequency of earthquake activity was observed. The largest event recorded was the local (Richter) magnitude 5.1 (duration magnitude 4.7) Ragged Point earthquake on 17 September 1991 northwest of San Simeon (Figure 2.6-40 inset). The focal mechanism of this event is oblique thrust, typical of nearby recorded earthquakes. Earthquake data since January 1997 also do not show any significant change in the frequency or epicentral patterns of seismic activity in the region.

The seismicity data presented in Reference 14 is consistent with the LTSP observations and conclusions (LTSP Final Report). Specifically:

- Epicentral patterns of earthquakes have not changed. As shown in Figure 2.6-40, microearthquakes continue to occur to the north, along a northwest trend to San Simeon, east of the Hosgri fault zone, and in the southern offshore region.

- Selected seismicity cross sections A-A' through D-D' along the Hosgri fault zone (Figure 2.6-41) show that onshore and nearshore hypocenters extend to about 12-kilometers depth, consistent with the seismogenic depth range reported for the region (LTSP Final Report). Seismicity cross section B-B', across the Hosgri fault zone, shows the Hosgri fault zone is vertical to steeply dipping. The earthquakes projected onto cross sections C-C' and D-D' are evenly distributed in depth.

- Focal mechanisms along the Hosgri fault zone (Figure 2.6-42) are primarily strike slip, consistent with the LTSP conclusion that the Hosgri is a northwest-trending, vertical, strike-slip fault (LTSP Final Report). Mechanisms from events within the Los Osos/Santa Maria domain show oblique slip and reverse fault motion, consistent with the geology.

- The location of the 1991 Ragged Point earthquake in the San Simeon region, as well as its size and focal mechanism, are consistent with previous earthquakes in the region.

## 2.6.2 VIBRATORY GROUND MOTIONS

### 2.6.2.1 Approach

10 CFR 72 102(f) states the following "The...DE for use in the design of structures must be determined as follows:

(1) For sites that have been evaluated under the criteria of Appendix A of 10 CFR 100, the DE must be equivalent to the safe shutdown earthquake (SSE) for a nuclear power plant."

Thus, DCPP ground motions are considered to be the seismic licensing basis, in accordance with 10 CFR 72.102(f), for the evaluation ISFSI design ground motions. Seismic analyses for the ISFSI used ground motions that meet or exceed the DCPP ground motions.

Vibratory ground motions were considered in the design and analyses (Section 8.2.1) of (1) the ISFSI pads, (2) the CTF, including the reinforced concrete support structure and structural steel, (3) the ISFSI casks and cask anchorage, (4) ISFSI pad sliding and cutslope stability, (5) transport route slope stability, and (6) transporter stability.

The approach used for developing the ground motion characteristics to be used for design and analysis of the ISFSI SSCs consisted of the following.

- Use the DCPP ground motions (Section 2.6.2.2) as the basis for developing the ISFSI design ground motions, in accordance with 10 CFR 72.102(f).

- Compare the earthquake source and distance and ISFSI site conditions with those at the DCPP to confirm the applicability of the DCPP ground motions to the ISFSI site.

- Because ISFSI pad sliding and cutslope stability, transport route slope stability, and transporter stability may be affected by longer-period ground motions than those characterized by the DCPP ground motions, develop appropriate response spectra for the analysis of these elements, conservatively taking into account the additional influence of near-fault effects, such as fault rupture directivity and fling, that have been recorded in recent large earthquakes.

- Develop, as necessary, spectra-compatible time histories for use in analyses and design.

### 2.6.2.2 DCPP Licensing-Basis Ground Motions

The basis for the DCPP design ground motions is discussed in the DCPP FSAR Update, Sections 2.5.2.9, 2.5.2.10, and 3.7.1. There are three design ground motions for the DCPP: the design earthquake (DE), DCPP FSAR Update, Figures 2.5-20 and 2.5-21; the double design earthquake (DDE), DCPP FSAR Update, Section 3.7.1.1; Reference 5; and the Hosgri earthquake (HE), DCPP FSAR Update, Figures 2.5-29 through 2.5-32, which was incorporated into the DCPP seismic design basis as part of the seismic reevaluation of applicable existing structures by PG&E, and is now required as part of the licensing basis at the plant.

As discussed in the DCPP FSAR Update, the seismic qualification basis for the plant is the original design earthquakes (DE and DDE), plus the HE evaluation, along with their respective analytical methods, acceptance criteria, and initial conditions. Future additions and modifications to the plant are to be designed and constructed in accordance with these seismic design bases. In addition, as discussed in the DCPP FSAR Update, certain future plant additions and modifications are to be checked against the insights and knowledge gained from the Long Term Seismic Program (LTSP) to verify that the plant's "high-confidence-of-low-probability-of-failure" (HCLPF) values remain acceptable (Reference 5). As part of the Long Term Seismic Program, response spectra were developed for verification of the adequacy of seismic margins of certain plant structures, systems, and components (LTSP Final Report). The DE, DDE, HE, and LTSP spectra are defined for periods up to 1.0 second, 1.0 second, 0.8 second, and 2.0 seconds, respectively.

### 2.6.2.3 Comparison of Power Block and ISFSI Sites

The Diablo Canyon ISFSI site is located in the plant site area of the licensed DCPP; therefore, the applicability of the DCPP ground motions to the ISFSI site was evaluated by comparing the ground-motion response characteristics of the ISFSI site with those of the plant site, and by comparing the distance from the controlling seismic source to the plant with the distance from the controlling source to the ISFSI.

As described in Section 2.6.1.4.2 and shown in Figures 2.6-6 and 2.6-11, the power block and the ISFSI are sited on bedrock that is part of the same, continuous, thick sequence of sandstone and dolomite beds of unit b of the Obispo Formation. In the classification of site conditions used for purposes of ground-motion estimation, both of these sites are in the "rock" classification (Reference 12).

Shear-wave velocity profiles from both sites are compared in Figure 2.6-35. As these comparisons indicate, shear-wave velocities from surface refraction and borehole geophysical surveys at the ISFSI site are within the same range as those obtained at the power block site. The velocity profiles at both sites are consistent with the "rock" classification for purposes of ground-motion estimation (Reference 12).

The earthquake potential of the significant seismic sources in the region was characterized during development of the DCPP FSAR Update and the Long Term Seismic Program (LTSP Final Report). The Hosgri fault zone, at a distance of 4.5 kilometers, was assessed to be the controlling seismic source for the DCPP (DCPP FSAR Update, Sections 2.5.2.9 and 2.5.2.10; LTSP Final Report, Chapters 3 and 4). The ISFSI is approximately 800 ft to 1,200 ft east of the power block, and is thus only slightly farther from the Hosgri fault zone (Figure 2.6-4).

Therefore, because both sites are classified as rock, and because within the rock classification they have similar ranges of shear-wave velocities, and the distance to the controlling seismic source is essentially the same, the DCPP ground motions are judged to be applicable to ISFSI design.

### 2.6.2.4 Spectra for ISFSI Pads, Casks and Cask Anchorage, and CTF

The DE, DDE, HE, and LTSP spectra (Figures 2.6-43 and 2.6-44; the DE is one-half the DDE and is not shown) are applicable to the analysis of the pads, casks and cask anchorage, and CTF (Section 8.2.1.2).

For cask anchorage design, the design spectra were defined by the HE spectrum for periods up to 0.8 second, and the LTSP spectrum for periods up to 2.0 seconds. New three-component, spectrum-compatible time histories were developed for the HE and LTSP by modifying recorded ground motions using the spectral matching procedure described by Silva and Lee (Reference 15). The recorded time histories used in the spectral matching were selected based on their similarity to the DDE, HE and LTSP earthquakes. The NRC Standard Review Plan spectral matching criteria (Section 3.7.1, NUREG-0800) were followed for 4-percent, 5-percent, and 7-damping; however, the NUREG requirement for a minimum value for the power spectral density (PSD) based on an NRC Regulatory Guide 1.60 spectral shape is not applicable to the spectral shapes of the HE or LTSP. The objective of the minimum PSD requirement was met by requiring the spectrum of each time history to be less than 30 percent above and 10 percent below the target spectrum. This ensures that no Fourier amplitudes are deficient in energy for the frequency range of interest.

### 2.6.2.5 ISFSI Long-Period Earthquake (ILP) Spectra and Time Histories For Pad Sliding, Slope Stability, and Transporter Stability Analyses

Because ISFSI pad sliding and cutslope stability, transport route slope stability, and transporter stability may be affected by longer-period ground motions than those characterized by the DCPP ground motions, PG&E has developed longer-period spectra and associated time histories for the analysis of pad sliding, slope stability, and transporter stability. These are referred to as the ISFSI long period (ILP) ground motions (Figures 2.6-45 and 2.6-46). The ILP spectra represent 84th percentile horizontal and vertical spectra, at damping values of 2 percent, 4 percent, 5 percent, and 7 percent, that extend out to a period of 10 seconds.

New information has become available from analytical studies of near-fault strong-motion recordings of large earthquakes in the past decade to evaluate the influence of near-fault effects, such as fault rupture directivity and tectonic deformation (fling), especially on ground motions in the longer-period range. PG&E has incorporated the influence of rupture directivity and fling in the ILP spectra and time histories used for the analyses of pad sliding, slope stability, and transporter stability.

Development of the ILP horizontal spectra (Figure 2.6-46) incorporated the following assumptions and considerations:

- Although the LTSP (LTSP Final Report) considered alternative styles of faulting for the Hosgri fault zone, the weight of the evidence favored strike-slip, and subsequent earthquake data and geologic and geophysical data interpretations (References 14 and 16) indicate the style of faulting is strike slip. Therefore, ground-motion characteristics appropriate for strike-slip earthquakes were used.
- The effect of directivity was analyzed for the case in which rupture begins at the southern end of the Hosgri fault zone, progresses 70 kilometers to the northwest where it passes at a closest distance of 4.5 kilometers from the plant site, and continues an

additional 40 kilometers to the northwest end of the Hosgri fault zone. This assumption is conservative, because this rupture scenario has the greatest directivity effects at the site.

- The ILP horizontal spectrum at 5-percent damping at periods less than 2.0 seconds envelopes the DDE, HE, and LTSP spectra.
- The spectrum based on the Abrahamson and Silva (Reference 16) attenuation relation is consistent with the envelope of the DDE, HE, and LTSP spectra at 2 seconds, and has the same slope-with-period as the Sadigh (Reference 17) and Idriss (References 18, 19, and 20) attenuation relations, so it was used to extrapolate the envelope spectrum to 10 seconds. This spectrum is the 84th percentile horizontal spectrum.
- The 5-percent-damped horizontal spectra were increased to assure they envelope the Hosgri spectra at 4-percent and 7-percent damping ratios. Scaling factors for computing spectra at damping values other than 5 percent are from Abrahamson and Silva (Reference 16).
- Abrahamson's (Reference 21) and Somerville and others' (Reference 22) models were used to scale the average horizontal spectrum, to compute the fault-normal and fault-parallel ground-motion components, incorporating directivity effects.
- The fault-normal component was increased in the period range of 0.5 second to 3.0 seconds to account for possible directivity effects for earthquakes having magnitudes less than 7.2 at periods near 1 second.
- Because fling can occur on the fault-parallel component for strike-slip faults, a model was developed to compute the 84th percentile ground motion due to tectonic fling deformation at the ISFSI accompanying fault displacement on the Hosgri fault zone in a magnitude 7.2 earthquake. The fling arrival time was selected, and the fling and the transient fault-parallel ground motion were combined so as to produce constructive interference of the fling and the S-waves, resulting in a conservative fault-parallel ground motion.

Development of the ILP vertical spectra (Figure 2.6-46) incorporated the following assumptions and considerations:

- The ILP vertical spectrum at 5-percent damping at periods less than 2 seconds is defined by the envelope of the DDE, HE, and LTSP (Reference 5) spectra.
- Current empirical attenuation relations (References 16, 17, and 23) were used to estimate the vertical-to-average-horizontal ratio for periods greater than 2 seconds; the value of two-thirds is conservative. The envelope vertical spectrum at 5-percent damping at periods less than 2 seconds was extended to a period of 10 seconds using two-thirds the average horizontal spectrum.

- The 5-percent-damped vertical spectra were increased to assure they envelop the Hosgri spectra at 4 percent and 7 percent damping ratios. Scaling factors for computing spectra at damping values other than 5 percent are from Abrahamson and Silva (Reference 16).

Five sets of spectrum-compatible acceleration time histories were developed to match the ILP ground motions spectra. The recordings in the table below were selected because they are from strike-slip earthquakes of magnitude 6.7 or greater, recorded at distances less than 15 kilometers from the fault, and contain a range of characteristics of near-fault ground motions.

| Earthquake | Magnitude | Recording | Distance (km) | Site Type |
|---|---|---|---|---|
| 1992 LANDERS | 7.3 | Lucerne | 1.1 | Rock |
| 1999 Kocaeli | 7.4 | Yarimca | 8.3 | Soil |
| 1989 Loma Prieta | 6.9 | LGCP | 6.1 | Rock |
| 1940 Imperial Valley | 7.0 | El Centro #9 | 8.3 | Soil |
| 1989 LOMA PRIETA | 6.9 | Saratoga | 13.0 | Soil |

The NRC Standard Review Plan spectral matching criteria (Section 7.1, NUREG-0800) recommends 75 frequencies for spectral matching. Augmented frequency sampling at 104 frequencies was used to account for the broader frequency range being considered for the ISFSI analyses. The interpolation of the response spectral values was done using linear interpolation of log spectral acceleration and log period. The NRC requirement permits not more than 5 of the 75 frequencies to fall below the target spectrum, and no point to fall below 0.9 times the target spectrum. This requirement was adhered to with the 104 frequencies.

The time histories were matched to the target spectra at 5-percent damping. The mean response spectrum of the five sets must envelop the target to meet the criteria of SRP 3.7.1. This criterion was applied to the damping values of 2 percent, 4 percent, 5 percent, and 7 percent.

The fault-parallel time histories were modified to include the effects of fling.

### 2.6.2.6 Transport Route and Transporter Design-Basis Ground Motions

As discussed in Section 2.6.1.9 and shown in Figures 2.6-6 and 2.6-7, the transport route is underlain by Obispo Formation bedrock consisting of unit b dolomite and sandstone (the same bedrock as at the power block and ISFSI sites), and unit c claystone and shale. Varying thicknesses of dense soil deposits overlie the bedrock.

Because the transport route is about the same distance from the Hosgri fault zone as the DCPP and the ISFSI sites, the ILP spectra are appropriate for use along the transport route where the route is constructed on bedrock and where the transport route crosses surficial deposits over bedrock (approximately two-thirds of the route). An evaluation of the impact of a seismic event occurring during cask transport is discussed in Section 8.2.1.2.1.

### 2.6.3 SURFACE FAULTING

Potentially active faults at Diablo Canyon and in the surrounding region were identified and characterized in the DCPP FSAR Update, Section 2.5.3, the LTSP Final Report, Chapter 2, and the LTSP Addendum (Reference 7, Chapter 2). Together, these documents provide a comprehensive evaluation of the seismotectonic setting and location of capable faults in the plant site region, and document the absence of capable faults beneath the power block and in the plant site area. These studies used detailed mapping of Quaternary marine terraces and paleoseismic trenching to document the absence of middle to late Pleistocene faulting in the plant site area, including the ISFSI study area (LTSP Final Report, p. 2-38, Plates 10 and 12). Hence, there are no capable faults at the ISFSI site.

Several minor bedrock faults were encountered in trenches at the ISFSI site during site characterization studies (described in Section 2.6.1.6.2.2). These faults are similar to minor faults that are commonly observed throughout the Miocene Obispo and Monterey formations in the Irish Hills (DCPP FSAR Update, Section 2.5.1; References 9 and 11). Similar minor bedrock faults encountered beneath the power block strike generally northwest to west, dip 45 degrees to 85 degrees, and have displacements of up to several tens of feet (DCPP FSAR Update, Section 2.5.1.2.5.6, Figure 2.5-14).

The faults at the ISFSI site (Figure 2.6-8) are near-vertical (dip generally 70 to 90 degrees) and trend northwest, subparallel to the regional structural trend of the Pismo syncline (Figure 2.6-29). As described in Section 2.6.1.6.2.2, individual faults have vertical separation of a few tens of feet or less; cumulative vertical separation across the fault zone is greater than 50 ft, down on the northeast (Figure 2.6-11). Subhorizontal slickensides on the fault plane indicate a significant component of oblique strike slip, so total displacement is hundreds of feet. Detailed site investigations, including mapping and trench excavations, show that the individual faults generally extend across the ISFSI site and at least across the lower slope above the ISFSI.

The faults do not align with any significant bedrock fault in the plant site area (Figures 2.6-4 and 2.6-6), nor do the faults have major stratigraphic displacement. The origin of the faults may be related to one or more of three possible causes, all prior to 1 million years ago.

The faults most likely formed during a period of regional transtensional deformation during the Miocene, when normal and strike-slip faulting occurred in the region. This most directly explains the observed normal-oblique slip on the fault zone. A transition to transpressional deformation occurred during the late Miocene to Pliocene, and is well expressed in the offshore Santa Maria Basin and along the Hosgri fault zone (LTSP Final Report). The minor bedrock faults at the ISFSI site were subsequently rotated during the growth of the Pismo Syncline, although the faults occur near the flat-lying crest of a small parasitic anticline and, thus, have not been rotated significantly. Given this origin, the faults formed during the Miocene, contemporaneous with the transtensional formation of Miocene basins along the south-central coast of California, prior to 5 million years ago.

Alternatively, the minor faults may be secondary faults related to growth of the regional Pismo syncline (Figure 2.6-4), as concluded for the small bedrock faults at the power block (DCPP FSAR Update, p. 2.5-49, -50). As shown on Figure 2.6-29, the faults trend subparallel to the axis of the Pismo syncline, and are located near the crest of a small anticline on the southwestern limb of the syncline. The apparent oblique displacements observed on the faults may be related to bending-moment normal faults and right shear along the axial plane of the small anticline that formed in the Pliocene to early Quaternary. The zone of minor faulting may have used the area of diabase intrusion as an area of crustal weakness to accommodate tensional stresses along the axial plane of the anticline. As described in the DCPP FSAR Update, pages 2.5-14, -33, -34, and in the LTSP reports (LTSP Final Report, p. 2-34 to -38; and Reference 7, p. 2-10), growth of the Pismo syncline and related folds ceased prior to 500,000 years to 1,000,000 years ago. Thus, the observed minor faults also ceased activity prior to 500,000 years to 1,000,000 years ago.

A third alternative explanation for origin of the minor bedrock faults is that they are related to intrusion of the diabase into the Obispo Formation. Diabase is present locally in the ISFSI study area. Forceful intrusion, or magmatic stoping of the diabase may have produced faulting in response to stresses induced by the magma intrusion in the adjacent host rock. Hydrothermal alteration is extensive in the diabase. The friable sandstone and dolomite in the ISFSI study area are spatially associated with the zone of faulting (Figures 2.6-8 and 2.6-11), indicating the faults may have acted as a conduit for hydrothermal solutions. Assuming the hydrothermal fluids were associated with the diabase intrusion, the minor faults predate, or are contemporaneous with, intrusion of the diabase. Diabase intrusion into the Obispo Formation occurred in the middle Miocene (References 10 and 11), indicating the faulting would have occurred prior to or contemporaneous with the diabase intrusion in the middle Miocene, more than 10 million years ago. The faulting may have originated by transtensional regional deformation, as described above, then subsequently was modified by diabase intrusion.

In addition to their probable origin related to transtensional deformation in the Miocene (or to growth of the Pismo syncline in the Pliocene to early Quaternary, or to intrusion of the diabase in the middle Miocene), several additional lines of evidence indicate the minor faults are not capable and do not present a surface faulting hazard at the site:

- As described in the LTSP Final Report, pages 2-37 to -39, Plates 10 and 12), the Quaternary marine terrace sequence in the plant site vicinity is not deformed, providing direct stratigraphic and geomorphic evidence demonstrating the absence of capable faulting. The minor faults observed at the ISFSI site project northwest across, but do not visibly displace, any of the lower marine terrace platforms, within a limit of resolution of ±5 ft, indicating the absence of deformation in the past 120,000 years. Assuming the displacement does not die out at the coast, this resolution is enough to recognize the greater-than-50-ft of vertical separation on the faults at the ISFSI site.

- As described in the DCPP FSAR Update, (p. 2.5-35 to -50, Figures 2.5-13 to 2.5-16), similar northwest-trending minor faults were mapped in bedrock in the power block area. Detailed trenching investigations of these faults and mapping of the power block excavation provided direct observation that they do not displace and, hence, are older than the late Pleistocene (120,000 years old) marine terrace deposits. By analogy, the minor faults at the ISFSI site also would be older than late Pleistocene.
- Interpretation of aerial photographs taken before the 1971 excavation of the ISFSI site area (former borrow area) and construction of the raw water reservoir (Figure 2.6-31), shows there are no geomorphic features in the ISFSI study area (tonal lineaments, drainage anomalies, scarps) indicative of displacement of the minor faults prior to grading. The landscape in the ISFSI study area is interpreted to have formed in the middle to late Quaternary, about 430,000 years ago, based on the preserved remnants of marine terraces in the surrounding site area.

Based on these lines of evidence, the minor faults observed in bedrock at the ISFSI site are not capable; hence, there is no potential for surface faulting at the ISFSI site.

## 2.6.4 STABILITY OF SUBSURFACE MATERIALS

### 2.6.4.1 Scope

An extensive program of field investigations, in situ testing, and laboratory testing was conducted to define the static and dynamic characteristics of the soil and rock materials. The scope of the program is summarized in Table 2.6-1. A detailed discussion of the test procedures and results is presented in Reference 3, Data Reports B, C, F, G, H, and I, and Reference 9. The results are summarized below.

### 2.6.4.2 Subsurface Characteristics

The geology at the subgrade of the foundation of the ISFSI pads (elevation about 302 ft, 8 ft below the pad grade) is shown in Figure 2.6-32. The subsurface beneath the ISFSI pads consists of dolomite ($Tof_{b-1}$), sandstone ($Tof_{b-2}$), friable dolomite ($Tof_{b-1a}$), and friable sandstone ($Tof_{b-2a}$) (Section 2.6.1.7). The bedrock contains minor faults and joints (Section 2.6.1.6.2). The groundwater table is near elevation 100 ft, about 200 ft below the foundation elevation. Clay beds of limited extent occur at a few locations under the ISFSI pads, below the surface of the cutslope, and in the existing slope above the pads (Section 2.6.1.7).

The geology at the CTF foundation grade is shown in Figure 2.6-32. At this grade (elevation about 286 ft), the bedrock consists of sandstone and friable sandstone (Section 2.6.1.8). At the site, the sandstone may have a few minor faults and joints, similar to those described in Section 2.6.1.6.2. Because the rocks are the same, the static and dynamic engineering properties of the rock at the foundation of the CTF were selected to be the same as those at the ISFSI pads.

The transport route traverses thick surficial deposits along nearly two-thirds of its route, including a new 500-foot-long section of thick, engineered fill near Patton Cove. It is constructed on engineered fill placed on dolomite and sandstone for the rest of its length (Section 2.6.1.9).

The detailed geologic characteristics of these rock units are described in Section 2.6.1.4.2.

### 2.6.4.3 Parameters for Engineering Analysis

#### 2.6.4.3.1 ISFSI and CTF Sites

The static and dynamic engineering properties for use in foundation analyses of the rock at the ISFSI and CTF sites are as follows:

**Density:** A density of 140 pounds per cubic ft (pcf) was chosen as appropriate for foundation analyses (Reference 3, Data Report I).

**Strength:** A friction angle for the rock mass of 50 degrees was chosen as appropriate for foundation analyses. This friction angle is consistent with that used in the slope stability analyses (Section 2.6.5.1.2.3).

**Poisson's ratio:** A representative value of Poisson's ratio of 0.22 for dolomite and sandstone was selected as appropriate for analyses. A representative value of 0.23 was selected for friable rock. These values were derived from seismic velocity measurements in the bedrock below the footprint of the pads, and laboratory-based measurements on samples of bedrock from beneath the pads (Reference 2, Attachment 16; Reference 3, Data Report I).

**Young's modulus**: Representative values of Young's modulus of between 1.34 times $10^6$ psi (mean) and 2.0 times $10^6$ psi ($84^{th}$ percentile upper bound) for dolomite and sandstone were selected as appropriate for analyses. A representative value of 0.2 times $10^6$ psi was selected for friable rock. These values were derived from seismic velocity measurements in the bedrock below the footprint of the pads, and laboratory-based measurements on samples of bedrock from beneath the pads (Reference 2, Attachment 16; Reference 3, Data Report I).

#### 2.6.4.3.2 Slopes

Static and dynamic engineering properties of soils and rock at the ISFSI site for use in slope stability analyses are as follows:

**Rock Strength:** A friction angle of 50 degrees for the rock mass was selected for stability analyses of the hillslope above the ISFSI pads. A range of friction angles between 16 degrees and 46 degrees for rock discontinuities was selected for stability analyses of the cutslopes behind the ISFSI pads. Further discussion of rock strength parameters is provided in Sections 2.6.5.1.2.3 and 2.6.5.2.2.3.

**Clay Bed Strength and Unit Weight:** The following parameters were defined for clay:

- unit weight, 115 pcf (Reference 3, Data Report G)
- shear strength, drained, c' = 0 psf; ø' = 22 degrees
- shear strength, undrained, lower of c = 800 psf and ø=15 degrees or ø = 29 degrees.

Further discussion of clay strength parameters is provided in Section 2.6.5.1.2.3.

**Shear wave velocities:** Representative values of shear wave velocities were selected for stability analyses (Section 2.6.5.1.3.2). These values were based on suspension geophysical surveys in boreholes beneath the footprint of the pads, as well as on data summarized in the Addendum to the LTSP Final Report (Reference 7, Chapter 5, Response to Question 19).

**Dynamic shear modulus and damping values:** Relationships of the dynamic shear modulus and damping values with increasing shear strain were selected for stability analyses (Section 2.6.5.1.3.2), based, in part, on literature review and dynamic tests of DCPP rock core samples performed in 1977 and 1988 (Reference 2, Attachment 21).

Additional considerations for the selection of rock and clay properties for specific static and dynamic stability analyses, and the calculation of seismically induced displacements are presented in Section 2.6.5.1.3.

#### 2.6.4.3.3 Transport Route

As described earlier, the transport route generally follows existing Plant View, Shore Cliff, and Reservoir roads (Figure 2.6-7). The specifications for the construction of these roads required all fills to be compacted to 90-percent relative density, and the upper 2.5 ft to be compacted to 95-percent relative density. Fills on slopes were benched and keyed a minimum of 6 ft into the hillside (Reference 24). Based on these requirements, the road base and subgrade material are expected to be at least as capable for transporter loads and earthquake ground motions as the underlying rock and soil.

The new section of the transport route near Patton Cove will be constructed on engineered fill, as will a section of the route near the CTF (Figure 2.6-7). These fills and the overlying road subgrade also will be constructed to the same specifications as the existing roads (Reference 24). Both new roadway sections will support the imposed loads.

Where the transport route follows Plant View, Shore Cliff and Reservoir roads to Hillside Road, the alignment is founded on marine terrace deposits overlain by dense colluvial deposits. The remaining portions of the route, on Reservoir Road (beyond station 34+00), are founded on cuts made in the dolomite and sandstone. The static and dynamic engineering properties of the rock and soil deposits underlying the transport route are summarized in Reference 9, Tables 1 and 2.

#### 2.6.4.4 Static Stability

The ISFSI pads will be founded on dolomite, sandstone, friable dolomite, and friable sandstone (Figure 2.6-32). The CTF will be founded on sandstone and friable sandstone (Figure 2.6-32). This bedrock will support the proposed facilities without deformation or instability. The borrow excavation removed between 75 ft and 100 ft of rock from the ISFSI and CTF sites. As a result, the existing rock is overconsolidated, and facility loads are likely to be much less than the former overburden loading on the rock (calculated to be about 10,000 to 14,000 psf). The overconsolidated state of the rock mass in the foundation precludes any settlement, including differential settlement between rock types, under the planned loading conditions.

As discussed in the DCPP FSAR Update, Section 2.5.4, there are no mines or oil wells in the plant site area. The two makeup-water wells draw water from fractured bedrock that is fed groundwater from the shallow alluvium along Diablo Creek (Section 2.5). No subsidence has been observed, nor is any expected, near these wells, which are approximately 2,500 ft east of the ISFSI.

Similarly, there is no evidence of solution features or cavities within the dolomite and sandstone strata, or in the friable dolomite and friable sandstone, beneath the ISFSI, or in the plant site area. Hence, there is no potential for karst-related subsidence or settlement at the ISFSI or CTF sites.

There is no potential for differential settlement across the different rock units (sandstone, dolomite, friable sandstone, friable dolomite) at the ISFSI, because the rock is well consolidated, joints and fractures are tight, and the friable rocks have almost no joints. Although no piping voids in the friable rocks are expected beneath the ISFSI pads, very small voids (a few inches across) are possible, as found in the friable dolomite in one of the trenches (Reference 3, Data Report D, trench T-20A. The foundation will be below the dilated zone for the borrow area cutslope (observed to be at about 4 ft in the trenches), and the rock mass is expected to be tight, with no open fractures. The rock mass is also overconsolidated, having had 100 ft of rock overburden removed from the location of the borrow area in the vicinity of the ISFSI for construction of the raw water reservoir and the 230-kV and 500-kV switchyards (Figure 2.6-10).

There is no potential for displacement on the faults at the sites, because the faults are not capable (Section 2.6.3). No differential displacement or settlement is expected during potential ground shaking.

### 2.6.4.5 DYNAMIC STABILITY

The ISFSI is located entirely within bedrock. There are no loose, saturated deposits of sandy soil beneath the pads or CTF site, and the groundwater table is near elevation 100 ft, about 200 ft below the foundation level. Therefore, there is no potential for liquefaction at either site.

The CTF foundation will be embedded into rock at least 20 ft below grade, as shown on Figure 2.6-32. This precludes the development of unstable foundation blocks under static or dynamic loading conditions.

Because the transport route subgrade will be on engineered fill on rock and well-consolidated surficial deposits, no liquefaction or other stability problems are expected.

### 2.6.4.6 POTENTIAL FOR CONSTRUCTION PROBLEMS

No significant construction-related problems are anticipated for preparation of the ISFSI and CTF foundations subgrade. The permanent groundwater table is about 200 ft below the planned foundation elevations (Section 2.5), and groundwater is not expected to rise to within the zone of foundation influence. The rock mass is generally tight, and does not have significant voids or soft zones that would require grouting or dental work, with the possible exception of small piping voids related to the friable dolomite. The fractures are tight or filled, and are tightly confined by the surrounding competent rock. The prepared foundation pads will be level, and will be a considerable distance from descending slopes, thus precluding development of unstable blocks or foundation loads into slopes.

## 2.6.5 SLOPE STABILITY

The ISFSI is located on the lower portion of a hillslope that has been modified by excavation for borrow materials during the construction of the DCPP. Construction of the ISFSI pads, the CTF, and portions of the transport route will include cutslopes and fills. The purpose of this section is to examine the stability of the hillslope and the cuts and fills. For each slope, the static and seismic stability were analyzed, and the potential seismically induced displacements were estimated.

The analyses, which are summarized on Table 2.6-2, show that the hillslope and the cutslopes above the ISFSI are generally stable under modeled seismic inputs, slope geometries, and material properties. The seismically induced displacements of the rock mass above the ISFSI, estimated using very conservative assumptions, are small. Under the modeled seismic loads, small rock wedges appear to be susceptible to movement in the cutslopes around the pads. These potential hazards will be mitigated by setbacks in slope design, rock anchors, and debris fences, as discussed in Section 4.2.1.1.9.1. The slopes along the transport route and below the CTF are stable.

For each slope analysis, the objectives and scope of the stability analysis are defined, and the analysis methods are described. The slope geometry and selection of material properties are then given. Finally, the results of the analyses for the hillslope above the ISFSI, the ISFSI cutslopes, the slope below the CTF, and slopes along the transport route are presented.

### 2.6.5.1 Stability of the Hillslope above the ISFSI

A critical section of the hillslope above the ISFSI was analyzed to examine the static and dynamic stability of the jointed rock mass along postulated slide surfaces. Analyses also were conducted to estimate potential seismically induced displacements due to the vibratory ground motions derived in Section 2.6.2. In addition, an analysis was conducted to evaluate the conservatism of the analysis parameters and examine the geologic data to estimate past displacements due to earthquakes.

#### 2.6.5.1.1 Geometry and Structure of Rock Mass Slide Models

Cross section I-I' (Figure 2.6-18) parallels the most likely direction of potential slope failure, and illustrates the geometry of bedding in the ISFSI study area for analysis of slope stability. The cross section shows apparent dips, and the facies variation and interfingering of beds between the dolomite and sandstone (units $Tof_{b-1}$ and $Tof_{b-2}$) beneath the slope. The clay beds, where orientation and extent are critical to this evaluation of slope stability, have been correlated based on stratigraphic position, projection of known bedding attitudes, and superposition of sandstone and dolomite beds (clay beds have not been allowed to cross cut dolomite or sandstone beds, but have been allowed to cross facies changes). These clay beds, as drawn, are a conservative interpretation of their lateral continuity for the analysis of the stability of the slope.

Individual clay beds that are, in places, thick (more than about 0.5-inch thick) in the dolomite, may continue up to several hundred feet. Thinner clay beds are less laterally continuous. On cross section I-I' (Figure 2.6-18), clay beds are not shown to extend continuously through the slope, but are terminated at set distances from exposures in boreholes, trenches, or outcrops, reflecting the estimates of possible lateral continuity. Because of the generally limited lateral continuity of the clay beds, potential large surfaces (greater than several hundred feet in maximum dimension) likely would require sliding on several clay beds, and stepping between beds on joints and in places through rock in a "staircase" profile. Stepping between basal clay failure surfaces would probably be localized where the individual clay beds are stratigraphically close and are thin and pinch out. Other likely locations for stair-stepping failure or structural boundaries for possible rockslide margins are at changes in structural orientation (transitions from monocline to syncline), and along the lateral margins of the slide. These limit the size of potential rock masses. Faults at the site are subparallel to the potential down-slope motion, and impart a strong near-vertical fabric in the rock mass. It is likely that lateral margins for potential larger rockslides would develop, at least partially, along these faults.

Based on the above considerations, three rock mass slide models, comprising ten potential slide surfaces, were defined for cross section I-I' of the hillslope:

Model 1. A shallow slide mass model (Figure 2.6-47) involving sliding rock masses along shallow clay beds encountered in trench T-14A and boring 01-I. It toes out at the upper part of the tower access road.

Model 2. A medium-depth slide mass model (Figure 2.6-48) involving sliding rock masses along clay beds encountered at depths of between about 25 ft and 175 ft in borings 01-F, 00BA-1, and 01-I, and trench T-11D. It toes out on the slope between the ISFSI and below the tower access road.

Model 3. A deep slide mass model (Figure 2.6-49) involving sliding along deep clay beds encountered in borings 01-H, 01-F, 00BA-1, and 01-I at depths of between about 50 ft and 200 ft. It toes out behind or below the proposed ISFSI cutslope and pads.

Model 1 has been segmented into two possible geometries, labeled 1a and 1b on Figure 2.6-47. These two modeled slide blocks daylight at a clay bed encountered in trench T-14A (model 1a), or along the projected dip of a clay bed encountered in boring 01-I. The failure headscarp/tension break-up zone extends upward from the inferred maximum upslope extent of the clay bed in trench T-14A (model 1a), or from the inferred likely uphill extent of a clay bed encountered in boring 01-I.

Model 2 has been segmented into three subblocks: 2a, 2b, and 2c (Figure 2.6-48). The three blocks daylight along a clay bed encountered in trench T-11D (2a and 2b), or along the dip projection of a clay bed encountered in boring 00BA-1 (2b). Model 2a breaks up near trench T-14A at the location of a major structural discontinuity for potential slide blocks; the transition between the monocline and syncline where the bedding geometry (strike and dip) changes. Models 2b and 2c break up from the basal failure planes in a "stair-stepping" manner between clay beds, and have a common headscarp that daylights about 50 ft above the brow of the 1971 borrow cut excavation. The geometry of the headscarp break-up zone is inferred to be controlled by the uphill limit of clay beds encountered in the borings, and dominant steep joint fabric in the rock mass.

Model 3 has been segmented into three subblocks: 3a, 3b, and 3c. The three blocks daylight in the ISFSI pads cutslope, or at the base of the cutslope (Figure 2.6-49). All three modeled blocks have basal slide surfaces along clay beds encountered in borings 01-F, or 00BA-1 and

01-I. Models 3a and 3b break up with headscarp/tension zones at the location of the structural change in bedding geometry described for model 2a (3a and 3b), or about 75 ft above the top of the borrow cut (3c) at an inferred maximum uphill extent of clay beds encountered in boring 01-I. Model 3 has been further segmented into 3c-1, which daylights beyond the ISFSI pads, and 3c-2, which daylights at the base of the first cutslope bench.

For all models, the toe daylight geometry reflects the propensity for failure planes to break out along bedding planes and along the projection of clay beds. In contrast, the geometry of the headscarp/tension failure was inferred to be controlled by the dominant steep (greater than 70 degrees) joint/fault fabric in the rock mass.

#### 2.6.5.1.2 Static Stability Analysis

##### 2.6.5.1.2.1 Method

The static stability analysis of the hillslope was conducted using the computer program UTEXAS3 (Reference 25). Spencer's method, a method of slices that satisfies force and moment equilibria, was used in the analysis.

##### 2.6.5.1.2.2 Assumptions

The following assumptions were made:

- The clay beds are saturated. This assumption is reasonable, because during the rainy season, rainfall would infiltrate the slope through the fractured rock and perch temporarily on the clay beds, and would saturate at least the upper part of the clay.

- There is little water in the slope. This assumption is reasonable, because the groundwater table is about 200 ft below the ISFSI site, and the rock is fractured and well-drained. There are no springs from perched water tables near the ISFSI slope.

- The lateral margins of the potential slide masses have no strength. This is conservative, because the margins of a potential failure wedge would, in part, follow discontinuous joints, small faults, and, in part, break through rock. Friction between rock surfaces and by asperity overriding, or shearing along the lateral slide margins would provide some resistance to sliding.

- The upper 20 ft of the rock mass forming the head of a potential sliding mass has been modeled as a tension crack, that is, the zone has been given no strength. This assumption is conservative, because the dilated zone is only about 4 ft deep (Reference 2, Attachment 16).

- The head of the slide below the tension crack would break irregularly along joints and clay beds and through some rock. The strength assigned to this rock mass is discussed below.

- The orientation, continuity, and extent of the clay beds is assumed to be as shown on cross section I-I'. This is reasonable, because the extent of the clay beds and their dip is based on extensive geologic data from the ISFSI study area.
- The strength of the clay (discussed below) is assumed to apply along the entire length of a clay bed, as shown on cross section I-I'. This is conservative, because the clay beds are commonly thin and irregularly bedded, providing rock contact through the beds, thereby increasing the strength.

### 2.6.5.1.2.3 Material Properties

Drained and undrained clay-bed strength parameters were developed from the results of strength and index testing performed on clay-bed samples collected from borings and trenches excavated at the site. Strength tests consisted of consolidated-undrained triaxial compression tests (CU) with pore pressure measurements, drained and undrained monotonic direct-shear tests, and undrained cyclic direct-shear tests (Reference 3, Data Report G). Atterberg limits tests were conducted on the clay-bed samples to measure their liquid limits (LL) and plasticity indices (PI). Drained strength parameters were developed from the results of the CU triaxial and drained monotonic direct-shear tests, and from published empirical correlations with Atterberg limits. Drained strength was taken as the post-peak strength (defined as strength at the maximum displacement) from the drained direct-shear tests, and the lower of either the stress at 5 percent axial strain or the post-peak strength for the CU tests. Undrained strength parameters were developed from the results of the CU triaxial, undrained monotonic and cyclic direct-shear, and Atterberg limits tests. As with the drained strength parameters, the undrained strength was taken as post-peak strength from the monotonic direct-shear tests, and the lower of either the stress at 5 percent axial strain or the post-peak strength for the CU tests.

Undrained strength parameters c = 800 psf and ø = 15 degrees were determined from analysis of the undrained strength data (Figure 2.6-50). Similarly, c' = 0 psf, and ø' = 22 degrees were selected based on analysis of the drained strength data (Figure 2.6-51). Because the overburden pressure under the original ground surface is higher than the consolidation pressure used in most of the laboratory strength tests, overconsolidation effects are likely present in the laboratory test results. This effect was conservatively removed at low confining pressures by estimating corresponding undrained shear strengths for a maximum overconsolidation ratio (OCR) of 3.0 and determining an equivalent friction angle, as shown in Figure 2.6-50, of 29 degrees (with no cohesion). Accordingly, undrained strength parameters were selected as the lower of ø = 29 degrees and ø = 15 degrees (Figure 2.6-50).

Two different empirical methods were used to develop in situ rock mass strength envelopes for the dolomite and sandstone (units $Tof_{b-1}$ and $Tof_{b-2}$): Barton and Choubey (Reference 26), and Hoek and Brown (Reference 27).

The Barton-Choubey method estimates the in situ shear strength of naturally occurring rock discontinuities (joints, bedding planes, faults) in relatively hard rock on the basis of field and laboratory measurements of discontinuity properties. Shear strength envelopes for discontinuity surfaces within the shallow rock mass at the ISFSI site were used in the stability analyses of surficial rock mass sliding, wedge, and topple slope failures in the proposed cutslope above the ISFSI, and frictional sliding along shallow rock discontinuities below the foundation of the ISFSI pads. The range of strength envelopes for dolomite ($Tof_{b-1}$) and sandstone ($Tof_{b-2}$) discontinuities calculated using the Barton-Choubey method are plotted in Figure 2.6-52, using the derived stress-strain data.

The Hoek-Brown method is an empirically based approach that develops nonlinear shear-strength envelopes for a rock mass, and accounts for the strength influence of discontinuities (joints, bedding planes, faults), mineralogy and cementation, rock origin (for example, sedimentary or igneous), and weathering. The resulting rock-mass shear-strength envelopes were used for evaluation of the ISFSI pads and CTF foundation properties, and for stability analyses of potential bedrock failures within jointed confined rock at the ISFSI site. The Hoek-Brown method is for rock masses having similar surface characteristics, in which there is a sufficient density of intersecting discontinuities such that isotropic behavior involving failure along multiple discontinuities can be assumed. The method is not for use when failure is anticipated to occur largely through intact rock blocks, or along discrete, weak, continuous failure planes (such as weak bedding interfaces). The structure (or failure) geometry must be relatively large with respect to individual block size. The rock mass conditions and relative size differences between rock blocks, potential deep-seated masses, and the ISFSI and CTF foundations for which the Hoek-Brown criterion is being applied are appropriate and meet these rock-mass requirements. Strength envelopes for dolomite and sandstone calculated using the Hoek-Brown method are plotted in Figures 2.6-53 and 2.6-54, using the derived stress-strain data.

A strength envelope having a friction angle, ø, of 50 degrees and cohesion, c, of zero was selected for the portion of the rock mass consisting of dolomite (unit $Tof_{b-1}$) and sandstone ($Tof_{b-2}$) below the dilated zone (Figures 2.6-53 and 2.6-54). This envelope is lower than (but approximately parallel to) the envelopes for either dolomite or sandstone derived from the empirical Hoek-Brown method, and is more nearly equal to the post-peak strength envelope for the friable sandstone derived from laboratory tests of nonjointed rock blocks. The interpreted post-peak strength envelope for the friable rocks has a friction angle, ø, of 51.2 degrees and cohesion, c, of zero (Figure 2.6-55). Accordingly, a ø of 50 degrees was also selected for the friable rocks.

#### 2.6.5.1.2.4 Results

The static factors of safety computed using UTEXAS3 (Reference 25) for the ten slide surfaces analyzed are shown in Table 2.6-3 (Reference 2, Attachment 19). The table shows that, in all cases, the computed factor of safety varies between 1.62 and 2.86. It is, therefore, concluded that the hillslope is stable.

#### 2.6.5.1.3 Seismically Induced Displacements

##### 2.6.5.1.3.1 Method

The selected slide surfaces were analyzed to estimate the potential for earthquake-induced displacements by using the concept of yield acceleration proposed by Newmark (Reference 28) and modified by Makdisi and Seed (Reference 29). The procedure used to estimate permanent displacements involved the following steps:

- A yield acceleration, $k_y$, at which a potential sliding surface would develop a factor of safety of unity, was estimated using limit-equilibrium, pseudostatic slope-stability methods. The yield acceleration depends on the slope geometry, the phreatic surface conditions, the undrained shear strength of the slope material, and the location of the potential sliding surface.

- Computations were made using UTEXAS3 (Reference 25) to identify sliding masses having the lowest yield accelerations. A two-stage approach was used that consisted of first calculating the normal stresses on the failure plane under pre-earthquake (static) loading conditions using drained strength properties. For each slice, the normal effective stress on the failure plane was then used to calculate the undrained strength on the failure plane. In the second stage of the analysis, horizontal seismic coefficients were applied to the potential sliding mass, and the stability analysis was repeated using the undrained strengths calculated at the end of the first stage. The yield acceleration was calculated by incrementally increasing the horizontal seismic coefficient until the factor of safety equaled unity.

  The material properties used for the UTEXAS3 analysis (unit weights and shear strength) were the same as those for the static stability calculations. Drained rock strengths were used for both stages of the yield acceleration analysis. Drained clay strengths were used for the first stage and a bilinear undrained strength envelope was used for the clay beds in the second stage of the analysis.

- The seismic coefficient time history (and the maximum seismic coefficient, $k_{max}$) induced within a potential sliding mass was estimated using two-dimensional, dynamic finite-element methods. The seismic coefficient is the ratio of the force induced by an earthquake in a sliding block to the total mass of that block. Alternatively, the seismic coefficient time history can be obtained directly by averaging acceleration values from several finite-element nodes within the sliding block at each time interval, as long as variations in the accelerations between nodes are not substantial.

- Earthquake-induced seismic coefficient time histories (and their peak values, $k_{max}$) for the potential sliding surfaces were computed using the two-dimensional, dynamic finite-element analysis program QUAD4M (Reference 30). This is a time-step analysis that incorporates a Rayleigh damping approach, and allows the use of different damping ratios in different elements. The program uses equivalent linear strain-dependent modulus and damping properties, and an iterative procedure to estimate the nonlinear strain-dependent soil and rock properties.

- The QUAD4M program (Reference 30) was used to analyze three slide surfaces (1b, 2c, and 3c) for which the calculated yield acceleration values were the lowest (Table 2.6-3). Because the base of the finite element mesh is at a depth of 300 ft, and because QUAD4M only allows the input motion to be applied at the base, the base motion was first computed by deconvolving the surface ground motion using a one-dimensional wave propagation analysis (SHAKE, Reference 31) to obtain motions at the level of the base of the two-dimensional finite-element model.
- For a specified potential sliding mass, the seismic coefficient time history of that mass was compared with the yield acceleration, $k_y$. When the seismic coefficient exceeds the yield acceleration, downslope movement will occur along the direction of the assumed failure plane. The movement will decelerate and will stop after the level of the induced acceleration drops below the yield acceleration, and the relative velocity of the sliding mass drops to zero. The accumulated permanent displacement was calculated by double-integrating the increments of the seismic coefficient time history that exceed the yield acceleration.

#### 2.6.5.1.3.2 Material Properties

The material properties needed for the QUAD4M analyses are the unit weight, the shear modulus at low shear strain, $G_{max}$, and the relationships describing the modulus reduction and damping ratio increase with increasing shear strain (Reference 2, Attachment 20, Figures 7 and 8). The rock mass was modeled as having a unit weight and shear wave velocity that vary with depth, based on field measurements of shear wave velocity and laboratory values for unit weight. The shear wave velocity profile used is shown in Reference 2, Attachment 20, Figure 6.

#### 2.6.5.1.3.3 Seismic Input

The seismic input consisted of the five sets of time histories developed to match the ILP ground-motion spectra (Section 2.6.2.5). Both fault-parallel and fault-normal components were defined for each of the five motions postulated to occur on the Hosgri fault zone at a distance of 4.5 kilometers from the site. Because the strike of the Hosgri fault zone is 36 degrees from the orientation of cross section I-I', the input motions were rotated to the direction of cross section I-I'. For a specified angle of rotation, there will be 10 rotated earthquake motions along I-I', because the fault-normal component will be either positive (to the east) or negative (to the west) and each needs to be considered separately.

#### 2.6.5.1.3.4 Analysis

Acceleration time-histories were calculated for 26 locations within the three selected slide surfaces (1b, 2c, and 3c) (Reference 2, Attachment 21, Figure 2). Average acceleration time histories were computed for each rock mass. Sensitivity studies using a cross section having a slightly different orientation indicated that the calculated peak accelerations are not significantly influenced by orientation or the total height of the hillslope.

Because the slope at the ISFSI site is a rock slope and its seismic response is anticipated to be generally similar to the input rock motions, the earthquake-induced deformation was first estimated using a Newmark-type analysis for a sliding block on a rigid plane (Reference 28). An estimated yield acceleration of 0.20 g (Table 2.6-4) was used to calculate the deformation of the sliding block. The displacement was computed for the negative direction (representing down-slope movement) only. The down-slope permanent displacement of the sliding block was integrated by using rock motions in the positive direction (representing up-slope direction) only. These preliminary displacement estimates were used to help in selecting the ground-motion time histories that provided the largest permanent displacement.

Table 2.6-4 shows the calculated down-slope permanent displacements (for the five sets of rotated rock motions) following the Newmark sliding block approach. The results (for a rotation angle ø = 36 degrees) indicate that, on average, ground-motion sets 1, 3, and 5 provided the largest displacements (2.4 ft to 2.9 ft). A sensitivity analysis was performed to evaluate the effect of the uncertainty in the direction of cross section I-I' (Figure 2.6-18) relative to the fault strike (Figure 2.6-29). For this analysis, ø was varied by ±10 degrees. As shown in Table 2.6-4, for a ø of 46 degrees, ground-motion set 1 (with a negative fault-normal component) and set 5 (with a positive fault-normal component) produced the largest displacements (3.3 ft and 2.8 ft, respectively). This is because the fault-normal components are stronger than the fault-parallel components in most cases, and for a ø of 46 degrees, the I-I' direction is closer to the fault-normal direction. Set 3, when combined with the negative fault-normal component, produced 2.8 ft of displacement; however, when combined with the positive fault-normal component, produced a much smaller displacement than that of set 5. Based on the rigid sliding block analyses, two rotated ground motions: set 1 motions (rotated 46 degrees with a negative fault-normal component) and set 5 motions (rotated 46 degrees with a positive fault-normal component) were used in the two-dimensional finite-element analyses (Reference 2, Attachment 20).

The potential sliding masses and the node points of the computed acceleration time histories were used to develop average-acceleration time histories for each sliding mass. The seismic coefficient time histories were then double integrated to obtain earthquake-induced displacements for any specified yield acceleration. As mentioned before, the integration was made for the ground-motion amplitudes exceeding the yield acceleration in the positive direction only, and the resulting displacement was computed for potential sliding in the down-slope direction. The relationships between calculated displacement and yield acceleration, $k_y$, for the three potential sliding masses considered are presented in Reference 2, Attachment 21, Figures 5 and 6, for input motion sets 1 and 5, respectively. The normalized relationships between calculated displacement and yield acceleration ration, $k_y/k_{max}$, for the three potential sliding masses considered are presented on Figures 7 and 8 of Reference 2, Attachment 21, for input motions sets 1 and 5, respectively.

**2.6.5.1.3.5 Results**

The earthquake-induced down-slope displacements for the potential slip surfaces analyzed are summarized on Table 2.6-5. Computed permanent displacements using ground-motion set 1 as input range from about 3.1 ft, for sliding mass 1b, on the upper slope, to about 1.4 ft, for sliding mass 3c, on the lower slope. Computed displacements using ground-motion set 5 as input were lower, and ranged from 2.4 ft, for sliding mass 1b, to about 0.6 foot, for sliding mass 3c.

Sliding mass 1b (located in the upper portion of the slope) daylights at a horizontal distance of about 400 ft from the toe of the cutslope behind the pads. As mentioned above, the computed displacements for this sliding mass ranged between 2.4 ft and 3.1 ft. Sliding mass 2c (located in the middle of the slope) daylights about 100 ft from the toe of the cutslope. The computed displacements for this sliding mass ranged between 2.5 ft and 3 ft. The computed displacements for sliding mass 3c (located in the lower portion of the slope) ranged between 0.6 ft and 1.4 ft. Two additional potential sliding masses were analyzed in addition to 3c: sliding mass 3c-1, which daylights 70 ft beyond the north edge of the ISFSI pads, and sliding mass 3c-2, which daylights at the first bench on the cutslope behind the pads (Figure 2.6-56). The computed displacements for sliding mass 3c-1 ranged between 0.4 ft and 1.2 ft. For sliding mass 3c-2, the computed displacements ranged between 0.8 ft and 2.0 ft, depending on the input motion used in the analysis. Given the planned mitigation measures for the ISFSI (Section 4.2.1.1.9), none of the potential displacements indicated by any of the rock mass models would impact the ISFSI pads.

**2.6.5.1.3.6 Estimating Displacements Based on Geologic Data**

Potential slide mass displacement can be estimated by evaluating past performance of the hillslope above the ISFSI site. As described below, the topographic ridge upon which the ISFSI site is located has been stable for the past 500,000 years or more (Reference 2, Attachment 16; LTSP Final Report, p. 2-38). A geologic analysis of slope stability, therefore, provides insights into the minimum shear strength and lateral continuity of the clay beds used in the analysis and, hence, a check on the conservatism of the assumptions used to analyze the stability of the hillslope above the ISFSI site.

Geomorphic and geologic data from mapping and trenching in the ISFSI study area show no evidence of past movements of large rock masses on the slope above the ISFSI (Reference 2, Attachment 16). Analysis of pre-construction aerial photographs shows no features indicative of such landslides: no arcuate scarps, no vegetational lineaments indicative of filled fissures, and no textural differences in the rock exposures or slopes indicative of a broken rock mass at the ISFSI study area. Similarly, the many trenches excavated into the slope, the tower access road cuts, the extensive outcrops exposed by the 1971 borrow cut, and the many borings exposed no tension cracks or fissure fills on the hillslope (Reference 3, Data Reports A, B, and D). Open cracks or soil-filled fissures greater than 1 foot to 2 ft in width would be easily recognized across the slope, given the extensive rock exposure provided by the borrow cut. Therefore, it is reasonable to conclude that any cumulative displacement in the slope greater than 3 ft would have produced features that would be evident in rock slope. The absence of this evidence places a maximum threshold of 3 ft on the amount of cumulative slope displacement that could have occurred in the geologic past.

The hillslope at the ISFSI site is older than at least 500,000 years, because remnants of the $Q_5$ (430,000 years old) marine terrace are cut into the slope west of the ISFSI site (Reference 2, Attachment 16; LTSP Final Report, p. 2-18). Preservation of the terrace documents that the slope has had minimal erosion (a few tens of feet) since that time. Moreover, gradual reduction of the ridge by erosion at the ISFSI site would not destroy deep tension cracks or deep disruption of the rock mass; these features would be preserved as filled fractures and fissures, even as the slope is lowered.

The topographic ridge upon which the ISFSI site is located is presumed to have experienced strong ground shaking from numerous earthquakes on the Hosgri fault zone during the past several hundred thousand years. Studies for the LTSP (LTSP Final Report) estimated a recurrence interval of 11,350 years for a magnitude 7.2 earthquake on the Hosgri fault zone. Assuming that deep cracks from rock mass movements during the past 400,000 years would have been preserved, approximately 35 to 40 large earthquakes have occurred during the past 400,000 years without causing significant (greater than 3 ft) cumulative slope displacement.

#### 2.6.5.1.3.7 Assessment of Conservatism in Displacement Estimates

Because a major portion of the rock mass slide surfaces analyzed is along clay beds, an approximate analysis of the slope at its pre-borrow excavation configuration was conducted to assess the degree of conservatism associated with the assumptions used in the analysis, in particular, the lateral continuity and shear strength of the clay beds. The calculation consisted of extending the potential slide surfaces 1a and 1b (located in the upper part of the slope) to the pre-excavated ground surface, and varying the undrained strength of the clay bed until a yield acceleration corresponding to a displacement of 4 inches was calculated. Ground-motion sets 1 and 5, multiplied by 1.6 and rotated through the same angle as in the previous analysis ($\phi$ = 46 degrees) were used. Several combinations of the undrained strength parameters c and $\phi$ were considered in the analysis. The results indicate that the calculated undrained clay bed shear strength is significantly greater than the undrained shear-strength parameters developed from laboratory test data. It is reasonable to conclude, therefore, that the clay bed strength properties used in the analyses are conservative (that is, the clay beds are thin, with rock-to-rock contact through some of the length of the bed that increases the strength), and that the clay beds are more limited in lateral extent than was assumed in analysis.

### 2.6.5.2 Stability of Cutslopes

Construction of the ISFSI will involve preparing cutslopes along the southwestern, southeastern, and northeastern margins of the site (Figure 2.6-32). The stability of these cutslopes was evaluated using kinematic, pseudostatic, and dynamic analyses.

#### 2.6.5.2.1 Kinematic Analysis

Three potential failure modes were identified for analysis of the cutslopes along the margins of the ISFSI site (Reference 2, Attachment 17):

- planar sliding on a single discontinuity
- wedge sliding on the intersection of two discontinuities
- toppling of blocks

##### 2.6.5.2.1.1 Method

Kinematic analyses, based on the collected fracture data, were performed for each of the three ISFSI site cutslopes: east cutslope (northeast), back cutslope (southeast), and west cutslope (southwest), proposed to be excavated at an inclination of 70 degrees. Discontinuity data from the trenches and outcrops in the area of each cutslope (Reference 3, Data Report F) were applied in the analysis (Figures 2.6-57, 2.6-58, and 2.6-59). Data from outcrops along Reservoir Road were applied in the analyses of the slope above the road (Figures 2.6-37 and 2.6-38).

Using the Markland procedure (Reference 32), discontinuities were analyzed for three modes of rock block failure. All kinematic analyses used a friction angle (ø) of 28 degrees to represent sliding resistance along dilated joints or discontinuities in the rock mass. This friction angle value represents a conservative estimate for rock friction, and was selected on the basis of laboratory direct-shear test data on borehole core joints, and estimation of in situ shear strength using the Barton-Choubey method (Figure 2.6-52). Discontinuities generally are 2 ft to 4 ft long, and locally up to 14 ft long (Reference 3, Data Report F).

##### 2.6.5.2.1.2 East Cutslope

Kinematic analyses of the east cutslope are shown on Figure 2.6-57. The analysis shows low potential for toppling failure, as only a few random discontinuities plot within this failure envelope. There is a moderate to high potential for planar sliding failure, as numerous discontinuities from discontinuity set 2, as well as some random discontinuities, plot within the planar sliding failure envelope. Potential also exists for wedge sliding along the intersection lines between discontinuity sets 1 and 2, and between sets 2 and 4; though these intersections plot very close to the failure envelope, these lines represent the average orientation of the set and there is a scatter of orientations around this mean. Thus, there is a moderate to high potential for planar sliding, and a moderate to high potential for wedge sliding failures in the east cutslope.

**2.6.5.2.1.3 Back Cutslope**

Kinematic analyses of the back cutslope are shown on Figure 2.6-58. The analysis shows low potential for toppling failure, as only a few random discontinuities plot within this failure envelope. Planar sliding failure represents a low to moderate potential, as a few discontinuities from sets 1 and 2, as well as a number of random discontinuities, plot within the planar sliding failure envelope. Potential exists for wedge sliding along the intersection line of discontinuity sets 2 and 3, whereas another intersection (1 and 3) plots outside but relatively close to the failure envelope and should be considered a potential hazard, given that these lines represent the average orientation of the set and that there is a scatter of orientations around this mean. Thus, there is a high potential for wedge failure and minor planar sliding failure in the back cutslope.

Reducing the rock friction angle value to a value appropriate to represent the strength of the bedding-parallel clay beds results in a larger failure envelope, and introduces the possibility of planar sliding failures along the clay beds in the back cutslope and in the hill above the ISFSI site. Static and dynamic modeling of potential sliding along clay beds is presented in Sections 2.6.5.1.2 and 2.6.5.1.3.

A portion of the back cutslope will be in friable dolomite. This material does not behave as a jointed rock mass but, rather, behaves as a stiff soil. The potential exists for slumps within this material.

**2.6.5.2.1.4 West Cutslope**

Analyses of the west cutslope are shown on Figure 2.6-59. The west cutslope shows a high potential for topple failure. The majority of discontinuity set 2, as well as some fractures from set 1, plot within the zone of potential failure for toppling. However, analyses of planar and wedge sliding failures show low and very low potential, respectively, for these modes of failure in the west cutslope, as very few discontinuities (and none belonging to any of the defined sets) fall within the failure envelope for planar sliding, and none of the discontinuity intersections fall within the failure envelope for wedge sliding failure. Thus, the failure mode for the west cutslope is topple failure. A portion of the southwest side of the ISFSI slope will be in a fill prism; therefore, the topple failure mode would not be applicable there.

**2.6.5.2.1.5 Results**

None of the three potential failure modes described above pose a threat to the ISFSI, because potential displacements will be mitigated using conventional methods and appropriate setback distances from the toe of cutslopes, as discussed in Section 4.2.1.1.9.

#### 2.6.5.2.2 Pseudostatic Analyses of Potential Wedge Slides

A pseudostatic seismic analysis of the wedges identified in the kinematic analysis was conducted to assess cutslope stability under seismic loads.

##### 2.6.5.2.2.1 Geometry and Dimensions of Wedge Blocks

The size of potential wedge block failures in the ISFSI cutslope (Figure 2.6-32) will be controlled, in part, by the spacing, continuity, and shear strength of discontinuities in the rock mass. Both the dolomite (unit $Tof_{b-1}$) and sandstone (unit $Tof_{b-2}$) bedrock at the site are jointed and faulted. Joints and faults in friable dolomite and friable sandstone are less well developed and do not control the mechanical behavior of this rock; rather, strength of the friable rock is controlled primarily by the cementation properties of the rock.

The orientation of the joint sets varies somewhat across the site; however, field measurements of the discontinuities (Reference 3, Data Report F) document two primary, steeply dipping, joint sets: a west- to northwest-striking set, and a north-northwest- to north-striking set. The joints are continuous for about 1 foot to about 14 ft, and commonly die out or terminate at subhorizontal bedding contacts. Field observations from surface exposures and trenches show that the joints commonly are slightly open or dilated in the upper 4 ft, probably due to the stress unloading from the 1971 borrow excavation and surface weathering. Dilation of the joints reduces the shear strength of the discontinuity. To be conservative, the zone of near-surface dilation was assumed to extend to a depth of 20 ft on the ISFSI cutslope.

Joints in the dolomite typically are spaced about 1 ft to 3 ft apart, and divide the rock mass into blocks having an average dimension of 1 foot to 3 ft; typical maximum dimensions are about 14 ft (Reference 3, Data Report F, Table F-6). Twenty ft was conservatively assumed to be the maximum block size in the wedge block stability analysis. This dimension would allow for multiple-block wedges to form in the cutslope.

##### 2.6.5.2.2.2 Method

Kinematic analyses (Section 2.6.5.2.1) show that the proposed east and back cutslopes along the southeast margin of the ISFSI pads have potential for wedge slides. The back cutslope would be the highest, and also has the least stable geometry with respect to rock mass discontinuities. Pseudostatic wedge analyses of these cutslopes were performed to evaluate the potential for shallow wedge slides along joints emerging on the cut faces through the zone of stress-relieved rock (Reference 2, Attachment 18). Analyses were performed using SWEDGE (Reference 33) a computer program for the analysis of translational slip of surface wedges in rock slopes defined by two intersecting discontinuity (joint, fault, shear, or fracture) planes, a slope face, and an optional tension crack. The program performs analyses using two techniques: probabilistic analyses (probability of failure), and deterministic analyses (factor of safety). For probabilistic analyses, variation or uncertainty in discontinuity orientation and strength values can be accounted for, resulting in safety factor distribution and prediction of failure probability. For deterministic analyses, a factor of safety is calculated for a specified wedge geometry and a set of strength parameters.

Results from the kinematic analysis show that the most critical wedges are formed by intersections between steeply dipping, northwest-trending faults and joints that intersect at a high oblique angle. These fault/joint intersections plunge steeply to the northwest, and some could daylight on the proposed back cut. These wedge geometries were specifically modeled in the SWEDGE analyses. Planar sliding along low-angle clay beds is addressed in Section 2.6.5.1.3.

Probabilistic analyses were performed to evaluate the overall susceptibility of the slope to wedge failure, and to evaluate the sensitivity of failure to variations in material strength, geometry, and water conditions. Twenty-six separate model runs were performed using the probabilistic approach. Each probabilistic model run included 1,000 Monte Carlo iterations of input parameter variations to generate a probability distribution. After completing the probabilistic analyses, deterministic analyses were performed for the most critical modeled conditions in terms of probability of failure, and size and weight of wedge. Sixteen separate deterministic models were run that included variations in slope height and inclination, wedge geometry (with and without tension cracks), and degree of water saturation.

#### 2.6.5.2.2.3 Rock Wedge Strength Parameters

Strength values derived from the Barton-Choubey method (Reference 26) (Figure 2.6-52) were used for the analyses of potential shallow rock wedge failures of rock blocks along existing discontinuities within the stress-relieved outermost rock zone directly behind the cutslope face. Cohesion was neglected. The friction angles selected and used in the probabilistic analyses ranged from 16 degrees (clay-coated faults) to 46 degrees (clay-free joints), and from about 26 degrees to 31 degrees, respectively, for the deterministic analyses.

#### 2.6.5.2.2.4 Assumptions

The following assumptions and parameters were used for the pseudostatic analysis:

- Three 70-degree cutslope geometrics were analyzed for the back cutslope: a 20.5-ft-high cutslope, a 31.8-ft-high cutslope, and 52.3-ft-high cutslope. The 20.5-ft-high cutslope models potential failures from base of cut to the intermediate bench

  (Figure 2.6-60). The 31.8-ft-high cutslope models potential failures from the intermediate bench to top of cut. The 52.3-ft-high cutslope models potential failures from base of cut to top of cut, at an "average" inclination of about 47 degrees.

- Each slope was evaluated with and without tension cracks, for example, in the case of the back cutslope, tension cracks were located at distances of 1.6 ft and 23 ft back from the crest of the slope. These distances are reasonable for a slope model, because the fractures at the ISFSI site have spacings of up to several feet, and the cutslope bench is 25 ft wide.

One set of tension cracks (at 23 ft) specifically models the potential for tension cracks to develop along a backfilled trench for a drainage pipe at the back of the intermediate bench.

- Analyses were performed for each cutslope configuration using (1) a horizontal (out-of-slope) pseudostatic seismic coefficient of 0.5 g, and (2) dry and partially saturated rock mass (water levels at one-half the height of the slope). The value of 0.5 g was derived using the procedure described by Ashford and Sitar (Reference 34), and is approximately two-thirds of the peak horizontal acceleration of 0.83 g from the LTSP spectra shown in Figure 2.6-43. This level of reduction has been shown to be appropriate for pseudostatic analyses of slopes (Reference 35).

#### 2.6.5.2.2.5 Results

The results of the pseudostatic probabilistic SWEDGE analysis for the back cutslope and the east cutslope are presented in Tables 2.6-6 and 2.6-7, respectively. Results of the deterministic analyses for these cutslopes are presented in Table 2.6-8. The probabilistic analyses show that rock wedges in the modeled cutslopes (Figure 2.6-60) have a low probability of failure in a dry condition. The probability of failure increases significantly with partial saturation of the slope and the addition of seismic force. The largest predicted wedge, with a factor of safety less than 1.0, weighs 4,475 kips and has an estimated face area of 2,649 square ft (Table 2.6-6).

Deterministic analyses were performed to calculate support forces required to restrain the wedges and achieve a factor of safety of 1.3 under seismic loading conditions (Table 2.6-8). The calculated total support force to stabilize the largest predicted wedge to a factor of safety of 1.3 is 1,881 kips. For an assumed anchor spacing of 5 ft by 5 ft, this force translates to 32 kips per anchor (Table 2.6-8). The design of slope reinforcement to prevent wedges from displacing is described in Section 4.2.1.1.9.

### 2.6.5.3 Slope Stability at CTF Site

In a previous submittal examining the stability of the slope behind DCPP Unit 1 (Reference 9, p. 30-36), it was shown that displacements along the interface between colluvial and terrace deposits within the underlying bedrock would be limited. The results of this analysis also indicate that the farthest extent of these estimated displacements is at the uppermost edge of the colluvium/bedrock interface, which is more than 100 ft west of the CTF (Figure 2.6-7), and similar to the relationship shown in cross sections B-B''' and L-L' (Figures 2.6-11 and 2.6-19). Therefore, slope-related displacements at the CTF site are estimated to be nil.

### 2.6.5.4 Slope Stability Along the Transport Route

#### 2.6.5.4.1 Static Stability

As discussed in Section 2.6.1.12.3, the Patton Cove landslide is more than 100 ft from the transport route, and it is not likely to encroach headward to where it would affect the route.

Small debris flows (up to 3 ft deep on the road) could impact the roadway as they issue from the swales on the steep slopes above the road (Section 2.6.1.12.3). These debris flows occur infrequently during or shortly following severe rainstorms (Reference 7), and are relatively easy to clear from the road.

Kinematic analyses of the stability of the slope above the transport route are shown on Figures 2.6-37 and 2.6-38. (Reference 2, Attachment 17, Figures 7 and 8). The north-trending slope (station 43+00 to 46+00) shows moderate potential for toppling failure, as a large portion of set 1 plots within this failure envelope. There is low potential of planar sliding failure, and very low potential for wedge sliding failure. Due to the very low inclination of the northwest-trending slope (station 35+00 to 43+00), this slope shows low potential for all three failure modes. Thus, the only potentially significant failure mode is for small topple failures along the transport route cutslopes.

#### 2.6.5.4.2 Dynamic Stability and Displacements

Stability analyses using the ILP ground motions (Section 2.6.2.5) were performed on the hillslope behind Unit 2 using cross section L-L' (Figure 2.6-19). Borings drilled during investigations for the power block along the slope provided data for modeling the slope. The results of these analyses indicate the bedrock slope and the transport route that crosses it are expected to undergo only minor displacements of about 1.0 ft or less during the possible occurrence of the ILP ground motions (Reference 2, Attachment 25).

An additional location, shown on cross section D-D' (Figure 2.6-16), along the transport route also was modeled, and the responses to the ILP ground-motions were assessed in a similar manner. Results from this analysis show that this location also is expected to undergo only minor displacements of about 1.0 ft or less. Other locations along this road cut are expected to perform similarly.

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CHAPTER 3

# PRINCIPAL DESIGN CRITERIA

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## 3.3 DESIGN CRITERIA FOR SAFETY PROTECTION SYSTEMS

The Diablo Canyon ISFSI is designed for safe storage of spent nuclear fuel and associated nonfuel hardware. The ISFSI storage facility in general, and the HI-STORM 100 System storage casks in particular, are designed to protect the MPC contents and prevent release of radioactive material under normal, off-normal, and accident conditions in accordance with applicable regulatory requirements contained in 10 CFR 72 (Reference 1). Section 3.2 provides the design criteria for environmental conditions and natural phenomena for ISFSI SSCs. This section provides the other design criteria for the ISFSI SSCs.

### 3.3.1 HI-STORM 100 SYSTEM

#### 3.3.1.1 General

The primary safety functions of each of the major components comprising the Diablo Canyon ISFSI are summarized below, with appropriate references to the HI-STORM 100 System FSAR (Reference 2) or other sections of this SAR for additional information. Table 3.4-6 provides a list of ASME Code alternatives for the HI-STORM 100 System.

##### 3.3.1.1.1 Multi-Purpose Canister

The MPC is comprised of a cylindrical, strength-welded shell, fuel basket, lid, vent and drain port cover plates, and a welded closure ring. The MPC provides criticality control, decay heat removal, shielding, and acts as the primary confinement boundary for the storage system. The MPC may contain, at prescribed fuel basket locations, a damaged fuel container (DFC) that provides confinement, structural support, and retrievability for damaged fuel assemblies or fuel debris. A detailed description, design drawings, and a summary of the design criteria for the MPCs are provided in Sections 1.2.1.1, 1.5, and 2.0.1, respectively, of the HI-STORM 100 System FSAR, as amended by LAR 1014-1 (Reference 3).

##### 3.3.1.1.2 HI-STORM 100SA Overpack

The HI-STORM 100SA overpack is a rugged, heavy-walled, cylindrical, steel structure. The structure is comprised of inner and outer concentric, carbon-steel shells, a baseplate, and a bolted top lid (comprised of steel plates and a concrete shield) with integral outlet vents. The annulus between the inner and outer shells is filled with concrete. A shortened, seismically-anchored version of the overpack, denoted as the HI-STORM 100SA, is used at the Diablo Canyon ISFSI

The overpack provides support and protection for the MPC during normal, off-normal, and accident conditions including natural phenomena such as tornadoes and earthquakes; provides radiation shielding; and facilitates rejection of decay heat from the MPC to the environs to ensure fuel cladding temperatures remain below acceptable limits. Detailed descriptions, design drawings, and a summary of the design criteria for the overpack are provided in Sections 1.2.1.2.1, 1.5, and 2.0.2, respectively, of the HI-STORM 100 System FSAR, as amended by LAR 1014-1.

#### 3.3.1.1.3 HI-TRAC 125 Transfer Cask

The HI-TRAC 125 transfer cask is a rugged, heavy-walled, cylindrical steel vessel weighing a maximum of 125 tons during use. The cask guides, retains, protects, and supports the MPC during load handling and transfer operations, including submersion in the SFP where the MPC is loaded. During load handling operations to and from the SFP with a loaded MPC, the transfer cask retains the unwelded MPC lid using a top lid retention device. The transfer cask also limits MPC vertical dynamic loading to within acceptable design-basis limits in the event of a postulated load drop inside the FHB/AB by using a removable bottom-mounted impact limiter. The transfer cask also features a single bottom lid that is removed at the CTF to facilitate the transfer of the MPC to or from the overpack. While submerged, the transfer cask prevents most of the exterior surfaces of the MPC from becoming contaminated by preventing contact with the SFP water.

Upon removal from the SFP, the transfer cask provides shielding to maintain personnel exposure ALARA, and facilitates heat transfer from the MPC to the environs. A more detailed description, and a summary of the design criteria for the transfer cask are provided in Sections 1.2.1.2.2, and 2.0.3, respectively, of the HI-STORM 100 System FSAR; and in Sections 5.1 and 10.2 of this SAR. A modified version of the HI-TRAC 125 transfer cask, known as HI-TRAC 125D, will be used to support Diablo Canyon ISFSI operations. See Section 4.2.3.2.4 for more detailed discussion of HI-TRAC 125D.

### 3.3.1.2 Protection by Multiple Confinement Barriers and Systems

#### 3.3.1.2.1 Confinement Barriers and Systems

The HI-STORM 100 System provides several confinement barriers for the radioactive contents. Intact fuel assemblies have cladding that provides the first boundary within the MPC preventing release of the fission products. (The MPC confinement and radiological evaluations do not take credit for the cladding.) A DFC prevents the dispersal of gross particulates within the MPC for any fuel assemblies classified as damaged fuel or fuel debris. The MPC is a strength-welded enclosure that provides the confinement boundary for all normal, off-normal and accident conditions, including natural phenomena. The MPC confinement boundary is defined by the MPC baseplate, shell, lid, port cover plates, and the welds joining these components, as shown in Figure 3.3-1. The closure ring provides a redundant boundary. Refer to the drawings in Section 1.5 of the HI-STORM 100 System FSAR for details of the MPC confinement boundary design.

#### 3.3.1.2.2 Cask Cooling

The HI-STORM 100 System provides decay heat removal both during processing and final storage of the MPC. As described previously, the transfer cask conducts heat from the MPC until the MPC is transferred to the overpack where convective cooling is established as depicted in Figure 3.3-2. The thermal design of the HI-STORM 100 System is discussed in detail in Chapter 4 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, and in Section 4.2.3.3.3 of this SAR.

### 3.3.1.3 Protection by Equipment and Instrumentation Selection

#### 3.3.1.3.1 Equipment

The cask transporter and CTF provide protection functions to the MPC and are discussed in Sections 3.3.3 and 3.3.4, respectively.

#### 3.3.1.3.2 Instrumentation

No instrumentation is required for storage of spent nuclear fuel and associated nonfuel hardware at the Diablo Canyon ISFSI. Due to the welded closure of the MPC, the passively-cooled storage cask design, and the Diablo Canyon ISFSI TS requirement for periodic checks of the casks, the loaded overpacks do not require continuous surveillance and monitoring or operator actions to ensure the safety functions are performed during normal, off-normal or postulated accident conditions.

### 3.3.1.4 Nuclear Criticality Safety

The HI-STORM 100 System is designed to ensure the stored fuel remains subcritical with $k_{eff}$ less than 0.95 under all normal, off-normal, and accident conditions. A detailed discussion of the criticality analyses for the HI-STORM 100 System is provided in Chapter 6 of the HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1. Section 4.2.3.3.5 of this SAR includes a summary discussion of the HI-STORM 100 System criticality design.

#### 3.3.1.4.1 Control Methods for Prevention of Criticality

The design features and control methods used to prevent criticality for all MPC configurations are the following:

(1) Incorporation of permanent neutron absorbing material (Boral) attached to the MPC fuel basket walls with a minimum required loading of the $^{10}B$ isotope.

(2) Favorable geometry provided by the MPC fuel basket.

(3) Loading of certain fuel assemblies is performed in water with a soluble boron content as specified in the Diablo Canyon ISFSI TS.

There are a number of conservative assumptions used in the HI-STORM 100 System criticality analyses, including not taking credit for fuel burnup, fuel-related burnable neutron absorbers, and only crediting 75 percent of $^{10}B$ isotope loading in the Boral neutron absorbers. A complete list of the conservative assumptions in the HI-STORM 100 System criticality analyses is provided in Section 6.1 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1.

#### 3.3.1.4.2 Error Contingency Criteria

Provisions for error contingency are built into the criticality analyses discussed in Chapter 6 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1. Because biases and uncertainties are explicitly evaluated in the analyses, it is not necessary to introduce additional contingency for error.

#### 3.3.1.4.3 Verification Analyses

The criticality analyses for the HI-STORM 100 System were performed using computer codes validated for use in this application under the Holtec International Quality Assurance Program. A discussion of the analysis and the applicable computer codes is provided in Section 6.1 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1. Criticality benchmark experiments are discussed in Section 6.5 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1.

### 3.3.1.5 Radiological Protection

Radiation exposure due to the release of material from the storage system is precluded by the confinement boundary design, as discussed in Section 3.3.1.2. The confinement boundary is designed to maintain its integrity during all normal, off-normal, and accident conditions including natural phenomena. Radiation exposure due to direct and sky shine radiation is minimized to the extent practicable through the use of the "time, distance, and shielding" philosophy. This philosophy is implemented at the Diablo Canyon ISFSI through access control, minimization of required maintenance, and the design of the HI-STORM 100 System.

#### 3.3.1.5.1 Access Control

The Diablo Canyon ISFSI storage pads are surrounded by two fences. The inner is a protected area fence in compliance with the requirements of 10 CFR 73.55. The outer is a restricted area fence in compliance with 10 CFR 20. Only authorized personnel with a need to be in these areas will be permitted entrance. These areas do not require the continuous presence of operators or maintenance personnel. During normal storage operations, the HI-STORM 100 System requires only infrequent, short-duration personnel activity to perform necessary checks on the material condition of the casks and to ensure the overpack air ducts are free of blockage. Higher occupancy times with a greater number of personnel will occur during placement of loaded overpacks at the storage pads and during construction of any additional storage pads. These activities will be governed by the DCPP radiation protection program to ensure occupational radiation exposures are maintained ALARA. Chapter 7 and Section 9.6 provide additional details regarding the implementation of access control at the Diablo Canyon ISFSI.

**3.3.1.5.2 Shielding**

The HI-STORM 100 System is designed to minimize radiation doses to DCPP personnel and the public through the use of a combination of concrete, lead, and steel shielding. The HI-STORM 100 System is designed to meet the annual dose limit of 25 mrem specified in 10 CFR 72.104 for annual dose at the DCPP owner-controlled-area boundary. The steel shell of the overpack includes concentric inner and outer shells. The annulus between the shells is filled with unreinforced concrete. The requirements for the unreinforced concrete used for shielding are stated in Appendix 1.D to the HI-STORM 100 System FSAR. The steel overpack lid is designed with steel-encased concrete shields to minimize the dose contribution due to sky shine.

The transfer cask is also fabricated from concentric steel shells. The annulus between the shells is filled with lead to provide significant gamma shielding while maintaining the diameter of the transfer cask small enough for loading into the SFP. The transfer cask also includes a water jacket surrounding the main body of the cask. The water jacket is filled with water after the loaded MPC and transfer cask are removed from the SFP to allow as much structural shielding as possible to be designed into the transfer cask without exceeding the 125-ton design weight. Water is not required in the water jacket to provide adequate shielding while there is water inside the MPC cavity. The water in the water jacket provides necessary shielding for neutrons after the water is drained from the inside of the MPC. The MPC lid, the transfer cask top lid, and the bottom shield are designed to provide necessary shielding during onsite transport of the transfer cask in the horizontal position.

The objective of shielding is to ensure that radiation dose rates at the following locations are below acceptable levels for those locations:

- Immediate vicinity of the storage cask
- Restricted area boundary
- Controlled area (site) boundary

Dose rates in the immediate vicinity of the loaded overpack are an important factor in consideration of occupational exposure. A design objective for the maximum average radial surface dose rate has been established as 60 mrem/hr. Areas adjacent to the inlet and exit vents that pass through the radial shield are limited to 60 mrem/hr. The average dose rate at the top of the overpack is limited to less than 60 mrem/hr.

A detailed discussion of the HI-STORM 100 System generic shielding evaluation, including modeling, source-term assumptions, and resultant dose rates is provided in Chapter 5 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1 (Reference 3). The site-specific shielding analysis is discussed in Section 7.3. Estimated occupational exposures and offsite doses for fuel loading, cask handling activities, and storage at the Diablo Canyon ISFSI have been evaluated for DCPP fuel and are discussed also in Sections 7.4 and 7.5.

#### 3.3.1.5.3 Radiological Alarm Systems

The HI-STORM 100 System, when used outside the FHB/AB, does not produce any solid, liquid, or gaseous effluents. Release of loose contamination is not a factor because the HI-STORM overpack is not submerged in the SFP or otherwise subject to contamination. The transfer cask and MPC are submerged in the SFP, but contamination of the MPC is limited to the top of the MPC lid by the annulus seal, which prevents SFP water from coming into contact with the sides and bottom of the MPC. Upon removal from the SFP, the transfer cask and top of the MPC will be decontaminated. Therefore, the inadvertent release of loose contamination from the transfer cask produces a negligible dose effect.

The dose rates for a given storage cask at the Diablo Canyon ISFSI will be stable and decreasing over time due to the decay of the fuel sources stored inside. There is no credible event that could cause an increase in dose rate from the casks.

Based on the foregoing, there is no need for either airborne or area radiological alarms at the Diablo Canyon ISFSI storage pads or CTF. Radiological alarms, if required for operations inside the FHB/AB, will be implemented under the DCPP radiological protection program.

### 3.3.1.6 Fire and Explosion Protection

There are no combustible or explosive materials associated with the HI-STORM 100 System, except for the fuel contained in the cask transporter fuel tank. Such materials will not be permanently stored within the Diablo Canyon ISFSI protected area. The cask transporter may be parked within the ISFSI, which has been evaluated. However, for conservatism, several hypothetical fire and explosion events were evaluated for the Diablo Canyon ISFSI. Design criteria for fires and explosions are discussed in Section 2.2 and summarized in Section 3.4.

The generic fire evaluations for both the loaded overpack and the loaded transfer cask are described in Section 11.2.4 of the HI-STORM 100 System FSAR. The fire evaluations assume a maximum of 50 gallons of combustible fuel. Therefore, any transport vehicle used to move the loaded overpack or transfer cask is limited by the Diablo Canyon ISFSI TS to 50 gallons. A site-specific fire evaluation for the Diablo Canyon ISFSI site is provided in Section 8.2.5.

Small overpressures may result from accidents involving explosive materials that are stored or transported near the storage site. Explosion is an accident loading condition evaluated in Section 3.4.7.2 of the HI-STORM 100 System FSAR. An instantaneous overpressure of 10 psig and a steady-state overpressure of 5 psig for the storage cask were evaluated and found to be acceptable. A Diablo Canyon ISFSI explosion evaluation for transport to and from the CTF, at the CTF, and at the ISFSI storage pads is discussed in Section 8.2.6.

#### 3.3.1.7 Materials Handling and Storage

##### 3.3.1.7.1 Spent Fuel Handling and Storage

Spent fuel will be moved within the DCPP SFP and loaded into the HI-STORM 100 System in accordance with Diablo Canyon ISFSI TS, DCPP TS, and plant procedures. Only fuel assemblies meeting the burnup, cooling time, decay heat, and other limits of the Diablo Canyon ISFSI TS and SAR Section 10.2 will be loaded. Administrative controls will be used to ensure that no unauthorized fuel assemblies are loaded into the HI-STORM 100 System. The Diablo Canyon ISFSI TS and SAR Section 10.2 limits on fuel assemblies authorized for loading, in combination with the design features of the cask system described earlier in this section, ensure that:

- The $k_{eff}$ for the stored fuel will remain less than 0.95.
- Adequate cooling will be provided to ensure peak fuel cladding temperature limits will not be exceeded.
- Radiation dose rates and accumulated doses to plant personnel and the public will be less than applicable limits.

The fuel selection process includes a review of reactor operating records for each fuel assembly and nonfuel hardware chosen for loading into the HI-STORM 100 System. Each fuel assembly will be classified as intact fuel, damaged fuel, or fuel debris, in accordance with the applicable definitions in the Diablo Canyon ISFSI TS and SAR Section 10.2. Fuel assemblies classified as damaged fuel or fuel debris are required to be placed in DFCs for storage in the HI-STORM 100 System.

Section 3.3.1.5 discusses contamination as it relates to the operation of the HI-STORM 100 System. The Diablo Canyon ISFSI TS and SAR Section 10.2 provide the necessary limits on MPC moisture removal, helium backfill, and helium leakage prior to declaring the MPC ready for storage. Chapter 8 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, provides generic operating procedures for all facets of fuel loading, MPC preparation, and cask handling. The general operating sequence specific to the Diablo Canyon ISFSI is discussed in Sections 5.1 and 10.2 of this SAR. Implementation procedures will be developed based on both generic and site-specific guidelines, as applicable.

The HI-STORM 100 System is designed to allow retrievability of the fuel, as necessary. If the situation warrants fuel retrieval, the MPC is removed from the overpack and returned to the FHB/AB in the transfer cask. The MPC cavity gas is cooled, in accordance with the requirements of the Diablo Canyon ISFSI TS and SAR Section 10.2 and the HI-STORM 100 System FSAR. The MPC is reflooded, the lid removed, and the fuel assemblies are returned to the SFP. Fuel removal activities take place entirely inside the FHB/AB, ensuring that any radiological conditions are controlled and maintained ALARA.

#### 3.3.1.7.2 Radioactive Waste Treatment

There are no radioactive wastes created by the HI-STORM 100 System while in storage at the storage pads, transport to or from the CTF, or at the CTF. During fuel loading and cask preparation activities inside the plant facility, any radioactive wastes created (for example, from decontamination activities) will be treated and handled like any other radioactive waste under the DCPP radwaste management program.

## 3.3.2 ISFSI CONCRETE STORAGE PAD

The Diablo Canyon ISFSI includes a number of individual storage pads, which will be constructed periodically to meet fuel storage needs of DCPP. For simplicity, this discussion refers to a single storage pad. The design criteria are identical for all pads comprising the ISFSI.

### 3.3.2.1 General

The ISFSI concrete storage pad must be designed to support the weight of the loaded overpacks under all design basis static and dynamic conditions of storage. The pad must also be designed to support the studs that anchor the overpack to the pad and to maintain the integrity of the fastening mechanism embedded in the pad during a postulated design-basis event. The ISFSI pad has been evaluated for the physical uplift, pad sliding, and overturning moments caused by extreme environmental events (for example, tornado missiles, earthquakes, etc.). Therefore, the pad is engineered as a thick, heavily reinforced concrete structure.

Because tipover of a cask installed in an anchored configuration is not a credible event, the pad does not need to be engineered to accommodate this non-mechanistic event. Since the lifting devices are designed, fabricated, inspected, maintained, operated, and tested in accordance with NUREG-0612 (Reference 4), a drop of the loaded overpack will not occur; therefore, a specific lifting height limit for the cask at the ISFSI is not required to be established. Based on these two criteria, there is no maximum limit on the hardness of the concrete pad and subgrade.

### 3.3.2.2 Natural Phenomena

The Diablo Canyon ISFSI concrete storage pad is engineered to perform its design function under all loadings induced by design basis natural phenomena. The design criteria for the natural phenomena applicable to the Diablo Canyon ISFSI site, including seismic loadings, tornado wind, and missile loadings, are discussed in Section 3.2.

### 3.3.2.3 Design Criteria

The ISFSI pad and its embedment steel design must comply with the ACI 349-97, NUREG-1536 (Reference 5) and with NRC draft Regulatory Guide DG-1098 as applicable. A new Proposed Appendix B to the ACI 349-97 (dated 10/01/00) was used. (It may be noted that the NRC took exception to the Appendix B [of the 97 Code] as stated in DG-1098.) Specifically, the design strength capacity of the embedded base plate, concrete bearing, and diagonal tension shear capacity are in accordance with the design provisions of ACI 349-97 and the embedded anchorage is to meet the ductile anchorage provisions of the Proposed Draft New Appendix B to ACI 349-97 (dated October 1, 2000). The materials of construction (for example, anchor stud material and additives in the pad concrete) have been chosen to be compatible with the environment at the Diablo Canyon ISFSI site. ISFSI pad design life is 40 years. The surface anchorage studs (i.e. SA-193 B7 Studs and the exposed embedment plates) will be properly coated for corrosion protection.

The use of an embedded steel structure underneath the cask and in the concrete storage pad is to be employed at the Diablo Canyon ISFSI. The purpose of the embedded structure is to permit the cask anchor studs to be preloaded, while the embedded steel structural connection to the concrete does not involve a preload. The embedded structure, while not part of the cask system, is designed in accordance with the AISC Manual of Steel Construction (Reference 6) and the ACI 349-97 requirements.

#### 3.3.2.3.1 Load Combinations for the Concrete Storage Pad

Factored load combinations for ISFSI pad design are provided in the ACI-349-97 and supplemented by the factored load combinations from NUREG-1536 (Reference 5) Table 3.1 and NRC draft Regulatory Guide DG-1098, as applicable.

<u>Overturning and Sliding</u>

Since the casks at the Diablo Canyon ISFSI are anchored to the concrete pads, the load combinations from Table 3-1 of NUREG-1536 associated with gross sliding and overturning at the cask/pad interface are not applicable to the cask. The gross sliding of the loaded pad structure was evaluated using a dynamic non-linear seismic analysis to determine the extent of sliding. Pad overturning is not considered as a credible failure mechanism due to the size and geometry of the pad (that is, 68 ft wide by 105 ft long by 7.5 ft thick). The sliding analysis acceptance criteria is: The analysis is to show insignificant impact on the pad's ability to meet its functional requirements and the cask design qualifications as a result of potential pad sliding.

### 3.3.2.3.2 Load Combinations for the Cask Anchor Studs

The design of the cask anchor studs is governed by the ASME Code, Section III, Subsection NF and Appendix F (Reference 7). The applicable load combinations and allowable stress limits for the anchor studs attaching the cask to the intervening steel support structure are:

Normal Conditions:

Load Combination: D

Code Reference for Stress Limits: NF-3322.1 and NF-3324.6

Off-Normal Conditions:

Load Combination: D+F

Code Reference for Stress Limits: NF-3322.1 and NF-3324.6 with all stress limits increased by a factor of 1.33

Accident Conditions:

Load Combinations: D+E and D+$W_t$

Code Reference for Stress Limits: Appendix F, Sections F-1334 and F-1335

The axial stress in the cask anchors induced by pretensioning is kept below 75 percent of the material yield stress, such that during a seismic event the maximum stud axial stress remains below the limit prescribed for bolts in the ASME Code, Section III, Subsection NF, for Level D conditions.

### 3.3.2.3.3 Maximum Permissible Tornado Wind and Missile Load

During a tornado event, the HI-STORM 100 System may be subjected to a constant wind force and differential pressures. It may also be subjected to impacts by tornado-borne missiles. In contrast to a free-standing cask, the anchored cask system is capable of withstanding greater lateral pressures and impulsive loads from large missiles. The anchored HI-STORM 100SA cask design at the Diablo Canyon ISFSI has been analyzed assuming the lateral force from the site-specific design-basis, large-tornado-missile impact occurs at the worst-case height on the cask and the force created by the tornado wind action and differential pressure acts simultaneously at cask mid-height. The resulting overturning moment is bounded by the maximum seismic overturning moment applied to the cask anchorage embedment and the pad.

## 3.3.3 CASK TRANSPORTER

### 3.3.3.1 General

The cask transporter is a U-shaped tracked vehicle used for lifting, handling, and onsite transport of loaded overpacks and the transfer cask. The cask transporter does not have a suspension system (for example, springs). The transporter consists of the vehicle main frame, the lifting towers, an overhead beam system that connects the parallel lifting towers, a cask restraint system, the drive and control systems, and a series of cask lifting attachments. The casks are individually carried within the internal footprint of the transporter tracks (Sections 4.3 and 4.4 provide more detailed descriptions of cask transportation components and operating characteristics). The cask is supported by the lifting attachments that are connected to the overhead beam. The overhead beam is supported at the ends by a pair of lifting towers. The lifting towers transfer the cask weight directly to the vehicle frame and ultimately to the tracks and the transport route surface. The cask transporter has the added capability of being able to raise and lower an MPC between the transfer cask and the overpack when used in conjunction with the CTF. The transporter's CTF functions are contained in Section 2.3.3.1 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1.

### 3.3.3.2 Design Criteria

The key design criteria for the cask transporter are summarized in Table 3.4-4. The bases for these criteria are discussed in the sections below.

#### 3.3.3.2.1 Design Life

The cask transporter design life of 20 years has been established based on a reasonable length of time for a vehicle of its type with normal maintenance. The cask transporter may be replaced or recertified for continued use at the end of its design life.

#### 3.3.3.2.2 Environmental Design Criteria

The cask transporter is an "all-weather" vehicle. It is designed to operate in both rain and snow over a temperature and humidity range that bounds the historical conditions at the Diablo Canyon site. Materials that would otherwise degrade in an coastal marine environment will be appropriately maintained.

A lightning strike on the cask transporter would not structurally affect the ability of the transporter to hold the load. Due to the massive amount of steel in the structure, the current would be transmitted to the ground without significantly damaging the transporter. However, the driver may be affected by a lightning strike. Therefore, the transporter design includes fail-safe features to automatically shutdown the vehicle into a safe, stopped, and braked condition if the operator is injured or incapacitated for any reason while handling a loaded cask.

Flooding is not a concern on the transport route as discussed in Section 3.2.2. Sources of fires and explosions have been identified and evaluated. Fixed sources of fire and explosion are sufficiently far from the transport route to not be of concern (Section 2.2). Mobile sources of fire and explosion, such as fuel tanker trucks, will be kept at a safe distance away from the transporter during cask movement through the use of administrative controls. The cask transporter is diesel-powered and is limited to a maximum fuel volume consistent with that used in the HI-STORM 100 System fire accident analysis. The hydraulic fluid used in the cask transporter is nonflammable.

#### 3.3.3.2.3 Regulatory Design Criteria and Industry Standards

The transporter is designed, fabricated, inspected, maintained, operated, and tested in accordance with applicable guidelines of NUREG-0612, which allows the elimination of the need to establish a cask lift height limit.

#### 3.3.3.2.4 Performance Design Criteria

As described in Section 4.4, the cask transporter must lift and transport either the loaded transfer cask or the loaded overpack, including the weight of all necessary ancillary lift devices such as rigs and slings. The loaded overpack, being the heavier of the two casks to be lifted, provides the limiting weight for the design of the transporter.

#### 3.3.3.2.5 Stability Design Criteria

The cask transporter is custom designed for the Diablo Canyon site, including the transport route with its maximum grade of approximately 8.5 percent. It will remain stable and will not experience structural failure, tip over, or leave the transport route should a design-basis seismic event occur while the loaded transfer cask is being moved to the CTF, while transferring an MPC at the CTF, while moving a loaded overpack from the CTF to the storage pad, or while moving a loaded overpack on the storage pad. In addition, the cask transporter is designed to withstand design-basis tornado winds and tornado-generated missiles without an uncontrolled lowering of the load or leaving the transport route. All design criteria for natural phenomena used to design the cask transporter are specific to the Diablo Canyon site (Sections 3.2 and 3.4 provide further information).

#### 3.3.3.2.6 Drop Protection Design Criteria

In accordance with NUREG-0612, prevention of a cask or MPC drop is provided by enhancing the reliability of the load supporting systems by design, using a combination of component redundancy and higher factors of safety than would normally be used for a commercial lift device. Load supporting components include the special lifting devices used to transfer the force of the payload to the cask transporter lift points (including attachment pins, as appropriate), the cask transporter lift points, the overhead beam, the lifting towers, and the vehicle frame. The design criteria for each of the components of the cask transporter are the following:

Slings and Special Lifting Devices

The transfer cask horizontal lift rig, HI-TRAC lift links, MPC downloader slings, overpack lifting brackets, and HI-STORM lift links are designed to applicable guidelines of NUREG-0612.

Cask Transporter Lift Points, Overhead Beam, Vehicle Body and Seismic Restraints

The cask transporter lift points, overhead beam, and load supporting members of the vehicle body (whose failure would result in an uncontrolled lowering of the load) are designed to applicable guidelines of NUREG-0612.

Lifting Towers

The lifting towers are designed with redundant drop protection features. The primary cask lifting device is the hydraulic system, which prevents uncontrolled cask lowering through the control of fluid pressure in the system. A mechanical backup load retaining device, independent of the hydraulic lifting cylinders, is provided in case of failure of the hydraulic system. This may consist of load blocks, pawl and detent, locking pins, or other suitably designed positive mechanical locking device.

#### 3.3.3.2.7 Drive System Design Criteria

The cask transporter is capable of forward and reverse movement as well as turning and stopping. It includes an on-board engine capable of supplying enough power to perform its design functions. The cask transporter includes fail-safe service brakes (that is, brakes that automatically engage in any loss of power and/or independent emergency) and parking brakes. The brake system is capable of stopping a fully loaded cask transporter on the maximum design grade. The cask transporter is equipped with an automatic drive brake system that applies the brakes if there is a loss of hydraulic pressure or the drive controls are released. The cask transporter is not capable of coasting on a 10 percent downward grade with the brakes disengaged due to the resistance in the drive system.

#### 3.3.3.2.8 Control System Design Criteria

The cask transporter is equipped with a control panel that is suitably positioned on the transporter frame to allow the operator easy access to the controls located on the control panel and, at the same time, allow an unobstructed view of the cask handling operations. The control panel provides for all-weather operation or will be enclosed in the cab. The control panel includes controls for all cask transporter operations including speed control, steering, braking, load raising and lowering, cask restraining, engine control and "dead-man" and external emergency stop switches.

The drive control system is capable of being operated by a single operator from an on-board console. The control panel contains all gauges and instruments necessary for the operator to monitor the condition and performance of both the power source and hydraulic systems. A cask lift-height indicator is provided to ensure the loaded casks are lifted only to those heights necessary to accomplish the operational objective in progress.

#### 3.3.3.2.9 Cask Restraint Design Criteria

The cask transporter is equipped with a cask restraint to secure the cask during movement. The restraint is designed to prevent lateral and transverse swinging of the cask during cask transport. The restraint is designed to preclude damage to the cask exterior with padding or other shock dampening material used, as necessary.

## 3.3.4 CASK TRANSFER FACILITY

### 3.3.4.1 General

The ISFSI CTF is used in conjunction with the cask transporter to accommodate MPC transfers between the transfer cask and the overpack. The CTF is designed to position an overpack sufficiently below grade where the transfer cask can be mated to the overpack using the cask transporter. The CTF lifting platform acts as an elevator to raise and lower the overpack. In the full-up position, the overpack base is approximately 40 inches below grade. The surface of the CTF contains an approach pad that supports the loaded transporter and provides a laydown area for the transfer cask, cask transport frame, mating device, seismic restraint, and other load handling equipment.

### 3.3.4.2 Design Criteria

The rated load of the CTF lifting system is the bounding weight of a loaded overpack (360,000 lb). The design criteria for the specific subcomponents are discussed below. The CTF is designed to withstand a design-basis seismic event without an uncontrolled lowering of the lifted load. The design life of the CTF is 40 years. Design criteria for the CTF are summarized in Table 3.4-5.

#### 3.3.4.2.1 Main Shell Design Criteria

A cylindrical steel shell forms the opening in the ground into which the overpack is lowered, provides the support for the lifting jacks, and provides a setdown location for the lifting platform when it is fully lowered. The main shell forms a cylindrical opening of approximately 150 inches in diameter and approximately 200 inches deep. Three extensions run the length of the cylinder and form the locations for the jacks. The shell is also equipped with a sump for collecting and disposing of incidental water from the CTF. The surrounding area is reinforced concrete. The resulting structure is a flat-surfaced pad with a steel-lined hole. The main shell is designed in accordance with applicable portions of ASME Section III, Subsection NF.

### 3.3.4.2.2 Lifting Jacks

Three lifting jacks provide the lifting force for the lifting platform. The jacks are located on the circumference of the main shell in the extensions. The jacks are supported at the top end and suspend the lifting platform by bearing on a traveling nut on each jack screw. All jacks operate in unison to keep the platform level through the entire travel range (approximately 160 inches). The jacks are interconnected with an electronic position monitoring and control system. The maximum lift speed of the jacks is 12 inches/minute and will not unwind on loss of the driver.

### 3.3.4.2.3 Drive and Control System

A drive and control system provides the power and control for the lifting jacks. Electrical power is supplied to each jack drive motor. The speed is reduced via one or more gearboxes. The relative position of each jack is monitoring by the drive and control system to stop all jacking if a mismatch is detected. Position switches limit the travel beyond established points. The control system is designed in accordance with applicable guidelines of NUREG-0612, Section 5.1.6 (2). The lifting jack design ensures the load will stop in position on a loss of electrical power to the drive and control system.

### 3.3.4.2.4 Lifting Platform

A lifting platform provides the support of the overpack and transmits the lifting jack force to the cask. Multiple beams or a single torsion box-type beam forms the lifting platform. The platform provides a level base on which the overpack rests. To interface with the lifting jacks, the platform has extensions that enter into each main shell extension. Uniform loading of the lifting platform is afforded by the location and controlled movement of the jacks. Radial stability of the lifting platform is provided by the main shell.

Wheeled or low-friction pad-type vertical guides or runners are provided to prevent damage to the main shell and lifting platform at the interface locations. The guides (or runners) are capable of restraining the lift platform under the maximum horizontal loading due to a design basis seismic event.

#### 3.3.4.2.5 HI-STORM Mating device

A mating device provides structural support and shielding at the interface between the top of the open overpack and the bottom of the transfer cask during MPC transfer operations. The mating device also facilitates the removal of the pool lid from the transfer cask prior to MPC transfer operations.

#### 3.3.4.2.6 Seismic Restraint

A removable seismic restraint provides lateral structural support in the gap between the overpack and the CTF main shell.

#### 3.3.4.2.7 Reinforced Concrete Support Structure

The reinforced concrete surrounding the shell is capable of supporting a loaded transporter and handling any seismic loads applied through the shell. The reinforced concrete base pad supports the CTF shell and a steel pedestal base that supports the lifting platform when it is in the full-down position. The approach pad is designed for the weight of the transporter with a loaded overpack. Independent tie-down blocks at the surface of the CTF will be provided to hold the transporter in place during the MPC transfer operation. The reinforced concrete structure is qualified to ACI-349-97 (Reference 8), NUREG-1536, and DG-1098, as applicable.

##### 3.3.4.2.7.1 Design Load Combinations

Factored load combinations for the CTF concrete structure design are provided in the ACI 349-97 and supplemented by the factored load combinations from NUREG-1536 (Reference 8), Table 3.1, and NRC draft Regulatory Guide DG-1098 (Reference 6), as applicable.

### 3.3.5 REFERENCES

1. 10 CFR 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.

2. Final Safety Analysis Report for the HI-STORM 100 System, Holtec International Report No. HI-2002444, Revision 0, July 2000.

3. License Amendment Request 1014-1, Holtec International, Revision 2, July 2001, including Supplements 1 through 4 dated August 17, 2001; October 2, 2001; October 12, 2001; and October 19, 2001; respectively.

4. Control of Heavy Loads at Nuclear Power Plants, USNRC, NUREG-0612, July 1980.

5. Standard Review Plan for Dry Cask Storage Systems, USNRC, NUREG-1536, January 1997.

6. Manual of Steel Construction, American Institute of Steel Construction, 9th Edition.

7. Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NF, American Society of Mechanical Engineers, 1995 Edition including 1996 and 1997 Addenda.

8. ACI-349-97, Code Requirements for Nuclear Safety Related Concrete Structures, American Concrete Institute, (with Draft Appendix B [10/01/00]).

9. Draft Regulatory Guide DG-1098, Safety Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessel and Containment), USNRC, August 2000.

## 3.4 SUMMARY OF DESIGN CRITERIA

The major ISFSI structures, systems, and components (SSCs) classified as important to safety are the HI-STORM 100 System, the storage pad, the transporter, and the CTF. The principal design criteria for these SSCs are summarized in Tables 3.4-1 through 3.4-6.

- Table 3.4-1 provides the site-specific design criteria for environmental conditions and natural phenomena.
- Table 3.4-2 provides design criteria applicable to the HI-STORM 100 System. Detailed design criteria for the MPC, the overpack, and the transfer cask are listed in the HI-STORM 100 System FSAR, Tables 2.0.1, 2.0.2, and 2.0.3, respectively, as amended by LAR 1014-1 (References 1 and 2). Detailed anchorage design requirements are discussed in Section 4.2.
- Table 3.4-3 provides the design criteria for the storage pad.
- Table 3.4-4 provides the design criteria for the cask transporter.
- Table 3.4-5 provides the design criteria for the CTF.
- Table 3.4-6 provides a list of ASME Code alternatives for the HI-STORM 100 System.

### 3.4.1 REFERENCES

1. Final Safety Analysis Report for the HI-STORM 100 System, Holtec International Report No. HI-2002444, Revision 0, July 2000.

2. License Amendment Request 1014-1, Holtec International, Revision 2, July 2001, including Supplements 1 through 4 dated August 17, 2001; October 5, 2001; October 12, 2001; and October 19, 2001; respectively.

TABLE 3.1-2

SUMMARY OF FUEL THERMAL AND RADIOLOGICAL CHARACTERISTICS

| Parameter | Diablo Canyon[(a)] | MPC Limiting Values |
|---|---|---|
| Maximum decay heat per assembly | 1,500 Watts | See footnote (b) |
| Maximum assembly average burnup | ~58,000 MWD/MTU | See footnotes (b) and (c) |
| Maximum initial enrichment | 5 percent | See footnote (b) |
| Minimum cooling time | 5 years | See footnote (b) |

(a) These are the DCPP fuel characteristics. The DCPP license limits the peak fuel rod burnup to 62,000 MWD/MTU, which corresponds to a fuel assembly average burnup of approximately 58,000 MWD/MTU.

(b) In many instances, allowable fuel parameters are a function of several factors such as MPC type, fuel condition, and the use of a uniform or regionalized loading strategy. Some are also dependent upon one another (that is, burnup and cooling time or decay heat and cooling time). The limiting assembly decay heat, burnup, initial enrichment, and cooling times are specified in SAR Section 10.2, which is consistent with the applicable limiting values in the HI-STORM 100 System CoC, as amended by LAR 1014-1. In all cases, the fuel stored will be within the limits controlled by the Diablo Canyon ISFSI Technical Specifications and specified in SAR Section 10.2.

(c) ZIRLO clad fuel is limited to a burnup of 45,000 MWD/MTU.

TABLE 3.4-2 Sheet 1 of 4

PRINCIPAL DESIGN CRITERIA APPLICABLE TO THE HI-STORM 100 SYSTEM

| Design Criterion | Design Value | Reference Documents |
|---|---|---|
| **GENERAL** | | |
| HI-STORM 100 System Design Life | 40 years | Holtec FSAR, Section 2.0.1 and Diablo Canyon ISFSI SAR Section 3.3.1.3.1 |
| ISFSI Storage Capacity | 140 casks (138 required + 2 spare locations) | Diablo Canyon ISFSI SAR Section 3.1 |
| Number of Fuel Assemblies | 4,400 (approx.) | Diablo Canyon ISFSI SAR Section 3.1 |
| Nonfuel Hardware | Borosilicate absorber rods<br>Wet annular burnable absorber rods<br>Thimble plug devices<br>Rod cluster control assemblies | Diablo Canyon ISFSI SAR Section 3.1.1.3 and Table 3.1-1 and Table 10.2-10 |
| **SPENT FUEL SPECIFICATIONS** | | |
| Type of Fuel | Non-consolidated PWR - Westinghouse 17 x 17 LOPAR and VANTAGE 5 | Diablo Canyon ISFSI SAR Section 3.1.1, 10.2.1.1, and Tables 10.2-1 through 10.2-5 |
| Fuel Characteristics | See Diablo Canyon ISFSI SAR Tables 3.1-1 and 3.1-2 for physical, thermal, and radiological characteristics | See Diablo Canyon ISFSI SAR Section 3.1.1, 10.2.1.1 and Tables 10.2-1 through 10.2-5 |
| Fuel Classification | Intact, Damaged, Debris | Diablo Canyon ISFSI SAR Section 3.1.1, 10.2.1.1, Tables 10.2-1 through 10.2-10, and Diablo Canyon ISFSI TS |
| **STRUCTURAL DESIGN** | | |
| Design Codes | ASME III-95, with 1996 and 1997 Addenda, Subsection NB ASCE 7-88; ANSI N14.6 (93); ACI-318 (95); and ACI-349 (85) | Holtec FSAR, as amended by LAR 1014-1, Tables 2.2.6, 2.2.7, 2.2.14, and 2.2.15 |
| Environmental Conditions and Natural Phenomena | See Diablo Canyon ISFSI SAR Table 3.4-1 | Diablo Canyon ISFSI SAR Sections 3.2 & 3.3 |

TABLE 3.4-2 Sheet 2 of 4

| Design Criterion | Design Value | Reference Documents |
|---|---|---|
| **STRUCTURAL DESIGN (continued)** | | |
| Weights | Maximum loaded transfer cask handling weight = 250,000 lb<br><br>Maximum loaded overpack weight = 360,000 lb<br><br>Transporter weight = 170,000 lb | Reference 4 Section 9.1.4.2.1.3 (fuel handling building crane capacity); Holtec FSAR, Section 3.2, as amended by LAR 1014-1; Diablo Canyon ISFSI SAR Section 4.3.2.1.1. |
| MPC Internal Pressure | Normal/off-normal = 100 psig<br><br>Accident = 200 psig | Holtec FSAR, Table 2.0.1, as amended by LAR 1014-1 |
| Cask Loads and Load Combinations | See HI-STORM 100 System FSAR | Holtec FSAR, Sections 2.2.1 through 2.2.3 and Tables 2.2.13 and 2.2.14, as amended by LAR 1014-1 |
| **THERMAL DESIGN** | | |
| Maximum Cask Heat Duty | Varies by MPC model, fuel loading strategy (uniform loading vs. regionalized loading), fuel assembly burnup, and cooling time<br><br>Maximum PWR basket heat duty = 28.74 kW | Holtec FSAR, Section 4.4.2, as amended by LAR 1014-1, Section 4.4.2 and Table 4.4.28 |
| Peak Fuel Cladding Temperature Limits | Long term (normal) limits vary based on fuel cooling time<br><br>Short term (accident) = 1058°F | Holtec FSAR, Rev. 1, Tables 4.3.7 and 4.A.2 for normal conditions and HI-STORM FSAR Table 4.3.1 for short term conditions |
| Other SSC Temperature Limits | Varies by material | Holtec FSAR, Tables 2.0.1 through 2.0.3, as amended by Holtec LAR |
| MPC Backfill Gas | 99.995% pure helium | Holtec CoC, Appendix A, Table 3-1, as amended by Holtec LAR 1014-1 and Diablo Canyon ISFSI SAR Section 10.2.2.4 |
| Maximum Air Inlet to Outlet Temperature Rise | 126°F | Holtec CoC, Appendix A, LCO 3.1.2, as amended by Holtec LAR 1014-1 |
| **RADIATION PROTECTION AND SHIELDING DESIGN** | | |
| Storage Cask Dose Rate Objectives | 60 mrem/hr on the sides, top, and adjacent to air ducts | Holtec FSAR, Section 2.3 5.2, as amended by LAR 1014-1; and Diablo Canyon ISFSI SAR 3.3.1.5.2 |
| Occupational Exposure Dose Limits | 5 rem/yr or equivalent | 10 CFR 20.1201 |

TABLE 3.4-2



| Design Criterion | Design Value | Reference Documents |
|---|---|---|
| **RADIATION PROTECTION AND SHIELDING DESIGN (continued)** | | |
| Restricted Area Boundary Dose Rate Limit | 2 mrem/hr | 10 CFR 20.1301 |
| Normal Operation Dose Limits to Public | 25 mrem/yr whole body<br><br>75 mrem/yr thyroid<br><br>25 mrem/yr and other critical organ | 10 CFR 72.104 |
| Accident Dose Limits to Public | 5 rem TEDE<br><br>50 rem DDE plus CDE<br><br>15 rem lens dose equivalent<br><br>50 rem shallow dose equivalent to skin or extremity | 10 CFR 72.106 |
| Overpack Unreinforced Concrete | Various | Holtec FSAR, Appendix 1.D, as amended by LAR 1014-1 |
| **CRITICALITY DESIGN** | | |
| Maximum initial fuel enrichment | $\leq 5\%$ | Holtec CoC, Tables 2.1-1 and 2.1-2, as amended by LAR 1014-1; and Diablo Canyon ISFSI SAR Sections 3.3.1.4.1 and 3.1.1.1, Tables 10.2-1 through 10.2-5, and the Diablo Canyon ISFSI TS |
| Control Method (Design Features) | MPC-32 fuel storage cell pitch $\geq$ 9.158 In and B-10 loading 0.0372 g/cm$^2$<br><br>MPC 24: flux trap size $\geq$ 1.09 inch and B-10 loading $\geq$ 0.0267 g/cm$^2$<br><br>MPC-24E AND 24EF: flux trap size $\geq$ 0.776 inch for cells 3,6, 19 and 22; $\geq$ 1.076 inch for all other fuel cells; and B-10 loading $\geq$ 0.0372 g/cm$^2$ | Diablo Canyon ISFSI TS |

TABLE 3.4-2



| Design Criterion | Design Value | Reference Documents |
|---|---|---|
| **CRITICALITY DESIGN (continued)** | | |
| Control Method (Operational) | For all MPC with maximum initial enrichment of ≤ 4.1 wt % ≥ 2000 ppm soluble boron in the MPC water during loading and unloading<br>For MPC-24/24E/24EF with maximum initial enrichment of >4.1 and ≤ 5.0 wt% ≥ 2000 ppm soluble boron in the MPC water during loading and unloading<br>For MPC-32 with maximum initial enrichment of >4.1 and ≤ 5.0 wt% ≥ 2600 ppm soluble boron in the MPC water during loading and unloading | Diablo Canyon ISFSI TS |
| Maximum $k_{eff}$ | <0.95 | Holtec FSAR, Table 2 0.1, as amended by LAR 1014-1; and Diablo Canyon ISFSI SAR Section 3.3.1.4 |
| **CONFINEMENT DESIGN** | | |
| Confinement Method | MPC with redundant welds | Holtec FSAR, Section 2.3.2.1 and Chapter 7, as amended by LAR 1014-1 |
| Confinement Barrier Design | Multi-purpose canister: ASME III, NB | Holtec FSAR, Tables 2.2.6 and 2.2.15, as amended by LAR 1014-1 and Diablo Canyon ISFSI TS |
| Maximum Confinement Boundary Leak Rate | 5.0 x $10^{-6}$ atm-cm$^3$/sec | Diablo Canyon ISFSI SAR Section 10.2.2.5 |

TABLE 3.4-6



LIST OF ASME CODE ALTERNATIVES FOR HI-STORM 100 SYSTEM

| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| MPC<br><br>MPC Basket Assembly<br><br>HI-STORM Overpack (steel structure)<br><br>HI-TRAC Transfer Cask (steel structure) | Subsection NCA | Design Specification | Not required (see Note #1). |
| | | Design Report | Not required (see Note #1). |
| | | Overpressure Protection Report | Not required (see Note #1). |
| | | Data Report | Not required (see Note #3). |
| | | Certification | Not required (see Notes #1, #2 and #3). |
| | | Stamping | Not required (see Notes #2, #3 and #4). |
| | | Nameplates. | Not required (see Note #5).<br><br><u>Note #1</u><br>Because the MPC, MPC Basket Assembly, HI STORM Overpack, and HI TRAC Transfer Cask are not ASME Code "N" stamped items, the Design Specifications, Design Reports, Certificates of Authorization, and Over Pressure Protection Report are not required. The HI-STORM FSAR includes the design criteria, service conditions, and load combinations for the design and operation of the HI-STORM 100 System. In addition it includes the stress analyses results that demonstrates that applicable Code stress limits are met. |

TABLE 3.4-6



| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| | | | Note #2<br>Because the MPC, MPC Basket Assembly, HI-STORM Overpack, and HI-TRAC Transfer Cask are not certified to the ASME Code (Section III), the term "Certificate Holder" is not applicable. To eliminate ambiguity, the responsibilities assigned in ASME Section III to the Certificate Holder, shall be interpreted to apply to PG&E (and by extension, to Holtec and its fabricators) if the requirement must be fulfilled.<br><br>Note #3<br>The fabricator (including the entity responsible for the final MPC closure weld) is not required to have an ASME-accredited QA program. The Fabricator will apply an approved QA program that meets the applicable regulatory requirements to all important-to-safety items and activities. As such, ASME Certification and Stamping is not required. The QA documentation package for each item will be in accordance with the applicable QA program.<br><br>Note #4<br>The ASME Section III term "Inspector" is herein defined as the Quality Assurance personnel assigned by PG&E to perform oversight (e.g., audit, inspection) of the design and manufacturing processes.<br><br>Note #5<br>In lieu of the requirements for Nameplates, items will be marked in accordance with 10 CFR 71 and 10 CFR 72 and the Holtec QA Program. |

| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| MPC basket supports and lift lugs | NB-1130 | NB-1132.2(d) requires that the first connecting weld of a nonpressure-retaining structural attachment to a component shall be considered part of the component unless the weld is more than 2t from the pressure-retaining portion of the component, where t is the nominal thickness of the pressure-retaining material.<br><br>NB-1132.2(e) requires that the first connecting weld of a welded nonstructural attachment to a component shall conform to NB-4430 if the connecting weld is within 2t from the pressure-retaining portion of the component. | The MPC basket supports (nonpressure-retaining structural attachment) and lift lugs (nonstructural attachments used exclusively for lifting an empty MPC) are welded to the inside of the pressure-retaining MPC shell, but are not designed in accordance with Subsection NB. The basket supports and associated attachment welds are designed to satisfy the stress limits of Subsection NG and the lift lugs and associated attachment welds are designed to satisfy the stress limits of Subsection NF, as a minimum. These attachments and their welds are shown by analysis to meet the respective stress limits for their service conditions. Likewise, non-structural items, such as shield plugs, spacers, etc. if used, can be attached to pressure-retaining parts in the same manner. |
| MPC | NB-2000 | Requires materials to be supplied by an ASME Material Organization. | Materials will be procured in accordance with an approved quality assurance program. |
| MPC, MPC basket assembly, HI-STORM | NB-3100<br>NG-3100 | Provides requirements for determining design- | These requirements are not applicable. The HI-STORM FSAR, serving as the Design Specification, establishes the |

TABLE 3.4-6



| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| overpack, and HI-TRAC transfer cask | NF-3100 | loading conditions, such as pressure, temperature, and mechanical loads. | service conditions and load combinations for the storage system. |
| MPC | NB-3350 | NB-3352.3 requires, for Category C joints, that the minimum dimensions of the welds and throat thickness shall be as shown in Figure NB-4243-1. | The MPC shell-to-baseplate weld joint design (designated Category C) does not include a reinforcing fillet weld or a bevel in the MPC baseplate, which makes it different than any of the representative configurations depicted in Figure NB-4243-1. The transverse thickness of this weld is equal to the thickness of the adjoining shell (1/2 inch). The weld is designed as a full penetration weld that receives VT and RT or UT, as well as final surface PT examinations. Because the MPC shell design thickness is considerably larger than the minimum thickness required by the Code, a reinforcing fillet weld that would intrude into the MPC cavity space is not included. Not including this fillet weld provides for a higher quality radiographic examination of the full penetration weld.<br><br>From the standpoint of stress analysis, the fillet weld serves to reduce the local bending stress (secondary stress) produced by the gross structural discontinuity defined by the flat plate/shell junction. In the MPC design, the shell and baseplate thicknesses are well beyond that required to meet their respective membrane stress intensity limits. |
| MPC, HI-STORM overpack steel structure, HI-TRAC transfer cask steel structure | NB-4220<br>NF-4220 | Requires certain forming tolerances to be met for cylindrical, conical, or spherical shells of a vessel. | The cylindricity measurements on the rolled shells are not specifically recorded in the shop travelers, as would be the case for a Code-stamped pressure vessel. Rather, the requirements on inter-component clearances (such as the MPC-to-transfer cask) are guaranteed through fixture- |

| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| | | | controlled manufacturing. The fabrication specification and shop procedures ensure that all dimensional design objectives, including inter-component annular clearances are satisfied. The dimensions required to be met in fabrication are chosen to meet the functional requirements of the dry storage components. Thus, although the post-forming Code cylindricity requirements are not evaluated for compliance directly, they are indirectly satisfied (actually exceeded) in the final manufactured components. |
| MPC Lid and Closure Ring Welds | NB-4243 | Full penetration welds required for Category C Joints (flat head to main shell per NB-3352.3). | MPC lid and closure ring are not full penetration welds. They are welded independently to provide a redundant seal. Additionally, a weld efficiency factor of 0.45 has been applied to the analyses of these welds. |
| MPC Lid to Shell Weld | NB-5230 | Radiographic (RT) or ultrasonic (UT) examination required. | Only UT or multi-layer liquid penetrant (PT) examination is permitted. If PT alone is used, at a minimum, it will include the root and final weld layers and each approximately 3/8 inch of weld depth. |
| MPC Closure Ring, Vent and Drain Cover Plate Welds | NB-5230 | Radiographic (RT) or ultrasonic (UT) examination required. | Root (if more than one weld pass is required) and final liquid penetrant examination to be performed in accordance with NB-5245. The MPC vent and drain cover plate welds are leak tested. The closure ring provides independent redundant closure for vent and drain cover plates. |
| MPC Enclosure Vessel and Lid | NB-6111 | All completed pressure retaining systems shall be pressure tested. | The MPC enclosure vessel is seal welded in the field following fuel assembly loading. The MPC enclosure vessel shall then be hydrostatically tested as defined in HI-STORM FSAR Chapter 9. Accessibility for leakage inspections preclude a Code compliant hydrostatic test. All MPC |

TABLE 3.4-6



| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| | | | enclosure vessel welds (except closure ring and vent/drain cover plate) are inspected by volumetric examination, except the MPC lid-to-shell weld shall be verified by volumetric or multi-layer PT examination. If PT alone is used, at a minimum, it must include the root and final layers and each approximately 3/8 inch of weld depth. For either UT or PT, the maximum undetectable flaw size must be demonstrated to be less than the critical flaw size. The critical flaw size nust be determined in accordance with ASME Section XI methods. The critical flaw size shall not cause the primary stress limits of NB-3000 to be exceeded.<br><br>The inspection process, including findings (indications), shall be made a permanent part of the user's records by video, photographic, or other means which provide an equivalent retrievable record of weld integrity. The video or photographic records should be taken during the final interpretation period described in ASME Section V, Article 6, T-676. The vent/drain cover plate weld is confirmed by leakage testing and liquid penetrant examination and the closure ring weld is confirmed by liquid penetrant examination. The inspection of the weld must be performed by qualified personnel and shall meet the acceptance requirements of ASME Code Section III, NB-5350 for PT or NB-5332 for UT. |
| MPC Enclosure Vessel | NB-7000 | Vessels are required to have overpressure protection. | No overpressure protection is provided. The function of MPC enclosure vessel is to contain the radioactive contents under normal. off-normal. and accident conditions. The MPC vessel |

TABLE 3.4-6



| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| | | | is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures. |
| MPC Basket Assembly | NG-2000 | Requires materials to be supplied by an ASME Material Organization. | Materials will be procured in accordance with an approved quality assurance program. |
| MPC Basket Assembly | NG-4420 | NG-4427(a) requires a fillet weld in any single continuous weld may be less than the specified fillet weld dimension by not more than 1/16 inch, provided that the total undersize portion of the weld does not exceed 10 percent of the length of the weld. Individual undersize weld portions shall not exceed 2 inches in length. | Modify the Code requirement (intended for core support structures) with the following text prepared to accord with the geometry and stress analysis imperatives for the fuel basket: For the longitudinal MPC basket fillet welds, the following criteria apply: 1) The specified fillet weld throat dimension must be maintained over at least 92 percent of the total weld length. All regions of undersized weld must be less than 3 inches long and separated from each other by at least 9 inches. 2) Areas of undercuts and porosity beyond that allowed by the applicable ASME Code shall not exceed 1/2 inch in weld length. The total length of undercut and porosity over any 1-foot length shall not exceed 2 inches. 3) The total weld length in which items (1) and (2) apply shall not exceed a total of 10 percent of the overall weld length. The limited access of the MPC basket panel longitudinal fillet welds makes it difficult to perform effective repairs of these welds and creates the potential for causing additional damage to the basket assembly (e.g., to the neutron absorber and its sheathing) if repairs are attempted. The acceptance criteria provided in the foregoing have been established to comport with the objectives of the basket design and preserve the margins demonstrated in the supporting stress analysis. |

TABLE 3.4-6



| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| | | | From the structural standpoint, the weld acceptance criteria are established to ensure that any departure from the ideal, continuous fillet weld seam would not alter the primary bending stresses on which the design of the fuel baskets is predicated. Stated differently, the permitted weld discontinuities are limited in size to ensure that they remain classifiable as local stress elevators ("peak stress", F, in the ASME Code for which specific stress intensity limits do not apply). |
| Overpack Steel Structure | NF-2000 | Requires materials to be supplied by an ASME Material Organization. | Materials will be procured in accordance with an approved quality assurance program. |
| Transfer Cask Steel Structure | NF-2000 | Requires materials to be supplied by an ASME Material Organization. | Materials will be procured in accordance with an approved quality assurance program. |
| Overpack baseplate and lid top plate | NF-4441 | Requires special examinations or requirements for welds where a primary member of thickness 1 inch or greater is loaded to transmit loads in the through thickness direction. | The margins of safety in these welds under loads experienced during lifting operations or accident conditions are quite large. The overpack baseplate welds to the inner shell, pedestal shell, and radial plates are only loaded during lifting conditions and have large safety factors during lifting. |
| HI-STORM overpack steel structure and HI- | NF-3256<br>NF-3266 | Provides requirements for welded joints. | Welds for which no structural credit is taken are identified as "Non-NF" welds in the design drawings by an "*". These |

TABLE 3.4-6



| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| TRAC transfer cask steel structure | | | non-structural welds are specified in accordance with the pre-qualified welds of AWS D1.1. These welds shall be made by welders and weld procedures qualified in accordance with AWS D1.1 or ASME Section IX.<br><br>Welds for which structural credit is taken in the safety analyses shall meet the stress limits for NF-3256.2, but are not required to meet the joint configuration requirements specified in these Code articles. The geometry of the joint designs in the cask structures are based on the fabricability and accessibility of the joint, not generally contemplated by this Code section governing supports. |
| HI-STORM overpack and HI-TRAC transfer cask | NF-3320<br>NF-4720 | NF-3324.6 and NF-4720 provide requirements for bolting. | These Code requirements are applicable to linear structures wherein bolted joints carry axial, shear, as well as rotational (torsional) loads. The overpack and transfer cask lid bolted connections in the structural load path are qualified by design based on the design loadings defined in the HI-STORM 100 FSAR. Bolted joints in these components see no shear or torsional loads under normal storage conditions. Larger clearances between bolts and holes may be necessary to ensure shear interfaces located elsewhere in the structure engage prior to the bolts experiencing shear loadings (which occur only during side impact scenarios).<br><br>Bolted joints that are subject to shear loads in accident conditions are qualified by appropriate stress analysis. Larger bolt-to-hole clearances help ensure more efficient operations in making these bolted connections, thereby minimizing time |

TABLE 3.4-6



| Component | Reference ASME Code Section/Article | Code Requirement | Alternative, Justification & Compensatory Measures |
|---|---|---|---|
| | | | spent by operations personnel in a radiation area. Additionally, larger bolt-to-hole clearances allow interchangeability of the lids from one particular fabricated cask to another. |

Note: Alternatives to the above table may be used when specifically authorized by the Director of the Office of Nuclear Material Safety and Safeguards or designee in accordance with 10 CFR 72.2 and as controlled by the Diablo Canyon ISFSI Technical Specifications.

# CHAPTER 4

# ISFSI DESIGN

## CONTENTS

CHAPTER 4

# ISFSI DESIGN

CONTENTS (Continued)

# CHAPTER 4

# ISFSI DESIGN

## TABLES

CHAPTER 4

# ISFSI DESIGN

## FIGURES

CHAPTER 4

# ISFSI DESIGN

FIGURES (continued)

## 4.2 STORAGE SYSTEM

Final construction design and analysis of the Diablo Canyon ISFSI storage pad and the CTF will be completed during the detailed design phase of the project. No significant changes are anticipated from the information presented.

### 4.2.1 STRUCTURES

Major important-to-safety ISFSI structures and their site locations are described in the following sections:

- Section 4.2.1.1 Cask Storage Pads
- Section 4.2.1.2 CTF
- Section 4.2.2 Site Layout
- Section 4.2.3 Storage Casks

See Figure 2.1-2 for the location of the Diablo Canyon ISFSI site in relation to the power block. See Figure 4.1-1 for the Diablo Canyon ISFSI site layout and the immediate surroundings.

#### 4.2.1.1 Cask Storage Pads

The Diablo Canyon ISFSI storage site is designed to include seven cask storage pads in a row. Each pad will accommodate up to 20 HI-STORM 100SA storage casks. Figure 4.1-1 shows the layout of the pads with the surrounding security fence, restricted area fence, and approximate dimensions. Seven storage pads provide sufficient storage space for DCPP spent fuel through plant decommissioning. The seismic design criteria for the cask storage pads are described in Section 3.2.3 and 3.3.2. Pad embedment design criteria are integrated with the storage cask pad design criteria, which is the primary focus of discussion in Section 3.3.2. A further discussion of the design criteria, analyses, and resulting design of the cask storage pads is provided here.

##### 4.2.1.1.1 Function

The function of the cask storage pads is to provide a level, competent structural surface for placement of the loaded overpacks for all design-basis conditions of storage. The storage casks (overpacks) are to be anchored to the pad by 16, 2-inch diameter, SA 193 Gr. B7 studs.

#### 4.2.1.1.2 Design Specifications

The cask storage pad design is based on a maximum, loaded-overpack weight of 360,000 lb each. This maximum weight bounds the maximum loaded weight of the overpacks proposed for use at the Diablo Canyon ISFSI. Each HI-STORM 100SA overpack proposed for use at the Diablo Canyon ISFSI can contain one of the following pressurized water reactor (PWR) fuel canisters: MPC-24, MPC-24E, MPC-24EF, or MPC-32, with maximum weights given in Table 4.2-1 of this SAR and shown in Table 3.2-1 of the HI-STORM 100 System FSAR (Reference 1), as amended by Holtec LAR 1014-1 (Reference 2). See Section 3.3.2 for more details on the storage pad design criteria.

#### 4.2.1.1.3 Plans and Sections

The site plan, which shows the locations of the concrete storage pads in relation to the power plant facility, is shown in Figure 2.1-2. A cross section of a typical concrete storage pad plan is shown in schematic Figure 4.2-1.

#### 4.2.1.1.4 Components

- **Embedment Steel Assembly:** This assembly consists of structural steel plates and rods. The function of this assembly is to properly distribute the loads imposed on the surface (by the storage casks) to the entire structure (Figure 4.2-2).

- **Reinforced Concrete:** The steel-reinforced concrete is designed for a mix with a compressive strength of 5,000 psi at 90 days. The reinforcing steel bars will have minimum 60,000-psi yield strength.

#### 4.2.1.1.5 Design Bases and Safety Assurance

The cask storage pads are classified as important to safety in order to provide the appropriate level of quality assurance in the design and construction. This classification is consistent with the recommendation made in Section 2.0.4 of the HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1, for deployment of the anchored HI-STORM 100SA overpack at a high-seismic site. This ensures that the cask storage pads will perform their intended functions.

#### 4.2.1.1.6 Storage Pad Design

The cask storage pads (total of seven) are structural units constructed of steel-reinforced concrete. Each concrete pad is approximately 68 ft wide by 105 ft long and 7.5 ft thick with longitudinal and transverse horizontal reinforcing bars near the top and bottom of the pads. The concrete compressive strength will be 5,000 psi at 90 days. The reinforcement bars will have minimum yield strength of 60,000 psi. Each pad accommodates a center-to-center spacing of 17 ft for the overpacks. Each of the cask storage pads accommodates up to

20 loaded overpacks (4 rows of 5). The sides of each storage pad are designed with an additional apron to provide maneuvering room for the cask transporter before it is driven onto the pad. The pads are nearly flush with grade to allow direct access by the cask transporter. The casks will be installed on the pads in a prescribed loading sequence to assure pad stability for all design-basis accidents and to maintain design qualifications. The loading sequence will be proceduralized.

The cask storage pad is designed with an embedded steel structure having a steel plate ring (Figure 4.2-1) at the surface of the concrete that mates with the bottom of the cask. Each cask is compressed against the embedment plate using 16 studs. Each stud is preloaded to approximately 157,000 lbf. The preload is achieved by threading the SA193-B7 studs into a coupling steel block located on the underside of the embedment plate, buried in the concrete. The seismic tensile/bending loads imposed on the pad will then be resisted by the long A-36 steel rods connected to the bottom base plate (Figure 4.2-2). The base plates are designed to provide sufficient bearing area onto the concrete so as to be able to transfer loads by bearing. Shear loads from each cask will be carried through the embedment plate/coupling blocks into the concrete.

#### 4.2.1.1.7 Storage Pad and Anchorage Analysis

The pad structural seismic analysis is performed by developing a finite-element model, using the ANSYS FEA Program (Reference 3) of a representative pad, which includes the casks and the supporting rock, to determine the potential for pad uplift and to calculate the stress fields in the concrete. The results of this static analysis are used in the design of the reinforcements to ensure that the bending moments are adequately carried by the pad, and that the stress limits of ACI 349-97 are satisfied. The specific pullout provisions of Appendix B are not applicable to anchorage and base plates of the proposed size. The anchorage is designed to meet the ductile-anchorage provisions of the October 1, 2000, Proposed Draft Appendix B to ACI 349-97. The methodology used assumes this loading imposed on the pad embedment structures is similar to an inverted column. Specifically, the design-strength capacity of the embedded base plate, concrete bearing, and diagonal tension-shear capacity computed in accordance with the design provisions of ACI 349-97 all exceed the required ductile design strength of the embedded anchor stud. Furthermore, the ultimate tensile strength of the reduced section at the thread root of the anchor bar is approximately 125 percent of the yield strength of the unreduced gross section of the anchor bar. Anchor bars are made of A36 steel, which has a well-defined yield plateau. Thus, if any overload occurs, the anchor bars will yield before any less ductile failure could occur. Lastly, the yield strength of the embedded anchor studs is more than 250 percent of the computed demand load on these bars to provide substantial margin against yielding. Reference 15 contains design and analysis information pertaining to the embedment support structure.

The pad was evaluated for sliding. Section 8.2.1.2.3.2 describes the dynamic non-linear time history analysis that was performed to evaluate pad sliding. Overturning is not considered as a credible failure, considering the overall geometry of the structure.

#### 4.2.1.1.7.1 Pad Static Analysis

A solid finite element model of the pad was developed (using the ANSYS FEA Program) to statically analyze the pad for loads imposed by the casks, as well as the pad-inertia loads, due to ZPA excitation from postulated bounding ground motions (Section 8.2.1.2.3.2). The static loading cases were performed for a range of ground/rock moduli of elasticity to account for variations in the rock properties. The earthquake loadings bound the other accidental loading conditions (for example, explosion and tower collapse) and natural phenomena accident conditions (for example, tornado and wind).

#### 4.2.1.1.7.2 Cask Dynamic Analyses

The storage cask is analyzed by a nonlinear, time history analysis for bounding ground motions. The resulting anchorage loading at the concrete/embedment interface is used for the detailed analysis of the pad and the embedment steel (see Section 4.2.1.1.7.1 for a discussion of the pad static analysis). The cask dynamic analysis is explained further in Section 8.2.1.2.3.1.

#### 4.2.1.1.8 Storage Pad Settlement

No pad settlement is anticipated as a result of the facility placement on the rock site (See Section 2.6.4.4 for more discussion).

#### 4.2.1.1.9 Slope Stabilization Measures

The following sections discuss slope stabilization and rock fall mitigation measures being taken to ensure the storage casks are not adversely affected by debris flow and rock falls.

#### 4.2.1.1.9.1 Cut Slope, Stabilization Design

As discussed in Sections 2.6.5.2.1 and 2.6.5.2.2, rock blocks exposed after cut-slope excavation have the potential to fall into the excavation under both static and seismic loading conditions. After excavation, cut-slope faces will be protected from weathering and minor raveling by a wire-mesh-reinforced shotcrete facing to stabilize the cut slope and prevent or minimize potential failures from occurring. To stabilize larger rock blocks, potentially prone to failure during seismic loading, rock anchors will be installed in approximately 2- to 3-inch diameter holes on approximately 5-ft centers and drilled subhorizontally approximately 30 ft deep from the cut-slope faces (Figure 4.2-3). Square concrete pads with steel top plates will be formed and cast over the holes to distribute anchor loads to the rock surface. High-strength, corrosion-protected bar anchors will be inserted into the holes, grouted and stressed. Each bar will be installed and proof-tested as recommended by the Prestressed Tensioning Institute (PTI). Additional holes, one approximately every fifth anchor, will be drilled between anchor holes and lined with PVC drainpipe to ensure the slope remains free for draining. The actual pattern will be adjusted during construction, based on the conditions found.

#### 4.2.1.1.9.2 Mitigation of Potential Displacements along Clay Beds

As discussed in Section 2.6.5.1.3, potential rock mass displacements along clay beds due to seismic ground motions are calculated to range from 1 to 3 ft on the clay beds located on the natural slope above the ISFSI site, and 1 ft to 2 ft on the clay beds inferred to daylight in the cut slope or pass just below the ISFSI site. The effects of these potential displacements will be mitigated, as described below.

Rocks dislodged by displacements along any of the several clay beds on the natural slope above the ISFSI site will be prevented from reaching the ISFSI site by a rockfall barrier constructed at the top of the ISFSI cut slope. This barrier will be designed to absorb and dissipate the kinetic energy of the rockfall and will be constructed of articulated steel posts, bundled wire ring steel nets, friction brake elements, anchoring and retaining ropes, and rock anchors.

Rocks offset by displacements along clay beds daylighting in the cut slope will be prevented from dislodging from the cut slope face by the wire-mesh-reinforced shotcrete facing and rock anchor system described in Section 4.2.1.1.9. The orientation of clay beds in the region of the cut slope is approximately parallel to the preferred rock anchor orientation, thereby minimizing the potential for damage to the anchors as a result of displacements along the clay beds. In the unlikely event that rock blocks are completely dislodged from the cut-slope face during a seismic event, the midslope bench width and offset distance from the slope base to the ISFSI pads are sufficient to accommodate the largest rock blocks as defined in Section 2.6.5.2.2.

In the event displacements occur along clay beds inferred to pass beneath the site, it is expected that any displacements propagating upward will do so through the weaker rock surrounding the massive, heavily reinforced concrete pads, and not impose significant additional loads or displacements on the pads themselves.

#### 4.2.1.2 CTF Support Structure

The CTF concrete support structure is a cylindrical, steel-lined structure, embedded in the rock, underground; made-up of steel-reinforced slabs and walls (Figure 4.2-4). This concrete structure houses the CTF steel shell structure consisting of lift platform and associated mechanical equipment. The facility is designed with a sump for incidental water collection. An associated standpipe will accommodate a temporary, drop-in sump pump for water removal. When not in use, the facility will be enclosed with a cover for personnel safety and protection of the structure from the environment. The transporter tie down locations immediately adjacent to the CTF support structure is shown on Figure 4.2-4. The tie downs will be supported by rock anchor installations into the ground. Holtec Drawing 3770, showing the CTF shell structure, is provided in Figure 4.4-3.

#### 4.2.1.2.1 Function

The function of the CTF support structure is to provide a flat, concrete pad at the bottom of the facility to accommodate installation of the CTF steel shell and lift platform, and to provide a rigid, concrete pad on the surface for the cask transporter. The CTF lifting platform function is to raise and lower the overpack for MPC transfer operations.

#### 4.2.1.2.2 Design Specifications

The structure will have provisions for a sump and sump pump to allow for removal of incidental rainwater. The CTF and its supporting structure will be qualified to withstand the design earthquake (DE), double-design earthquake (DDE), Hosgri earthquake (HE), and LTSP earthquakes without an uncontrolled lowering of the lifted load (Section 3.3.4). The earthquake loading bounds the other accidental loading conditions (for example, tower collapse) and natural phenomena accident conditions (for example, tornado and wind). See Section 3.3.4 for a discussion of the CTF design criteria.

#### 4.2.1.2.3 Static Analysis

The reinforced concrete was designed and evaluated for a transporter on top of the facility and the overpack in the CTF during the MPC transfer operation. The structure is designed for appropriate vertical and lateral loads imposed during the DE, DDE, HE and LTSP earthquakes. The concrete and the reinforcing steel have been designed in accordance with the requirements set forth in ACI 349-97 (Reference 4). A static, seismic analysis was performed on the CTF shell and lifting platform (Section 8.2.1).

#### 4.2.1.2.4 CTF Structure Layout

The structure is located on the ISFSI site approximately 100 ft from the concrete storage pads (Figure 4.1-1).

### 4.2.2 SITE LAYOUT

A plan view of the ISFSI storage site layout is shown in Figure 4.1-1. This figure shows the functional features of the storage site, including the locations of the CTF, the security and restricted area fences, and the access road that leads up from the DCPP. A section view of the ISFSI storage site is shown in Figure 4.2-5. This figure provides separation distances from the pad to nearby features, including the cut-slope hillside to the south and east of the pad.

As shown in Figures 4.1-1 and 4.2-5, a removable fence is located between the security fence and the raw water reservoirs. This fence provides protection against false security alarms due to authorized personnel, who are working in the raw-water-reservoir area, inadvertently stepping into an alarmed zone. If work activities in the raw-water-reservoir area required the fence to be temporarily removed, it can be with the appropriate, accompanying security compensating measures.

### 4.2.3 STORAGE CASK DESCRIPTION

The HI-STORM 100 System is used to store spent fuel and associated nonfuel hardware in a dry configuration at the Diablo Canyon ISFSI storage site. At Diablo Canyon, a shortened and anchored version of the standard HI STORM 100 System overpack will be used. This system is referred to as the HI-STORM 100SA. The free-standing version of the HI-STORM 100 System has been certified by the NRC for general use at applicable onsite ISFSIs operated by a 10 CFR 50 license holder. An anchored version of the HI-STORM 100 System (HI-STORM 100A and SA) is proposed as part of Holtec LAR 1014-1. Holtec Drawing 3769, showing the HI-STORM 100SA overpack-to-ISFSI pad (anchor stud/sector lug) arrangement is provided in Figure 4.2-6.

#### 4.2.3.1 Function

As discussed in Section 3.2, the HI-STORM 100 System is designed to store spent nuclear fuel and associated nonfuel hardware from DCPP under Diablo Canyon ISFSI site-specific normal, off-normal, and accident conditions of service, including the most severe design-basis natural phenomena in accordance with 10 CFR 72 (Reference 5). The HI-STORM 100 System design is summarized in Chapter 1 of this SAR and described in more detail in Chapters 1 and 2 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1.

The HI-STORM 100 System is designed to permit testing, inspection, and maintenance of the systems. The acceptance test and maintenance programs of the HI-STORM 100 System are specified in Chapter 9 of the HI-STORM 100 System FSAR. Because of the passive nature of the HI-STORM 100 System, onsite inspection and maintenance requirements are minimal. Surveillance requirements associated with operational control and limits are described in Chapter 10. Inspection and testing of important-to-safety components are performed in accordance with the Holtec International or PG&E Quality Assurance Program, as applicable.

Each of the HI-STORM 100 System components is described in further detail in the following sections. Figures, or reference to figures, in the HI-STORM 100 System FSAR are provided to illustrate the components and their functions.

#### 4.2.3.2 Description

In its final storage configuration, the HI-STORM 100 System consists of the following major components considered important to safety:

- Holtec multi-purpose canister

- Holtec damaged fuel container (DFC)

- HI-STORM 100SA overpack

Figure 4.2-7 (exploded isometric view) shows the components of the HI-STORM 100 System in its storage configuration with the HI-STORM 100SA overpack. The following sections provide a summary of the HI-STORM 100 System MPC, DFC, and overpack design bases and design relative to the storage requirements of the Diablo Canyon ISFSI. The Diablo Canyon onsite transporter is described in Section 4.3. Detailed operating guidance for MPC loading, onsite transport, and transfer of the MPC from the transfer cask to the HI-STORM overpack is provided in Sections 5.1 and 10.2 of this SAR. Design drawings for generic HI-STORM 100 System components, except the DFC, are contained in Section 1.5 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1. A figure depicting the DFC is contained in Section 2.1 of the HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1.

The HI-TRAC 125 transfer cask is used to provide the necessary structural support, shielding, heat removal, and missile protection as well as the means to transfer the loaded MPC between the transfer cask and the HI-STORM 100SA overpack. The transfer cask is not used in the final storage configuration of the HI-STORM 100 System at the storage pads. Design drawings for a standard transfer cask are provided in Section 1.5 of the HI-STORM 100 System FSAR.

#### 4.2.3.2.1 MPC

The MPC provides for confinement of radioactive materials, criticality control, and the means to dissipate decay heat from the stored fuel. It has the structural capability to withstand the loads created by all design basis accidents and natural phenomena. The MPC is a totally welded structure of cylindrical profile with flat ends. It consists of a honeycomb fuel basket, baseplate, MPC shell, MPC lid, vent and drain port cover plates, and closure ring. The MPCs, with different internal arrangements, can accommodate intact spent fuel, damaged fuel, fuel debris, and nonfuel core components, as discussed in Sections 3.1.1 and 10.2. The MPC lid provides top shielding and provisions for lifting the loaded MPC during transfer operations between the transfer cask and the overpack. The MPC fuel-basket assembly provides support for the fuel assemblies as well as the geometry and fixed neutron absorbers for criticality control. The MPC is constructed entirely from stainless steel, except for the neutron absorber (Boral, an aluminum alloy and boron carbide composite), and an aluminum washer in the vent and drain ports. A summary of the nominal physical characteristics of the MPC is provided in Table 4.2-1.

#### 4.2.3.2.2 DFC

The DFC is used to contain fuel assemblies classified as damaged fuel or fuel debris in the as required by the Diablo Canyon ISFSI TS and SAR Section 10.2. Damaged fuel may be stored in both the MPC-24E and the MPC-24EF, however, storage of fuel debris is only allowed in the MPC-24EF. Storage of damaged fuel or fuel debris is not permitted in the MPC-24 or the MPC-32. The DFC is a long, square, stainless-steel container with screened openings at the top and bottom. Each DFC is inserted into a designated storage cell within the MPC. The function of each DFC is to retain the damaged fuel or fuel debris in its storage cell and provide the means for ready retrievability. The DFC permits gaseous and liquid media to escape into the interior of the MPC, but minimizes dispersal of gross particulates during all design basis conditions of storage, including accident conditions. The total quantity of fuel debris permitted in a single DFC is limited to the equivalent weight and special nuclear material quantity of one intact fuel assembly. Proposed HI-STORM 100 System FSAR Figure 2.1.2B in Holtec LAR 1014-1 shows the general arrangement of the MPC-24E/EF DFC.

The lifting device at the top of the DFC is designed to meet the requirements of ANSI N14.6 (Reference 6) in accordance with applicable guidelines of NUREG-0612 (Reference 7). As discussed in the Holtec LAR 1014-1, Appendix 3.AS, the DFC is designed to meet ASME Section III, Subsection NG (Reference 8) allowables for normal handling and ASME Section III, Appendix F allowables for loadings experienced during a postulated, cask-drop accident.

#### 4.2.3.2.3 HI-STORM 100SA Overpack

The HI-STORM overpack is a rugged, heavy-walled, cylindrical, steel and concrete structure. The structure is made of inner and outer concentric carbon-steel shells, a baseplate, and a bolted lid (comprised of steel top plates and a concrete shield). The spacing of the carbon-steel inner and outer shells provides approximately 30 inches of annular space that is filled with unreinforced concrete for radiation shielding. The overpack is designed to permit natural circulation of air around and up the exterior shell of the MPC, via the chimney effect, to provide for the passive cooling of the spent fuel contained in the MPC. The cask has 4 air inlet ducts located at 90-degree spacing in the base of the cask and 4 air outlet ducts located in the top lid of the overpack. The cooling air enters the inlet ducts, absorbs heat from the MPC surface, and flows upward in the annulus between the MPC and exits at the outlet ducts.

A summary of the nominal physical characteristics of the overpack is provided in Table 4.2-2.

#### 4.2.3.2.4 HI-TRAC 125 Transfer Cask

The transfer cask is used to facilitate transport of the loaded MPC from the FHB/AB to the CTF and transfer of the loaded MPC into the overpack for storage at the ISFSI storage pad. It provides the necessary structural, shielding, and heat removal design features to protect the spent fuel and personnel during fuel loading, MPC preparation, and MPC transfer operations. The transfer cask is a rugged, heavy-walled, cylindrical steel vessel comprised of inner and outer concentric shells, a bolted pool lid, a top lid, and an outer circumferential water jacket. The annulus between the inner and outer steel shells is filled with lead. As needed, the water jacket is filled with water for shielding after the loaded transfer cask is removed from the spent fuel pool (SFP) and placed in the cask washdown area, but before the MPC interior is drained of borated water. The lead and the water in the jacket provide gamma and neutron shielding for personnel working on or near the loaded MPC to ensure occupational exposures are as low as is reasonably achievable (ALARA) during operations. The transfer cask is designed for transient use, to contain the MPC, and to be submerged in the SFP to support fuel loading. It includes lifting trunnions to allow the loaded transfer cask and MPC to be placed into and removed from the SFP for decontamination and preparation of the MPC for storage. The maximum design weight of the transfer cask is 125 tons, including a fully loaded MPC-32 with water in the MPC cavity and no water in the water jacket. Additional physical characteristics of the transfer cask are provided in Table 4.2-3. Figure 4.2-8 (isometric view) shows the HI-TRAC transfer cask and Figure 4.2-7 shows an isometric view of the HI-STORM 100 SA System. A more detailed description, design drawings, and a summary of the design criteria for the transfer cask are provided in Sections 1.2.1.2.2, 1.5, and 2.0.3, respectively, of the HI-STORM 100 System FSAR.

An optional design of the HI TRAC 125 transfer cask is being used at the Diablo Canyon ISFSI. This optional design, known as the HI-TRAC 125D, was developed by Holtec International and will be implemented under the provision of 10 CFR 72.48 for generic use with the HI-STORM 100 System after Amendment 1 to the HI-STORM CoC is approved. Holtec proprietary Drawing 3438 (see Section 1.1) is being provided to the NRC under separate cover (see Reference 9). A non-proprietary drawing will be included in Revision 1 to the HI-STORM 100 System FSAR The key differences between the generic HI-TRAC 125D and the generic HI-TRAC 125 design described above are as follows:

(1) The lower pocket trunnions have been removed as they are not needed to accommodate the Diablo Canyon ISFSI lifting and handling operations.

(2) Four attachment points with appropriate reinforcing steel have been added to the top of the transfer cask shell to allow for the use of temporary bumpers described below.

    The generic HI-TRAC 125D design will be slightly modified for the site-specific use at the Diablo Canyon ISFSI. This modification adds attachment points at the top (Figure 4.2-9) and bottom (Figure 4.2-10) of the transfer cask for the attachment of temporary bumpers used while handling the transfer cask in the DCPP FHB/AB. These bumpers are not used outside the DCPP FHB/AB. See Chapter 5 for more detailed discussion of the bumpers and attachment points.

(3) The transfer lid has been replaced by a HI-STORM mating device (see Figure 4.2-11). This device eliminates replacing the pool lid with a transfer lid while in the FHB/AB, thus reducing personnel dose. This design allows for the removal of the pool lid to facilitate MPC transfer at the CTF. The shielding previously provided by the transfer lid when the transfer cask is in the horizontal orientation is provided by a removable bottom shield that is integral to the cask transport frame (see Figure 4.2-12).

(4) The bottom baseplate diameter has been increased and an additional bolt circle added with 16 holes to accommodate the HI-TRAC bottom shield, the HI-STORM mating device, and an optional impact limiter. Gussets have been added to the baseplate to provide additional strength.

(5) The water jacket design has been changed from channel-and-plate design to a rib-and-shell design to better facilitate fabrication and reduce the number of welded joints.

(6) The pool lid and drain line have been slightly modified to improve the quality of the bolted joint and improve the operability of the drain.

### 4.2.3.3 Design Bases and Safety Assurance

The governing codes used for the design and construction of the HI-STORM 100 System steel components are listed in HI-STORM 100 System FSAR, Table 2.2.6, and are summarized below. Clarifications on the applicability of ACI 349-85 (Reference 10) to the unreinforced concrete used in the HI-STORM 100 overpack are provided in Appendix 1.D to the HI-STORM 100 System FSAR, as amended by LAR 1014-1. Table 3.4-6 provides a list of ASME Code alternatives for the HI-STORM System.

- MPC

| | |
|---|---|
| Pressure boundary | ASME Code Section III, Subsection NB |
| Fuel Basket | ASME Code Section III, Subsection NG |

- DFC

| | |
|---|---|
| Lifting Bolts | ANSI N14.6 per applicable guidelines of NUREG-0612, Section 5.1.6 |
| Steel Structure | ASME Code Section III, Subsection NG |

- Overpack

| | |
|---|---|
| Steel | ASME Code Section III, Subsection NF |
| Unreinforced Concrete | ACI-349-85 |

- Transfer Cask

| | |
|---|---|
| Steel Structure | ASME Code Section III, Subsection NF |
| Lifting Trunnion Blocks | ASME Code Section III, Subsection NF and ANSI N14.6 per applicable guidelines of NUREG-0612, Section 5.1.6 |
| Lifting Trunnions | ANSI N14.6 per applicable guidelines of NUREG-0612, Section 5.1.6 |

The safety classification of the components comprising the HI-STORM 100 System were determined using NUREG/CR-6407 (Reference 11) as a guide. Section 4.5 provides the safety classification of the HI-STORM 100 System components and additional detail on safety classification of components used at the Diablo Canyon ISFSI.

#### 4.2.3.3.1 System Layout

In its storage configuration, the HI-STORM 100 System consists of a fully-welded MPC placed inside of a vertical concrete overpack. Each MPC holds either 24 or 32 PWR spent fuel assemblies in an internal basket, depending on the particular MPC model. The specifics of the material approved for storage in the HI-STORM 100 System at the Diablo Canyon ISFSI storage site are discussed in Sections 3.1.1 and 10.2 and the Diablo Canyon ISFSI TS.

The HI-STORM 100 System is illustrated in Figure 4.2-7. Cross-sections of the PWR MPC baskets and an outline of the DFC are shown in the figures contained in Sections 1.2 and 2.1, respectively, of the HI-STORM 100 System FSAR, as amended by LAR 1014-1.

The transfer cask is designed for repetitive, transient use to contain one MPC during fuel loading, MPC preparation for storage, and transfer of the sealed MPC to the CTF. The transfer cask provides necessary shielding, heat removal, and structural integrity during the short time it contains the loaded MPC. The transfer cask is shown in Figure 4.2-8.

#### 4.2.3.3.2 Structural Design

The structural evaluation for the HI-STORM 100 System is contained in HI-STORM 100 System FSAR Chapter 3, as amended by LAR 1014-1, and in the accident analyses in Chapter 8 of this SAR. Structural evaluations and analyses of the HI-STORM 100 System components have been performed for all design basis normal, off-normal, and accident conditions and for design basis natural phenomena conditions in accordance with 10 CFR 72, Subpart L. The structural evaluations confirm that the structural integrity of the HI-STORM 100 System is maintained under all design-basis loads with a high level of assurance to support the conclusion that the confinement, criticality control, radiation shielding, and retrievability criteria are met.

The following discussion verifies that the Diablo Canyon ISFSI site-specific criteria are enveloped by the HI-STORM 100 System design.

##### 4.2.3.3.2.1 Dead and Live Loads

Dead loads are addressed in the HI-STORM 100 System FSAR, Section 2.2.1.1. The dead load of the overpack includes the weight of the concrete and steel cask and the MPC loaded with spent fuel. As identified in HI-STORM 100 System FSAR Table 2.1.6, the dead load of the overpack with the loaded MPC is calculated assuming the heaviest PWR assembly (B&W 15-by-15 fuel assembly type, wt = 1,680 lb, including nonfuel hardware) that bounds the Diablo Canyon fuel dead load (1,621 lb). The stresses calculated for the dead loads of the MPC and the overpack are shown to be within applicable Code allowables and, therefore, meet the Diablo Canyon ISFSI design criteria in Section 3.2.5 for dead loads.

The overpack is designed for two live loads, both of which act on the top of the overpack: (a) snow loads, and (b) the mating-device and transfer cask weight (during transfer operations) containing a fully loaded MPC. The HI-STORM 100 System FSAR uses a conservative, worst-case ground snow load of 100 lb/ft$^2$ as shown in HI-STORM 100 System FSAR Table 2.2.8, which exceeds any anticipated Diablo Canyon ISFSI site snow load. The live load capacity of the overpack is shown in HI-STORM 100 System FSAR, Section 3.4.4.3.2.1, to exceed the live load imposed by the loaded transfer cask. Since the live loads used in the HI-STORM 100 System generic analysis meet or exceed those that would be expected at the Diablo Canyon ISFSI, the HI-STORM 100 System FSAR analysis bounds the Diablo Canyon ISFSI design criteria specified for live loads and dead loads in Section 3.2.

As described above, the transfer cask dead load includes the weight of the cask plus the heaviest loaded MPC. The stresses calculated for the dead loads of the MPC and the transfer cask are shown to be within applicable Code allowables and, therefore, meet the Diablo Canyon ISFSI design criteria in Section 3.2.5 for dead loads.

#### 4.2.3.3.2.2 Internal and External Pressure

Internal and external pressure loads are addressed in the HI-STORM 100 System FSAR, Sections 3.4.4.3.1.2 and 3.4.4.3.1.7, respectively. The normal and off-normal condition design pressures for the MPC are 100 psig for internal pressure and 0 psig (ambient) for external pressure as shown in Table 2.2.1 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1. For accident conditions, the design pressure for the MPC is 200 psig for internal pressure and 60 psig for external pressure. Table 4.2-4 provides the maximum calculated MPC pressures for two normal conditions; no fuel rods ruptured and 1 percent fuel rods ruptured. The resultant pressure for the 10 percent rods rupture off-normal condition is provided in Section 8.1.1 and is below the 100 psig design pressure. The calculations assumed design basis heat load and bounding maximum fuel rod off-gas and internal pressure for DCPP fuel, considering a site-specific bounding value for fuel rod internal pressure. The internal pressure calculations for the MPC-32 bound those for the MPC-24, MPC-24E, and MPC-24EF because there is less free volume and more fuel inside the MPC-32 cavity, which creates higher pressures for the scenarios analyzed.

The MPCs are backfilled with helium during fuel loading operations to a nominal pressure of 31.3 psig at a reference temperature of 70°F. The internal pressure rises in proportion to the rise in MPC cavity gas absolute temperature due to the decay heat emitted by the stored fuel and as temperatures equilibrate to those associated with the normal condition 80°F day/night annual average ambient temperatures evaluated in the thermal analysis. This normal condition ambient temperature is higher than, and is therefore bounding for, the average day/night ambient temperature at the Diablo Canyon ISFSI site (Reference 12, Section 1.2.1.3).

MPC internal pressures were also evaluated for postulated accident conditions, including 100 percent fuel rod cladding rupture, assuming all rod fill gas and a conservative fraction of fission product gases, are released from the failed rods into the MPC. The resultant pressure from the 100 percent fuel rod rupture is provided in Section 8.2.14 and is below the MPC accident design pressure of 200 psig.

The stresses resulting from the internal and external pressure loads were shown to be within Code allowables. The Diablo Canyon ISFSI TS and SAR Section 10.2 ensure that the characteristics of the DCPP fuel to be loaded in a HI-STORM 100 System are consistent with the bounding fuel limits for array/class 17x17A and 17x17B fuel assemblies in Appendix B to the HI-STORM 100 System CoC (Reference 13). The pressure evaluations have appropriately accounted for the gas volume produced by burnable poison rod assemblies and integral fuel burnable absorber (IFBA) rods.

#### 4.2.3.3.2.3 Thermal Expansion

Thermal expansion-induced mechanical stresses due to nonuniform temperature distribution are identified in Section 3.4.4.2 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1. There is adequate space (gap) between the MPC basket and shell, and between the MPC shell and overpack or transfer cask, to ensure there will be no interference during conditions of thermally induced expansion or contraction. Table 4.4.15 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, provides a summary of HI-STORM 100 System component temperature inputs for the structural evaluation, consisting of temperature differences in the basket periphery and MPC shell between the top and bottom portions of the HI-STORM PWR MPC (MPC-24, MPC-24E, MPC-24EF, and MPC-32). The temperature gradients were used to calculate resultant thermal stresses in the MPC that were included in the load combination analysis. The stresses resulting from the temperature gradients were shown to be within Code allowables. Section 3.4.4.2 of the HI-STORM 100 System FSAR provides a discussion of the analysis and results of the differential thermal expansion evaluation. The Diablo Canyon ISFSI TS and SAR Section 10.2 ensure that the characteristics of the DCPP fuel to be loaded in a HI-STORM 100 System meet the limits delineated in Section 3.1.1. These limits are consistent with the bounding fuel limits for array/class 17-by-17A and 17-by-17B fuel assemblies in Appendix B to the HI-STORM 100 System CoC. Therefore, the thermal expansion evaluation, discussed above, in the HI-STORM 100 System FSAR, as amended by LAR 1014-1, will bound the conditions at the Diablo Canyon ISFSI.

#### 4.2.3.3.2.4 Handling Loads

Handling loads for normal and off-normal conditions are addressed in the HI-STORM 100 System FSAR, Sections 2.2.1.2, 2.2.3.1, and 3.1.2.1.1.2. The normal handling loads that were applied included vertical lifting and transfer of the overpack with a loaded MPC through all movements. The MPC and overpack were designed to withstand loads resulting from off-normal handling assumed to be the result of a vertical drop. In the case of Diablo Canyon, however, the vertical drop during onsite transport, outside the FHB/AB, is precluded with the use of a cask transporter that is designed, fabricated, inspected, maintained, and tested in accordance with NUREG-0612. Likewise, drops are precluded while the cask is lifted at the CTF since the CTF is designed, fabricated, inspected, operated, maintained, and tested in accordance with NUREG-0612. This approach is consistent with the provisions in the HI-STORM 100 System CoC described in Section 4.2.3.3.2.5 below. The preclusion of drop events was chosen as a design strategy to accommodate the anchored HI-STORM 100SA overpack, which requires a robust pad to ensure that the anchor studs and embedment structure remain fixed during postulated earthquake and tornado events.

The transfer cask is designed to withstand the loads experienced during routine handling, including lifting, upending, downending, and transfer to the CTF with a loaded MPC. Loads were increased by 15 percent in the analyses to account for dynamic effects from lifting operations (hoist load factor). The lifting trunnions, trunnion blocks, and load-bearing connection points (that is, pool lid bolted connections) were analyzed for normal handling loads, as described in Section 3.4.3.7 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1.

#### 4.2.3.3.2.5 Overpack/Transfer Cask Tipover and Drop

Outside the FHB/AB, tipover of a loaded overpack is a noncredible accident since the HI-STORM 100SA used at the Diablo Canyon ISFSI storage site is anchored to the ISFSI pad. When not on the ISFSI pad, the overpack will be either in the CTF or attached to the cask transporter (as described in Chapter 5). Both the CTF and the cask transporter are designed to preclude cask drops. The anchored HI-STORM 100SA overpack has been designed to withstand the worst-case, design-basis, seismic ground motion without failure of the anchor studs or the embedment. In addition, the anchored overpack has been analyzed for site-specific: (a) explosions, and (b) tornado wind concurrent with the impulse force of a large, design-basis, tornado-borne missile to verify that the anchorage design can resist the resultant overturning moment. The design criteria for the concrete storage pad and cask anchors are described in Section 3.3.2. The design and analysis of the concrete storage pad and anchorage embedment are discussed in Section 4.2.1.1.7. The analysis of the cask/pad interface under seismic loadings is described in Section 8.2.1.

The CTF and cask transporter are designed, fabricated, inspected, operated, maintained, and tested in accordance with NUREG-0612. Thus, there is no need to establish lift height limits or to postulate cask-drop events during transport to the pad, including activities at the CTF.

The cask lifting assembly on the transporter is a horizontal beam that is supported by towers at each end with hydraulic lifting towers. During movement of the transporter with the cask in a fixed elevation, a redundant load support system is used. This is further described in Section 4.3 and in Chapter 5.

#### 4.2.3.3.2.6 Tornado Winds and Missiles

Design criteria for tornado wind and missile impact are discussed in Section 3.2.1 of this SAR. The HI-STORM 100 System is designed to withstand pressures, wind loads, and missiles generated by a tornado, as described in Section 2.2.3.5 of the HI-STORM 100 System FSAR. In Section 8.2.2, the analysis of the Diablo Canyon ISFSI site design-basis tornado, including pressures, wind loads, and missiles is discussed. The MPC confinement boundary remains intact under all design-basis, tornado-wind, and missile-load combinations.

Tornado-wind and missile loads are evaluated for the overpack and the transfer cask. In the case of the transfer cask, the loaded transfer cask is always maintained in a restrained condition by the handling equipment while it is in a vertical position. Tipover or instability due to tornado-wind or missile impact is therefore a noncredible accident for the transfer cask (HI-STORM 100 System FSAR, Sections 2.2.3.1 and 3.4.8). However, missile penetration effects on the transfer cask and overpack have been evaluated.

#### 4.2.3.3.2.7 Flood

Flooding is addressed in Sections 3.2.2 and 8.2.3 of this SAR and in Sections 3.1.2.1.1.3 and 3.4.6 of the HI-STORM 100 System FSAR. The MPC is designed to withstand hydrostatic pressure (full submergence) up to a depth of 125 ft and horizontal loads due to water velocity up to 15 fps without tipping or sliding. The Diablo Canyon ISFSI and CTF are above probable maximum flood conditions; therefore, the HI-STORM 100 System FSAR evaluation bounds conditions at the Diablo Canyon ISFSI storage and CTF sites. Thus, the requirements of 10 CFR 72.122(b) are met with regard to floods.

#### 4.2.3.3.2.8 Earthquake

Design criteria for earthquake loads at the Diablo Canyon ISFSI are discussed in Section 3.2.3. The results of the seismic analyses are discussed in Section 8.2.1. Analyses were performed using the DE, DDE, HE, and LTSP ground motions to verify that the Diablo Canyon ISFSI SSCs (including components of the HI-STORM 100 system) meet their design requirements of 10 CFR 72.122(b) with regard to earthquakes. Although not considered a licensing basis, PG&E has evaluated the effects of these recent data (ILP ground motions, Section 2.6.2.4.2) to ensure appropriate design margins are maintained.

#### 4.2.3.3.2.9 Explosion Overpressure

Explosion overpressure loads are addressed in Sections 3.3.1.6 and 8.2.6.2.1 of this SAR and in Sections 3.4.7.2 and 11.2.11 of the HI-STORM 100 System FSAR. The HI-STORM 100 System MPC is analyzed and designed for accident external pressures up to 60 psig. The transfer cask overpressure design limit is 384 psig. The overpack is designed for steady-state and transient external pressures of 5 psig and 10 psig, respectively. As shown in Section 8.2.6, the Diablo Canyon ISFSI is not subject to credible explosions (that is, transient external pressures) that are in excess of 10 psig. Since the Diablo Canyon ISFSI will not experience explosion pressures that exceed 10 psig, the HI-STORM 100 System bounds the expected overpressure due to explosions at the Diablo Canyon ISFSI, as required per 10 CFR 72.122(c).

**4.2.3.3.2.10 Fire**

Design criteria for fire loads are addressed in Section 3.3.1.6 and in the HI-STORM 100 System FSAR, Section 11.2.4. The HI-STORM 100 System was analyzed for a fire of 50 gallons of combustible fuel from the cask transporter encircling the cask, resulting in temperatures up to 1,475°F and lasting for a period of 3.6 minutes. The analysis also evaluated the post-fire temperatures of the system for the duration of 10 hours. The evaluation of this fire and its effect on both the loaded overpack and the loaded transfer cask is discussed in Section 11.2.4 of the HI-STORM 100 System FSAR. The results of the analysis show that the intense heat from the fire only partially penetrated the concrete-cask wall. This fire would cause less than 1 inch of concrete to exceed temperature limits, and would have a negligible effect on shielding or MPC and fuel temperatures.

For the Diablo Canyon ISFSI, the threat of fire was evaluated for a variety of potential sources in addition to the transporter fire, including a vehicle fuel tank, other local fuel tanks, other combustible materials, and a vegetation fire. The results of this evaluation are discussed in Section 8.2.5.

The HI-STORM 100 System design meets the Diablo Canyon ISFSI design criteria for accident-level thermal loads as required per 10 CFR 72.122(c).

**4.2.3.3.2.11 Lightning**

A lightning strike of the HI-STORM 100 System at the Diablo Canyon ISFSI is addressed in Sections 3.2.6 and 8.2.8. The lightning strike accident is also discussed in the HI-STORM 100 System FSAR, Sections 2.2.3.11 and 11.2.12. The analysis shows that the lightning will discharge through the steel shell of the overpack or the transfer cask to ground through a ground connector. The lightning current will discharge through the affected steel structure and will not affect the MPC, which provides the confinement boundary for the spent fuel.

Therefore, the HI-STORM 100 System design meets the Diablo Canyon ISFSI design criteria in Section 3.2.6 for lightning protection, as required in 10 CFR 72.122(b).

**4.2.3.3.2.12 500-kV Line Drop**

The Diablo Canyon ISFSI storage site is located underneath and adjacent to 500-kV transmission lines. The HI-STORM 100 System design criteria for a 500-kV transmission line dropping and striking the HI-STORM 100 overpack or transfer cask is similar to the lightning strike. Section 8.2.8 of this SAR discusses the analysis of this accident and demonstrates that the MPC remains protected. The HI-STORM 100 System, therefore, meets the requirements of 10 CFR 72.122(b) for the 500-kV line break.

#### 4.2.3.3.3 Thermal Design

The environmental thermal design criteria for the Diablo Canyon ISFSI are discussed in Chapter 3.2.7. Thermal performance for the HI-STORM 100 System is addressed in Chapter 4 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1. The HI-STORM 100 System is designed for long-term storage of spent fuel and safe thermal performance during onsite loading, unloading, and transfer operations. The HI-STORM 100 System is also designed to minimize internal stresses from thermal expansion caused by axial and radial temperature gradients.

The HI-STORM 100 System is designed to transfer decay heat from the spent fuel assemblies to the environment. The MPC design, which includes the all-welded honeycomb basket structure, provides for heat transfer by conduction, convection, and radiation away from the fuel assemblies, through the MPC basket structure and internal region, to the MPC shell. The internal MPC design incorporates top and bottom plenums, with interconnected downcomer paths, to accomplish convective heat transfer via the thermosiphon effect. The MPC is pressurized with helium, which assists in transferring heat from the fuel rods to the MPC shell by conduction and convection. Gaps exist between the basket and the MPC shell to permit unrestrained axial and radial thermal expansion of the basket without contacting the shell, thus minimizing internal stresses. The stainless steel basket conducts heat from the individual spaces for storing fuel assemblies out to the MPC shell.

The HI-STORM 100SA overpack design provides an annular space between the MPC shell and the inner steel liner of the overpack for airflow up the annulus. Relatively cool air enters the four inlet ducts at the bottom of the overpack, flows upward through the annulus removing heat from the MPC shell by convection, and exits the four outlet ducts at the top of the cask.

The thermal analysis, discussed in Chapter 4 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, was performed using the ANSYS and FLUENT (Reference 14) computer codes. The HI-STORM PWR MPCs (MPC-24, MPC-24E, MPC-24EF, and MPC-32) were evaluated to determine the temperature distribution under long-term, normal storage conditions, assuming the MPCs are loaded with design basis PWR fuel assemblies. Maximum-assembly, decay-heat-generation rates for fuel to be loaded into these two MPC models are specified in SAR Section 10.2. The decay-heat-generation limits vary by cooling time.

The thermal analysis assumed that the HI-STORM overpacks are in an array, subjected to an 80°F-annual-average ambient temperature, with full insolation. The annual-average temperature takes into account day-and-night and summer-and-winter temperatures throughout the year. The annual-average temperature is the principal design parameter in the HI-STORM 100 System design analysis, because it establishes the basis for demonstration of long-term spent nuclear fuel integrity. The long-term integrity of the spent fuel cladding is a function of the average-ambient temperature over the entire storage period, which is assumed to be at the maximum annual-average temperature in every year of storage for conservatism. The results of this analysis are presented in Tables 4.4.9, 4.4.26 and 4.4.27 of the HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1, for MPC-24, MPC-24E, MPC-24EF, and MPC-32, respectively. The results, summarized in HI-STORM 100 System FSAR Table 4.2-3, indicate that temperatures of all components are within normal condition temperature limits. These results bound the Diablo Canyon ISFSI site since the average-annual temperature at the site is only 55°F (Section 2.3.2).

Section 11.1.2 of the HI-STORM 100 System FSAR discusses the temperatures of the HI-STORM 100 System for a maximum off-normal, daily-average ambient temperature of 100°F, which is an increase of 20°F from the normal conditions of storage discussed above. The maximum off-normal temperatures were calculated by adding 20°F to the maximum normal temperatures from the highest component temperature for the MPC-24, MPC-24E, MPC-24EF, and MPC-32. All of the maximum off-normal temperatures are below the short-term peak fuel cladding temperature limits (HI-STORM 100 System FSAR Table 2.2.3). Therefore, all components are within allowable temperatures for the 100°F-ambient-temperature condition. Since the highest hourly temperature recorded at the Diablo Canyon Site is 97°F (Section 2.3.2), the HI-STORM 100 System FSAR evaluation bounds the Diablo Canyon ISFSI site.

The thermal analysis in the HI-STORM 100 System FSAR discussed above includes the following global assumptions: (a) the concrete pad is assumed to be an insulated surface (that is, no heat transfer to or from the pad is assumed to occur), (b) adjacent casks are assumed to be sufficiently separated from each other (that is, cask pitch is sufficiently large) so that their ventilation actions are autonomous, and (c) the cask is assumed to be subject to full solar insolation on its top surface as well as view-factor-adjusted solar insolation on its lateral surface, based on 12-hour insolation levels recommended in 10 CFR 71 (800g-cal/cm$^2$ averaged over a 24-hour period as allowed in NUREG-1567). The evaluation of insolation is further discussed in Section 4.4.1.1.8 of the HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1.

Ambient-temperature and incident solar radiation (insolation) values applicable to the ISFSI site are summarized in Section 2.3.2. The highest-recorded-hourly temperature at the Diablo Canyon site is 97°F and the lowest temperature was below freezing for a few hours. The annual-average temperature is approximately 55°F. The maximum insolation values for the ISFSI site are estimated to be 766 g-cal/cm$^2$ per day for a 24-hour period and 754 g-cal/cm$^2$ for a 12-hour period.

Second-order effects such as insolation heating of the concrete pad, heating of feed air traveling downward between casks and entering the inlet ducts of the reference cask, and radiative heat transfer from adjacent spent fuel casks were not explicitly modeled in the HI-STORM 100 System FSAR analysis.

Within a loaded transfer cask, heat generated in the MPC is transported from the contained fuel assemblies to the MPC shell. A small, diametrical air gap exists between the outer surface of the MPC and the inner surface of the transfer cask. Heat is transported across this gap by the parallel mechanisms of conduction, natural convection, and thermal radiation. Assuming that the MPC is centered and does not contact the transfer cask walls conservatively minimizes heat transport across this gap. Additionally, thermal expansion that would minimize the gap is conservatively neglected.

Heat is transported through the cylindrical wall of the transfer cask by conduction through successive layers of steel, lead, and steel. A water jacket, which provides neutron shielding for the transfer cask, surrounds the cylindrical steel wall. The water jacket is composed of a carbon steel shell attached to the outer shell of the transfer cask by radial fins. Conduction heat transfer occurs through both the water cavities and the fins. While the water jacket openings are sufficiently large for natural convection loops to form, this mechanism is conservatively neglected. Heat is passively rejected to ambient from the outer surface of the transfer cask by natural convection and thermal radiation.

In the vertical position, the bottom face of the transfer cask is in contact with a supporting surface. This face is conservatively modeled as an insulated surface. Because the transfer cask is not used for long-term storage in an array, radiative heat blocking does not need to be considered. The transfer cask top lid is modeled as a surface with convection, radiative heat exchange with air, and a constant, maximum-incident solar heat flux load. Insolation on cylindrical surfaces is conservatively based on 12-hour levels prescribed in 10 CFR 71 and averaged on a 24-hour basis. Concise descriptions of these models are described in Section 4.5 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1.

The HI-STORM 100 System was analyzed for an extreme hot ambient temperature of 125°F averaged over a 72-hour time period. Section 8.2.10 of this SAR and Section 11.2.15 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, provide discussions of the analysis of this extreme temperature condition. The ambient temperature is applied coincident with full solar insolation. Resulting fuel cladding temperatures are well below their short-term temperature limit. The balance of the HI-STORM 100 System structure remains insignificantly affected. Since the extreme hot ambient temperature at the Diablo Canyon site is 104°F, the extreme hot ambient temperature evaluation in the HI-STORM 100 System FSAR bounds the conditions at Diablo Canyon.

The HI-STORM 100 System was also evaluated for a -40°F, extreme-low ambient temperature condition, as discussed in Section 4.4.3 of the HI-STORM 100 System FSAR. Zero decay heat generation from spent fuel, and no solar insolation were conservatively assumed. All materials of construction for the MPC and overpack will perform their design function under this extreme cold condition. Since the minimum temperature at the Diablo Canyon site is greater than 24°F (Table 3.4-1), the extreme low ambient temperature evaluation in the HI-STORM 100 System FSAR bounds the conditions at Diablo Canyon.

The thermal performance of the MPC to limit fuel cladding temperature inside the transfer cask during welding, draining, drying, and helium backfill operations, and during transportation of the loaded transfer cask to the CTF is bounded by the thermal evaluation performed with the MPC under a hypothetical, complete-vacuum condition. The vacuum condition is bounding for the other transient operational conditions mentioned above, because there is no fluid medium to transfer heat from the fuel to the MPC shell. In the other conditions, there is some amount of either helium or water in the MPC cavity to enhance heat transfer. All internal MPC heat transfer in the vacuum condition is through conduction and radiation.

Sections 4.5.1.1.4 and 4.5.2.2 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, discuss the thermal evaluation of the MPC under vacuum conditions and the resultant MPC and fuel cladding temperatures with design-basis heat load. Fuel cladding temperatures are shown in HI-STORM 100 System FSAR Table 4.5.9, and are all less than 1,000°F, which is less than the short-term temperature limit of 1,058°F. The design-basis heat load used for this evaluation bounds the heat load for all combinations of DCPP fuel to be loaded into the HI-STORM 100 System. The characteristics of the operations to be performed at Diablo Canyon are the same as those described in the HI-STORM 100 System FSAR. Therefore, the evaluations described in Section 4.5 of the HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1, bound operations at DCPP.

The above discussion demonstrates that the HI-STORM 100 System as deployed at the Diablo Canyon ISFSI meets the requirements of 10 CFR 72.122(h), 72.128(a)(4), and 72.236(f) and (g) for thermal design.

#### 4.2.3.3.3.1 HI-STORM Overpack at the CTF

The site-specific design of the Diablo Canyon CTF involves transferring a loaded MPC into the overpack with the overpack located below grade in a vault. The thermal implications of the difference between a loaded overpack located in a vault and one located at grade level have been evaluated.

Under normal conditions, the loaded overpack will remain in the vault only for the time it takes to remove the transfer cask from atop the overpack, retrieve and install the overpack lid, and raise the overpack out of the vault with the CTF lift system. This is expected to take less than 4 hours and has an insignificant effect on heat removal and fuel cladding temperatures.

Under off-normal conditions, such as a power failure affecting the CTF lift system, the condition could last several hours, depending upon the time it takes to complete corrective actions to restore power, or to provide an alternate power source. The effect of a loss of electrical power on the ability of the overpack to transfer the heat from the MPC to the environs is discussed in Section 8.1.6. The time frame computed before short-term peak fuel cladding temperature limits are reached is a sufficient amount of time to initiate corrective actions described in Section 8.1.6.

Accident conditions, such as a failure of one lift jack screw, may result in the loaded overpack being in the down position for an extended period of time, depending upon the severity of the failure. This accident and the corrective actions are discussed in more detail in Section 8.2.17 and the Diablo Canyon ISFSI TS.

#### 4.2.3.3.4 Shielding Design

Shielding design and performance for the HI-STORM 100 System is addressed in Section 3.3.1.5.2 and Chapter 7 of this SAR specifically for the Diablo Canyon ISFSI, and in Chapter 5 of HI-STORM 100 System FSAR for the HI-STORM 100 System generically. The HI-STORM 100 System is designed to maintain radiation exposure ALARA in accordance with 10 CFR 72.126(a). The concrete overpack is designed to limit the average external contact dose rates (gamma and neutron) to 60 mrem/hr on the sides, 60 mrem/hr on top, and 60 mrem/hr at the air inlets and outlets based on HI-STORM design basis fuel.

The overpack is a massive structure designed to provide gamma and neutron shielding of the spent fuel assemblies stored within the MPC. Most of the side shielding is provided by the overpack, although the MPC structure is credited in the shielding model. The overpack steel inner shell, the concrete-filled annulus, and the steel outer shell provide radiation shielding for the side of the overpack. The steel MPC lid and the overpack lid provide axial shielding at the top. The MPC lid is approximately 10 inches thick and is stainless steel. The overpack lid consists of a 4-inch thick steel top plate and steel-encased concrete. The lid shield configurations differ between the HI-STORM 100 and the HI-STORM 100S designs as shown on the respective drawings in Section 1.5 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1. In both designs, particular emphasis is placed on providing overpack lid shielding above the annulus between the MPC and the overpack inner shell, which is a streaming path.

The configuration of the inlet and outlet ducts in relation to the MPC prevents a direct radiation-streaming path from the MPC to outside the cask. The duct dose rates are further reduced by the installation of duct photon attenuators to minimize scatter (Figure 4.2-7). The HI-STORM 100 System design allows for necessary personnel access during inspection and maintenance operations, while keeping dose rates ALARA. The HI-STORM 100 System FSAR, Section 5.1.1, as amended by LAR 1014-1, provides generic calculated dose rates around the sides and top of the HI-STORM 100S overpack. Predicted Diablo Canyon ISFSI dose rates and site-specific dose evaluations are presented in Chapter 7 for the HI-STORM 100 System, and meet the requirements of 10 CFR 72.104 and 72.106.

The transfer cask provides shielding to maintain occupational exposures ALARA in accordance with 10 CFR 20, while also maintaining the maximum load on the FHB crane hook to 125 tons or less. The plant specific dose rates for a transfer cask loaded with design basis fuel are used to perform the occupational exposure estimate for MPC loading, closure, and transfer operations, as described in Chapter 7 of this SAR. The actual dose rates from a loaded transfer cask during operations in support of loading fuel for the Diablo Canyon ISFSI will be lower because the actual MPCs to be loaded will not contain design-basis fuel in every fuel storage location. Occupational exposures during transfer cask operations will be monitored and maintained ALARA in accordance with the DCPP radiation protection program and the requirements of 10 CFR 20.

The above discussion demonstrates that the HI-STORM 100 System as used at the Diablo Canyon ISFSI meets the requirements of 10 CFR 72.104, 72.106, 72.128(a)(2), and 72.236(d) for shielding design.

#### 4.2.3.3.5 Criticality Design

Criticality of the HI-STORM 100 System is addressed in Section 3.3.1.4 of this SAR and Chapter 6 of the HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1. The HI-STORM 100 System is designed to maintain the spent fuel subcritical in accordance with 10 CFR 72.124(a) and (b) with the MPC materials and geometry. The acceptance criterion for the prevention of criticality is that $k_{eff}$ remain below 0.95 for all normal, off-normal, and accident conditions.

Criticality safety of the HI-STORM 100 System depends upon the following four principal design parameters:

- Administrative limits on the maximum fuel assembly enrichment and physical properties acceptable for storage in the MPC

- The inherent geometry of the fuel basket designs within the MPC, including the flux-traps in the MPC-24, MPC-24E, and MPC-24EF (water gaps for loading fuel into submerged MPCs)

- The incorporation of permanent, fixed, neutron-absorbing panels (Boral) in the fuel basket structure to assist in control of reactivity

- Administrative controls requiring minimum concentrations of soluble boron in the MPC water during fuel loading and unloading, depending upon MPC model and fuel enrichment

The criticality analysis performed for the HI-STORM 100 System assumes only fresh fuel with no credit for burnup as a conservative bounding condition. In addition, no credit is taken for fuel-related burnable neutron absorbers, and it is assumed that the Boron-10 content in the Boral is only 75 percent of the manufacturer's minimum specified content. Other assumptions made to ensure the results of the analysis are conservative are identified in Section 6.1 of the HI-STORM 100 System FSAR. In its storage configuration, the HI-STORM 100 System is dry (no moderator), and the reactivity is very low ($k_{eff}$ less than 0.515). At the Diablo Canyon ISFSI, the fuel will always be in a dry, inert-gas environment. It is sealed within a welded MPC, and no credible accident will result in water entering the MPC.

The limiting reactivity condition occurs in the SFP during fuel loading, where assemblies are loaded into the MPC in close proximity to each other, with moderator between assemblies. All fuel loaded into the MPC-32, regardless of enrichment, requires a certain amount of soluble boron in the MPC during loading to preserve the assumptions of the criticality analyses. Higher enriched fuels loaded into the MPC-32, MPC-24, MPC-24E, or MPC-24EF also require soluble boron in the MPC during loading operations. The Diablo Canyon ISFSI TS ensure that soluble boron is appropriately maintained during fuel loading operations.

The results of the criticality analyses of different fuel types are shown in Chapter 6 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, for the MPC-24, MPC-24E, MPC-24EF, and MPC-32. The results confirm that the maximum reactivities of the MPCs are below the design criteria ($k_{eff}$ less than 0.95) for fuels with specified maximum allowable enrichments, considering calculational uncertainties. The PWR fuel types for which these analyses were performed are shown in Table 2.1.3 of the HI-STORM 100 System FSAR. With the exception of DCPP fuel assemblies with annular fuel pellets and Zirlo clad fuel with burnup > 45,000 MWD/MTU, all DCPP fuel is bounded by array/classes 17x17A and 17x17B. No credit is taken for neutron poison in the form of gadolinium in the fuel pellets or in the IFBA rods, therefore, fuel assemblies containing these poisons are acceptable for loading.

Accident conditions have also been considered, and no credible accidents have been identified that would result in exceeding the regulatory limit on reactivity. In Section 6.1 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, Holtec determined that the physical separation between overpacks due to the large diameter and cask pitch, and the concrete and steel radiation shields, are each adequate to preclude any significant neutronic coupling between HI-STORM 100 Systems.

Section 6.4.4 of the HI-STORM 100 System FSAR, as amended by Holtec LAR 1014-1, discusses the results of criticality analyses on MPCs storing damaged fuel in a Holtec damaged fuel container. Analyses were performed for three possible scenarios. The scenarios are:

- Lost or missing fuel rods, calculated for various numbers of missing rods in order to determine the maximum reactivity.
- Fuel assembly broken with the upper segments falling into the lower segment creating a close-packed array. For conservatism, the array was assumed to retain the same length as the original fuel assemblies.
- Fuel pellets lost from the assembly and forming powdered fuel dispersed through a volume equivalent to the height of the original fuel, with the flow channel and cladding material assumed to disappear.

Results of these analyses confirm that, in all cases, the maximum reactivity of the HI-STORM 100 System with design-basis failed fuel in the most adverse post-accident condition will remain well below the regulatory limit within the enrichment range analyzed.

The HI-STORM 100 System is designed such that the fixed neutron absorber (Boral) will remain effective for a storage period greater than 20 years, and there are no credible means to lose the Boral effectiveness. As discussed in Section 6.3.2 of the HI-STORM 100 System FSAR, the reduction in Boron-10 concentration due to neutron absorption from storage of design-basis fuel in a HI-STORM 100SA overpack over a 50-year period is expected to be negligible. Further, the analysis in Appendix 3.M.1 of the HI-STORM 100 System FSAR demonstrates that the sheathing, which affixes the Boral panel, remains in place during all credible accident conditions, and thus the Boral panel remains fixed for the life of the Diablo Canyon ISFSI. Therefore, verification of continued efficacy of the Boral neutron absorber is not required. This is consistent with the requirements of 10 CFR 72.124(b).

For MPCs filled with pure water, the reactivity of any PWR assembly with nonfuel hardware inserted into the guide tubes is bounded by (that is, lower than) the reactivity of the same assembly without the inserts. This is because the inserts reduce the amount of moderator, while the amount of fissile material remains unchanged. In the presence of soluble boron in the water, especially for higher-required soluble boron concentrations, it is possible that the nonfuel hardware in the PWR assembly results in an increase of reactivity. This is because the insert not only replaces water, but also replaces the neutron absorber in the water with a nonpoison material. To account for this effect, analyses with and without nonfuel hardware in the assemblies were performed for higher soluble boron concentrations in support of Holtec LAR 1014-1. The highest reactivities for either case are used as the basis of the criticality evaluation. Section 6.4.8 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1, provides additional discussion of the criticality effect of nonfuel hardware stored with PWR spent fuel assemblies.

During cask loading and unloading activities in the FHB/AB, criticality monitoring requirements of 10 CFR 72.124(c) will be met using a combination of installed and portable monitoring radiation monitoring instrumentation, in accordance with GDC-63 (to detect conditions that may result in excessive radiation levels and to initiate appropriate safety actions). As discussed in PG&E letter DCL-97-058, dated April 3, 1997, the radiation monitoring instrumentation generally conforms to the guidance of Regulatory Guide 8.12, "Criticality Accident Alarm Systems," and ANSI/ANS 8.3-1979, "Criticality Accident Alarm System." As discussed in DCPP FSAR Update Section 9.1.2.2, spent fuel pool radiation monitors RM-58 and RM-59 provide personnel protection and general surveillance of the spent fuel pool area. As discussed in DCL-97-058, portable radiation monitors will be placed in the cask washdown area to provide personnel protection and general surveillance of this area. On November 12, 1997, the NRC granted PG&E an exemption from the requirements of 10 CFR 70.24 concerning criticality monitors. In DCL-02-044 dated April 15, 2002, which submitted License Amendment Request 02-03, Spend Fuel Cask Handling, PG&E requested an exemption from the 10 CFR 72. 124(c) criticality monitoring requirement by requesting an extension of the NRC's November 12, 1997, exemption for the FHB/AB to envelop the activities associated with the Diablo Canyon ISFSI SAR.

In PG&E letter DCL-02-117, "Change in Licensing Basis Compliance from 10 CFR 70.24 to 10 CFR 50.68(b)," dated October 2, 2002, "PG&E informed the NRC that PG&E will revise the DCPP licensing basis to reflect compliance with 10 CFR 50.68(b) in lieu of 10 CFR 70.24 and that the exemption request in DCL-02-044 will be revised to request a similar exemption from 10 CFR 50.68(b) in lieu of 10 CFR 70.24.

The Holtec design, associated procedural controls, the proposed Diablo Canyon ISFSI Technical Specifications, and SAR Section 10.2 preclude accidental criticality when the spent fuel has been properly placed in the storage cask confinement system and the confinement system has been adequately drained, dried, inerted, and sealed.

The analysis of a fuel assembly drop onto the racks, and the drop of a fuel cask in the SFP, will show criticality is prevented and is also addressed in the 10 CFR 50 LAR in support of ISFSI licensing.

The above discussion demonstrates that the HI-STORM 100 System as deployed at the Diablo Canyon ISFSI meets the requirements of 10 CFR 72.124 and 72.236(c) for criticality design.

#### 4.2.3.3.6 Confinement Design

Confinement design for the HI-STORM 100 System is addressed in Chapter 7 of the HI-STORM 100 System FSAR, as amended by LAR 1014-1. The confinement vessel of the HI-STORM 100 System is the MPC, which provides confinement of all radionuclides under normal, off-normal, and accident conditions in accordance with 10 CFR 72.122(h). The MPC consists of the MPC shell, bottom base plate, MPC lid, vent and drain port cover plates, and the MPC closure ring, which form a totally welded vessel for the storage of spent fuel assemblies. The MPC requires no valves, gaskets, or mechanical seals for confinement. All components of the confinement system are classified as important to safety.

The MPC is a totally welded pressure vessel designed to meet the stress criteria of ASME Section III, Subsection NB. No bolts or fasteners are used for closure. All closure welds are examined using the liquid-penetrant method and helium leak tested to ensure their integrity. Two penetrations are provided in the MPC lid for draining, drying, and backfilling during loading operations. Following loading operations, vent and drain port cover plates are welded to the MPC lid. A closure ring, which covers the penetration cover plates and welds, is welded to the MPC lid to provide redundant closure of the MPC vessel. The loading and welding operations are performed inside the DCPP FHB/AB. There are no confinement boundary penetrations required for MPC monitoring or maintenance during storage.

The confinement features of the HI-STORM 100 System meet the requirements of 10 CFR 72.122(h).

### 4.2.4 INSTRUMENTATION SYSTEM DESCRIPTION

Monitoring of the loaded casks on the storage pad is necessary to ensure that the passive, air-cooled, convective heat transfer system for the MPC and overpack remains operable. Rather than install an active temperature monitoring system, PG&E has chosen to visually monitor overpack inlet and outlet air duct screens, as required by the Diablo Canyon ISFSI Technical Specifications, to verify the screens are free of blockage and intact.

### 4.2.5 COMPLIANCE WITH GENERAL DESIGN CRITERIA

Table 4.2-5 provides a tabular presentation of the locations in this SAR and/or the HI-STORM 100 System FSAR where compliance with the General Design Criteria of 10 CFR 72, Subpart F, is shown to be met.

### 4.2.6 REFERENCES

1. Final Safety Analysis Report for the HI-STORM 100 System, Holtec International Report No. HI-2002444, Revision 0, July 2000.

2. License Amendment Request 1014-1, Holtec International, Revision 2, July 2001 including Supplements 1 through 4 dated August 17, 2001; October 5, 2001; October 12, 2001; and October 19, 2001; respectively.

3. ANSYS Finite Element Modeling, ANSYS Inc., Southpointe 275 Technology Drive; Canonsburg, PA.

4. ACI-349-97, Code Requirements for Nuclear Safety Related Concrete Structures, American Concrete Institute (with 10/01/00 Draft Appendix B).

5. 10 CFR 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.

6. ANSI N14.6, Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More, American National Standards Institute, 1993 Edition.

7. Control of Heavy Loads at Nuclear Power Plants, USNRC, NUREG- 0612, July 1980.
8. Boiler and Pressure Vessel Code, Section III, Division I, American Society of Mechanical Engineers, 1995 Edition including 1996 and 1997 addenda.

9. Submittal of Holtec Proprietary and Non-Proprietary Drawing Packages, PG&E Letter to the NRC, DIL-01-008, dated December 21, 2001.

10. ACI 349-85, Code Requirements for Nuclear Safety Related Concrete Structures, American Concrete Institute.

11. Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety, USNRC, NUREG/CR-6407, February 1996.

12. Diablo Canyon Power Plant Units 1 & 2 Final Safety Analysis Report Update, Revision 14, November 2001.

13. 10 CFR 72 Certificate of Compliance No. 1014 for the HI-STORM 100 System, Holtec International, Revision 0, May 2000.

14. FLUENT Computational Fluid Dynamics Software, Fluent, Inc., Centerra Resource Park, 10 Cavendish Court, Lebanon, NH 03766.

15. PG&E Calculation No. 52.27.100.705 (PGE-009-CALC-001), "Embedment Support Structure."

## 4.3 TRANSPORT SYSTEM

The cask transporter is designed and used to safely lift, handle, and transport a HI-TRAC transfer cask or a HI-STORM 100SA overpack, loaded with spent fuel and associated nonfuel hardware, between the DCPP FHB/AB, the CTF, and the Diablo Canyon ISFSI storage pad site as described below. The movement is conducted exclusively on the DCPP site as shown in Figure 2.1-2. Due to its important-to-safety classification, the transporter is licensed under 10 CFR 72 (Reference 1). The cask transporter is designed to withstand all design-basis, natural-phenomena events while lifting, handling, and moving the loaded transfer cask or overpack without impairing its ability to safely hold the load.

### 4.3.1 FUNCTION

The functions of the cask transporter considered important to safety are:

- Transporting the loaded transfer cask, in the horizontal orientation, between the FHB/AB and the CTF.
- Upending and downending the loaded transfer cask between the horizontal and vertical orientations at the CTF.
- Lifting the loaded transfer cask and placing it atop the overpack at the CTF.
- Facilitating the transfer of the loaded MPC between the transfer cask and the overpack.
- Lifting the loaded overpack at the CTF.
- Transporting the loaded overpack between the CTF and its storage location on the Diablo Canyon ISFSI storage pad.

The cask transporter is capable of traveling over all of the road surfaces on the transport route. The road surfaces and underground facilities (see Section 4.3.3) will be evaluated to ensure the capability to support the weight of a cask transporter plus a loaded transfer cask or overpack.

### 4.3.2 COMPONENTS

This section describes the components used to lift, handle, and transport the loaded transfer cask and overpack to the CTF and Diablo Canyon ISFSI storage pad. Sections 3.3.3 and 3.4 provide discussion of the design criteria for the cask transportation system. Section 8.2.1 summarizes the results of the stress analyses under seismic loading, which bound the normal operation loads. Table 4.3-1 summarizes the functions of, and applicable design codes for, the transport system components that are considered important to safety and covered by an approved 10 CFR 72 quality assurance program.

#### 4.3.2.1 Cask Transporter

##### 4.3.2.1.1 Description

The cask transporter, shown in Figures 4.3-1 through 4.3-3, is a self-propelled, open-front, tracked vehicle used for handling and onsite transport of overpacks and the transfer cask with an MPC contained therein. It is nominally 25 ft long, 19 ft wide, and weighs approximately 85 tons, unloaded. It is designed with two steel tracks to spread out the load on the transport route surface as a distributed pressure load. These tracks provide the means to maneuver the cask transporter around the site. On top of the main structure is a lifting beam supported by two lifting towers that use hydraulic cylinders to provide the lifting force. The industrial-grade hydraulic cylinders are made of carbon steel to ensure high strength and ductility for all service conditions. The cask transporter is diesel-powered and is limited to a fuel volume of 50 gallons to comply with the Diablo Canyon ISFSI TS.

##### 4.3.2.1.2 Design

The cask transporter is custom-designed for conditions at the Diablo Canyon ISFSI site, including the transport route with its maximum grade of approximately 8.5 percent. It will remain stable and will not overturn, experience structural failure, or leave the transport route should a design-basis seismic event occur while the loaded transfer cask is being moved to the CTF; while transferring an MPC at the CTF; or while moving a loaded overpack from the CTF to the storage pad. In addition, the cask transporter is designed to withstand DCPP design-basis tornado winds and tornado-generated missiles without overturning, dropping the load, or leaving the transport route. Other natural phenomena, such as lightning strikes, floods and fires have been evaluated and accounted for in the cask transporter design. All design criteria for natural phenomena used to design the cask transporter are specific to the Diablo Canyon ISFSI site (see Sections 3.2 and 3.4 for detailed information).

A lightning strike on the cask transporter would not structurally affect the transporter's ability to hold the load. Due to the massive amount of steel in the structure, the current would be transmitted to the ground without significantly damaging the transporter. However, the driver may be affected by a lightning strike. Therefore, the transporter design includes fail-safe features to automatically shutdown the vehicle if the operator is injured or incapacitated for any reason.

Flooding is not a concern on the transport route for reasons discussed in Section 3.2.2. Sources of fires and explosions have been identified in Sections 2.2 and 3.3.1.6 and in Table 3.4-1, and have been evaluated with respect to cask integrity in Sections 8.2.5 and 8.2.6. Fixed sources of fire and explosion are sufficiently far from the transport route to be of no concern. Mobile sources of fire and explosion, such as fuel tanker trucks, will be kept at a safe distance away from the transporter during loaded cask movement through the use of administrative controls.

The cask transporter is capable of forward and reverse movement as well as turning and stopping. It includes an on-board engine that is capable of supplying enough power to perform its design functions. The cask transporter includes fail-safe service brakes (that is, setting brakes that automatically engage in any loss of power) and an independent parking brake. The brake system is capable of stopping and holding a fully loaded cask transporter on the maximum design grade. The cask transporter is also equipped with an automatic drive brake system that applies the brakes if there is a loss of hydraulic pressure or the drive controls are released. Additionally, the fully loaded cask transporter is not capable of coasting on a 10 percent downward grade with the brakes disengaged, due to the resistance in the drive system.

The cask transporter is equipped with a control panel that is suitably positioned on the transporter frame to allow the operator easy access to the controls located on the control panel and, at the same time, allow an unobstructed view of the cask handling operations. The control panel provides for all-weather operation or will be enclosed in the cab. The control panel includes controls for all cask transporter operations including speed control, steering, braking, load raising and lowering, cask restraining, engine control and "dead-man" and emergency stop switches. Additional emergency stop switches are located at ground level both in the front and rear of the transporter.

Figures 4.3-1 through 4.3-3 show the cask transporter (and associated components) performing its required functions. The cask transporter works with certain other ancillary components to facilitate the lifting and movement of the transfer cask and the overpack. Each ancillary component is described in Sections 4.3.2.2 through 4.3.2.8. Lifting of the loaded transfer cask and cask transport frame is accomplished using the transfer cask horizontal lift rig and the transfer cask lift slings. Transfer cask vertical handling, using the cask transporter, is performed using the transfer cask lift links. Likewise, overpack handling is performed only with the overpack in the vertical orientation using the HI-STORM lifting brackets.

The cask transporter and associated lifting components are classified important to safety, purchased commercial grade, and qualified for MPC and overpack transfer operations at the CTF by testing prior to service. These lifting components are defined as those components in the load path of the supported load. Special lifting devices, defined as any suspended load-bearing component below the integral load links, are designed in accordance with ANSI N14.6 (Reference 2) per the applicable guidance of NUREG-0612 (Reference 3). Table 4.3-1 provides a summary of the design code(s) applicable to each of the lifting and handling components.

On top of the main structure of the transporter is a lifting beam supported by two lifting towers that use hydraulic cylinders to provide the lifting force. Mechanical design features and administrative controls provide a defense-in-depth approach to preventing load drops during lifting and handling. The primary load-retaining devices of the cask transporter are the hydraulic cylinders. In combination, the hydraulic system is designed to carry twice the rated load, including a 15 percent hoist load factor, or 2.3 times the rated load (828,000 lb).

Once the cask is raised to its travel height by the cylinders, a redundant load support system is used. This may take the form of either locking pins and/or wedge brakes. Wedge brakes, by their shape, limit tower movement to the lift (up) direction only. Any failure of the lifting hydraulics will not result in an uncontrolled lowering of the load. Locking pins are inserted into each gantry leg to independently support the load when no vertical movement is needed. The wedge brakes are operable at all times when a load is being lifted or lowered. To remove the pins or wedge locks, the cylinder must first be extended slightly to take the load off the pin or wedge. The load may then be lowered using the lifting cylinders. Requiring the cylinders to take the load ensures that they are operational before lowering the load. Any failure of the hydraulic system at this time will be mitigated by the cylinder safety systems as described below.

The cask transporter hydraulic system wedge brake design prevents uncontrolled lowering of the load upon a loss of hydraulic fluid. A minimum amount of hydraulic fluid system pressure is required to disengage the wedge brakes to allow movement of the load. A loss of hydraulic fluid would drop the pressure in the system and engage the wedge brakes, preventing further movement of the load until corrective actions can be implemented.

The cask transporter is used to lift and place the loaded transfer cask atop the overpack for MPC transfer. During the MPC transfer process, the transfer cask trunnion connections to the cask transporter (that is, lift links) must be disconnected to provide access for the MPC downloader. Prior to disconnecting the lift links, the transporter is restrained. The restraint limits movement of the cask transporter during the time the cask transporter is disengaged from the transfer cask trunnions. Section 5.1 of this SAR provides additional detail on storage system operations.

The design of the cask transporter includes a lateral cask restraining system to secure the load during transport operations. The restraint system is designed to prevent lateral and transverse swinging of the load.

#### 4.3.2.1.3 Radiation Protection

The driver of the cask transporter is the only person in proximity to the transfer cask during onsite transfer operations who requires specific radiation protection consideration. Dose rate and accumulated dose estimates for the driver during cask transport operations are included in Section 7.4 using DCPP design-basis spent fuel source terms. All necessary radiation protection measures will be determined by DCPP radiation protection personnel at the time of fuel loading based on the actual dose rates in the immediate vicinity of the loaded transfer cask.

#### 4.3.2.1.4 Functional Testing and Inspection

As part of normal storage system operations, the cask transporter is inspected for operating conditions prior to each ISFSI loading campaign typically consisting of several casks. During the operational testing of this equipment, procedures are followed that will affirm the correct performance of the cask transporter features that provide for safe fuel-handling operations.

#### 4.3.2.2 Transfer Cask Horizontal Lift Rig

The transfer cask horizontal lift rig transmits the load of the lifted transfer cask from the transfer cask lift slings to the cask transporter lift points (Figure 4.3-1). The horizontal lift rig is a rectangular, structural-steel component that includes two attachment points at the top that connect to the cask transporter lift links and four attachment points at the bottom for the transfer cask lift slings. Because the transfer cask horizontal lift rig is designated as a special lifting device in the load path of the transfer cask during lifting and movement between the FHB/AB and the CTF, it is classified important to safety, and is designed in accordance with ANSI N14.6 per the guidance of NUREG-0612, Section 5.1.6.

#### 4.3.2.3 Transfer Cask Lift Slings

The transfer cask lift slings are used to support the weight of the loaded transfer cask and cask transport frame during horizontal lifting by the cask transporter (Figure 4.3-1). Two lift slings are used to support the transfer cask near the top and bottom of the cask. The two ends of each sling are attached to the transfer cask horizontal lift rig. The lifting slings are made from high-strength synthetic material suitable for the load and service conditions. The lifting slings are important to safety and are designed in accordance with ASME B30.9 (Reference 4) per the guidance of NUREG-0612, Section 5.1.6.

#### 4.3.2.4 Cask Transport Frame

The cask transport frame is an L-shaped steel cradle (Figure 4.2-12) used for rotating the transfer cask between the horizontal and vertical orientations (that is, upending and downending) in the receiving/shipping area of the FHB/AB and on the approach pad at the CTF (Figures 4.3-4 through 4.3-6). It is also attached to, but does not support, the transfer cask while the transfer cask is suspended from the transporter in the transfer cask horizontal lift rig during transport between the FHB/AB and the CTF (Figure 4.3-1). The use of the cask transport frame during cask transport operations is described in detail in Section 5.1.

Movement of the loaded transfer cask through the FHB/AB door is performed with the transfer cask and cask transport frame in the horizontal orientation using Hilman-type heavy-load rollers attached to the long side of the cask transport frame. The transfer cask and cask transport frame are rotated down directly onto a temporary length of track that runs from inside the FHB/AB to the access road located outside the FHB/AB roll-up door. The loaded cask transport frame exits the FHB/AB to the east and travels approximately 60 ft to the cask transporter. The route is level and straight. The roller device travels on a temporary rail system that distributes the load to selected areas of the roadway. The rollers are industrial-grade items that are designed appropriately to support the cask load. Because the cask transport frame is never in the load path for the lifted load, it is classified as not important to safety and is designed in accordance with the AISC Manual of Steel Construction (Reference 5).

### 4.3.2.5 HI-TRAC Lift Links

The HI-TRAC lift links are load-bearing, structural steel components used to connect the cask transporter lift points to the lifting trunnions on the transfer cask. The HI-TRAC lift links transfer the force of the loaded HI-TRAC transfer cask from the lifting trunnions to the cask transporter lifting points through connector pins. The lift links are important to safety, and are designed in accordance with ANSI N14.6 per the guidance of NUREG-0612, Section 5.1.6.

### 4.3.2.6 MPC Downloader Slings

The MPC downloader slings are used to lower (or raise) the loaded MPC during MPC transfer operations between the transfer cask and the overpack. The MPC downloader slings transmit the force of the loaded MPC from the MPC lift cleats to the MPC downloader. The MPC downloader slings are important to safety, and are designed in accordance with ASME B30.9 per the guidance of NUREG-0612, Section 5.1.6.

### 4.3.2.7 MPC Lift Cleats

The MPC lift cleats are ancillary devices temporarily attached to the MPC lid and used during transfer of the loaded MPC between the transfer cask and the overpack. The MPC lift cleats transmit the weight of the loaded MPC to the MPC downloader slings. The MPC lift cleats are classified as important to safety. The MPC lift cleats are special lifting devices that are designed in accordance with ANSI N14.6 per the guidance of NUREG-0612, Section 5.1.6.

### 4.3.2.8 HI-STORM Lifting Brackets

The HI-STORM lifting brackets (Figure 4.3-3) are load-bearing, structural steel components used to connect the cask transporter lifting points to the lid studs on the overpack. The HI-STORM lifting brackets transfer the weight of the loaded overpack from the lid studs to the cask transporter lift points through connector pins. The HI-STORM lifting brackets are special lifting devices that classified as important to safety, and are designed in accordance with ANSI N14.6 per the guidance of NUREG-0612, Section 5.1.6.

### 4.3.2.9 HI-STORM Lift Links

The HI-STORM lift links are load-bearing structural steel components used to connect the cask transporter lift points to the HI-STORM lifting brackets. The HI-STORM lift links are used to retrieve a loaded overpack from the CTF upon loss of the CTF lift system. The lift links are important to safety and are designed in accordance with ANSI N14.6 per the guidance of NUREG-0612, Section 5.1.6.

### 4.3.3 CASK TRANSPORT ROUTE

The cask transport route between the FHB/AB and the CTF and the Diablo Canyon ISFSI storage pads is shown in Figure 2.1-2. The route begins in the radiological control area (RCA) behind the FHB/AB, extends through the protected area past the Unit 2 cold machine shop (U2 CMS), along Plant View Road near Parking Lot 6, Shore Cliff Road (the main access road), and Patton Cove Bypass (Sections 2.6.1.2, 2.6.1.3.3, and 2.6.1.6.1) and then up along Reservoir Road. The route descends a maximum 8.5 percent grade (for approximately 200 ft) from the RCA to the U-2 CMS and then along Plant View Road, which is essentially flat. From the intersection of Plant View Road and Shore Cliff Road, there begins an approximate 6 percent uphill grade (for approximately 3,600 ft) that continues along Reservoir Road. The route ends with a right-hand turn to the CTF and ISFSI storage pad areas. This route consists of an asphalt roadway. The transport route has a 2 percent transverse slope into the hill from the southeast entry outside the plant protected area and south along Plant View Road up to where the road joins the main plant access road. The main plant road has a 2 percent crown for about 50 to 100 ft until the Patton Cove Bypass Road. The Patton Cove Bypass Road will have a 2 percent transverse slope towards its radius until it joins Reservoir Road at which the transverse slope is 2 percent into the uphill side of the road. The transport route is built to AASHTO H-20 and HS-20 pressure ratings, except for the turntables as discussed below. The roadway capacity to withstand the transporter weight has been verified. The underground utilities and structures will be evaluated and temporarily reinforced with steel plates, cribbing, and/or shoring as necessary to withstand the load from the loaded cask transporter. The transporter position on the road will be controlled to ensure an adequate standoff distance is maintained from potential hazards. The following is a discussion of underground utilities along the transport route.

Underground utilities and related valve boxes, pull boxes, catch basins, concrete pipeways, and the retaining wall east of the DCPP Unit 2 CMS are rated for H-20 traffic loads. Administrative controls will be established to preclude the transporter traversing the turntables that are located on the 115-ft Elevation. The turntables, used in the transfer of resin containers from the AB to the radwaste storage building, are only rated for 30 tons. Most pipes and conduits are buried 3 ft deep, except for utilities installed during the plant construction period and ground grid which are shallower, generally 1.5-ft deep. Pipes and conduits are generally nonmetallic, for example, asbestos-cement or polyvinyl chloride (PVC). Firewater line fittings are of ductile or cast iron. Valves are most commonly metallic.

None of the water lines or drains to be crossed are safety related for the 10 CFR 50 power plant. Firewater lines are 10 CFR 50 nonsafety-related, but they are subject to prescribed quality assurance requirements. Radwaste and makeup water lines in the RCA are encased in concrete. 10 CFR 50 safety-related, or nonsafety-related, circuitry passing beneath the route are contained in plastic conduits and are protected by a concrete cap or encasement.

Inside the RCA, the cask transporter will cross: makeup water; radwaste drainage; firewater; storm drains and pipeway drains; hydrogen and nitrogen gas lines in pipeways; electrical, lighting, and security system conduits and grounding; related concrete pipeways, valve boxes and pullboxes; and embedded rails.

From the Elevation 115-ft bench to the protected area (PA) gate near the Unit 2 CMS, utilities that cross the path include: 12-kV conduits near the road to the main warehouse; a drainage pipeway near the access road to the warehouse; domestic water and sanitary sewer lines near the CMS; and electrical and security conduits near the PA fence.

Along Plant View Road, from the PA to Area 10, and along Shore Cliff Road to Warehouse B, utilities include: PVC domestic water lines and asbestos cement pipe (ACP) raw water lines that run along the edge of the road; shallow steel water lines that cross the road near the south end of Building 201; electrical and telephone lines that run along the other lane; culverts; firewater lines, electrical and telecommunications conduits run from the Area 10 intersection near Warehouse B.

Utilities on Reservoir Road include: an ACP raw water pipeline, a fiberglass seawater reverse osmosis permeate pipeline with combination air valves, and electrical and telecommunications conduits. Abandoned sanitary sewer lines cross the road near the leach field. Culverts cross the road at various locations.

As the transporter ascends the hill along Reservoir Road, it passes beneath the Unit 2 500-kV transmission lines, which are approximately 55 ft above the road surface. To ensure there remains an electrically safe working distance between the transporter and the transmission lines, the maximum height of the lifting beam on the transporter will be administratively controlled in accordance with plant procedures.

### 4.3.4 DESIGN BASES AND SAFETY ASSURANCE

The design criteria and associated design bases for the transporter are presented in Section 3.3.3. The components of the transportation system in the direct load support path while the load is suspended (lifting points) are considered important to safety. The design and construction of important-to-safety items are conducted under an approved 10 CFR 72 quality assurance program. The design approach to classify certain load path members as important to safety with enhanced safety factors is taken to render all hypothetical transfer cask and overpack drop events outside the FHB/AB not credible. Section 8.2.4 describes this approach in more detail. As a defense-in-depth measure, however, the transportation system design and administrative controls are such that the transfer cask and overpack will be lifted only to those heights necessary for cask handling operations. These transporter design bases and administrative controls are in compliance with 10 CFR 72.128 (a) with regard to ensuring adequate safety under normal and accident conditions.

### 4.3.5 REFERENCES

1. 10 CFR 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.

2. ANSI N14.6, Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More, American National Standards Institute, 1993 Edition.

3. Control of Heavy Loads at Nuclear Power Plants, USNRC NUREG-0612, July 1980.

4. ASME B30.9-1996 through B30.9C-2000 Addenda, Slings, American Society of Mechanical Engineers.

5. Manual of Steel Construction, American Institute of Steel Construction, 9th Edition.

## 4.4 OPERATING SYSTEMS

### 4.4.1 LOADING AND UNLOADING SYSTEM

The dry storage cask handling systems are provided to lift, move, handle, and otherwise prepare an MPC loaded with DCPP spent fuel for storage at the Diablo Canyon ISFSI. Equipment is also available to unload an MPC in the unlikely event this becomes necessary. This section provides an overview of the functions and design of the equipment used to deploy the HI-STORM 100 System at the Diablo Canyon ISFSI for normal, off-normal, and accident conditions. Regulatory Guide 3.62 uses the term "emergency conditions." This SAR uses the term "accident conditions" for consistency with more recent regulatory guidance (that is, NUREG-1567). Movement of spent fuel assemblies between the spent fuel racks and the MPC is conducted in accordance with existing plant equipment and procedures, which will be modified, as necessary, to meet handling requirements and commitments as described in the DCPP 10 CFR 50 LAR, and is not specifically addressed here. Chapter 5 provides a detailed operating guidance regarding use of the structures, systems, and components to perform the various cask-handling activities.

Personnel radiation exposures occurring as a result of dry storage operations will be planned and monitored in accordance with the DCPP radiation protection program (Section 7.1).

#### 4.4.1.1 Function

The function of the loading system is to safely accomplish the following major objectives while maintaining occupational doses ALARA:

- Place the empty MPC and HI-TRAC transfer cask into the DCPP SFP using the FHB/AB crane.
- Load the MPC using 10 CFR 50 fuel handling equipment.
- After fuel loading, place the MPC lid and lid retention device on the MPC.
- Remove the loaded MPC and transfer cask from the SFP and place the assemblage down in the cask washdown area in the FHB/AB.
- Remove MPC lid retention device.
- Weld the MPC lid to the MPC shell.
- Helium leak test the MPC.
- Drain, dry, and backfill the MPC with helium.

- Weld the vent and drain port cover plates and closure ring to the MPC lid and shell.
- Install the transfer cask top lid.
- Lift and place the loaded transfer cask onto the cask transport frame.
- Downend the cask transport frame and loaded transfer cask from the vertical to the horizontal position.
- Move the loaded transfer cask out of the FHB/AB horizontally.
- Move the loaded transfer cask from just outside the FHB/AB to the CTF using the cask transporter.
- Pre-stage an empty HI-STORM 100SA overpack for MPC transfer at the CTF.
- Upend the loaded transfer cask to the vertical position and place it atop the empty overpack at the CTF using the cask transporter.
- Transfer the loaded MPC from the transfer cask to the overpack.
- Remove the empty transfer cask and place it in its designated storage area.
- Install the overpack lid.
- Move the loaded overpack to a storage pad using the cask transporter and place it in its designated position.

The same lifting and handling equipment is used in reverse order to return the loaded MPC to the cask washdown area in the FHB/AB in the unlikely event that an MPC needs to be unloaded. Loading and unloading operations are summarized below, including descriptions of the equipment used in performing these operations.

### 4.4.1.2 Major Components and Operating Characteristics

Detailed operational guidance is provided in Section 5.1. The following discussion provides an overview of the cask loading and unloading operations, including normal, off-normal, and accident conditions.

#### 4.4.1.2.1 Component Arrival and Movement to the Preparation Area

The MPC is a cylindrical, stainless steel pressure vessel containing an internal honeycomb fuel basket that is designed to house the spent fuel assemblies chosen for storage at the Diablo

Canyon ISFSI. The nominal thicknesses of the MPC shell, lid, and baseplate are 1/2 inch, 9-1/2 inches, and 2-1/2 inches, respectively. See Section 4.2.3.2.1 for detailed description of the MPC.

The MPC is shipped to the DCPP site with the fuel basket having been installed at the fabrication facility. Upon arrival at the site, the MPC is removed from the delivery vehicle, receipt inspected, and cleaned, as necessary, prior to being declared ready for installation into the transfer cask. The MPC is upended and removed from its transport frame.

The transfer cask is used to lift and move the MPC located inside it. It is used both before and after the MPC has been loaded with spent fuel assemblies. The transfer cask is designed to provide radiation shielding while maintaining the total weight of the loaded MPC and transfer cask within the load rating of the FHB crane (125 tons). The 125-ton transfer cask design includes a nominal 3/4-inch thick inner shell and a 1-inch thick outer shell; both made of carbon steel. The approximately 4-1/2 inch wide annulus between the inner and outer shells is filled with lead for gamma shielding. A water jacket attached to the outer shell provides a radial dimension of approximately 5.4 inches of water for neutron shielding. The top lid is composed of 2 carbon steel plates with a combined thickness of approximately 1-1/2 inches. Between the plates are 3-1/4 inches of Holtite neutron shielding material. The bottom lid is composed of two carbon steel plates with a combined thickness of approximately 3 inches. Between these plates are 2-1/2 inches of lead. The bottom lid also includes a drain to remove water during preparation activities. The top lid is bolted to allow reuse and has a nominal 27-inch diameter hole in the center. This hole and the bolted connection of the bottom lid allow raising and lowering of the loaded MPC during transfer operations between the overpack and the transfer cask, as described below. The transfer cask is designed for repetitive, transient use to facilitate the movement of the MPC between the overpack and the SFP. All surfaces exposed to the SFP water are coated with coatings compatible with the SFP water chemistry and any uncoated items are compatible with the SFP water chemistry. The Holtec proprietary drawings for the HI-TRAC 125D transfer cask design to be used at the Diablo Canyon ISFSI have been provided to the NRC (Reference 1) and non-proprietary drawings will be included in Section 1.5 of Revision 1 to the HI-STORM 100 System FSAR (Reference 2). Section 4.2.3.4 describes the modified version of the HI-TRAC 125 transfer cask to be used for Diablo Canyon ISFSI operations.

Like the MPC, upon arrival onsite, the transfer cask is removed from the delivery vehicle, inspected, cleaned as necessary, and upended to the vertical position with a lifting device such as a mobile crane. The pool lid is bolted to the bottom flange and the transfer cask is declared ready for use. The transfer cask lid is removed and the empty MPC is lifted and placed inside the transfer cask using the four lift lugs welded to the inside of the shell. The combined empty MPC and transfer cask assemblage is then attached to the cask transport frame, downended to the horizontal orientation and moved into the FHB/AB through the roll-up door on the east side of the building. All of the outdoor lifts of nonfuel bearing components are performed with suitably designed, commercial-grade lifting and rigging equipment or the transporter.

As discussed in the 10 CFR 50 LAR, an auxiliary lift component, custom designed for compatibility with both the DCPP FHB/AB cranes, provide an attachment point for one end of the redundant tension links used during horizontal load movements. A lift yoke, custom designed for compatibility with both the DCPP FHB/AB crane, the transfer-cask lifting trunnions, the redundant tensions links and SFP water chemistry, is used to upright the transfer cask and MPC while in the cask transport frame.

#### 4.4.1.2.2 Cask Preparation and Fuel Loading

Once in the FHB/AB, the transfer cask, with the empty MPC inside, is detached from the cask transport frame, and the transfer cask and MPC are moved to the cask washdown area. While in the FHB/AB, the transfer cask and cask transport frame are restrained to preclude an unanalyzed tip-over. While in the cask washdown area, an impact limiter is attached to the transfer cask using the bolt holes in the outermost bottom flange that were used to attach the bottom of the transfer cask to the cask transport frame (see Figure 4.4-1). The impact limiter is designed to limit cask deceleration to within the design-basis limit of 45 g under a postulated drop event. The cask is then placed on the floor, the lift yoke is disconnected, and the cask is prepared for movement to the SFP.

The annulus between the transfer cask and the MPC is filled with uncontaminated water (borated as necessary to match or exceed the MPC water concentration as described below) and an inflatable annulus seal is installed to prevent contamination of the outer MPC shell while it is submerged in the SFP. The MPC is then filled with water of the proper boron concentration, as required by the Diablo Canyon ISFSI TS. The lift yoke is reconnected and the transfer cask is lifted above the SFP wall, redundant tension links are installed between the crane auxiliary lift component and the yoke, and the lift component is raised slightly until the cask is suspended fully by the links. The cask is then traversed over the SFP wall into position over the cask recess area of the SFP and lowered using the lift component until the lower set of guides on the cask are engaged in corresponding guide channels of the permanent, in-pool, SFP frame structure. The SFP frame provides lateral support to the cask during its vertical load movement in the cask recess area of the spent fuel pool. The frame is a 10 CFR 50 structure described in the further detail in the DCPP 10 CFR 50 LAR supporting dry cask storage. The transfer cask water jacket remains empty to minimize the lifted weight of the cask.

The annulus overpressure system is attached; the cask is raised to remove the tension links and then lowered until resting on the bottom of the cask recess area of the SFP. The annulus overpressure system is a defense-in-depth measure to ensure that any breach of the annulus seal or bottom lid seal will force leakage of clean borated water into the SFP, and not contaminated SFP water into the annulus. The lift yoke is disconnected and the selected fuel assemblies are loaded into the MPC in accordance with plant procedures.

The drain line is attached to the MPC lid and, after fuel loading is complete, the MPC lid and lid restraint system are lowered into position on top of the MPC lift lugs. The lift yoke is attached to the transfer cask, the cask is lifted out of the SFP, and the annulus overpressure system is disconnected. Before moving laterally beyond the edge of the SFP wall, tension links are reinstalled on the FHB/AB crane from the auxiliary lift component to the yoke, which prevent downward vertical movement of the load. The tension links provide redundant drop protection during lateral crane movement, precluding the need to postulate a drop event between the SFP and the cask washdown area. After arriving above the cask washdown area, the tension links are removed to allow downward vertical load movement.

#### 4.4.1.2.3 MPC and HI-TRAC Preparation for Storage

The loaded transfer cask and MPC are lowered to the cask washdown area inside a seismic restraint structure and the cask is decontaminated. Water is added to the water jacket (this water may be unborated since it is contained within a separate pressure boundary and there is no potential for it to mix with the water in the MPC). The water jacket provides neutron shielding and replaces the shielding lost when the water in the MPC is drained.

The water level in the MPC is lowered slightly, and the MPC lid is welded to the MPC shell using the automated welding system (AWS) augmented by manual welding as necessary. Liquid penetrant (PT) examinations will be performed on the root and final weld layers, and each approximately 3/8-inch of weld depth. For the MPC-24, -24E, and –32, which have a 3/4-inch deep MPC lid-to-shell weld, this will require one or two intermediate PT examinations. For the MPC-24EF, which has a 1-1/4 inch deep lid-to-shell weld, four intermediate PTs will be required. The examinations are performed in accordance with the commitments in the HI-STORM 100 System FSAR.

After MPC-lid welding, the water in the MPC is raised again and a hydrostatic test is performed. Upon successful hydrostatic test completion, the MPC is drained of a small amount of water and a helium blanket is applied between the top of the water and the MPC lid. Helium leak testing is performed in accordance with ANSI N14.5-97 (Reference 3) to meet the acceptance criterion defined in SAR Section 10.2 and controlled in the Diablo Canyon ISFSI TS programs. Performance of the helium leak testing at this time allows detection of any leakage through the lid-to-shell weld before the MPC is drained of water. This sequence of activities allows the neutron shielding provided by the water in the MPC to be retained as long as possible in the loading process.

After successful helium leakage testing, the MPC is completely drained of water using the MPC blowdown system. The last of the water is removed via evaporation through the use of a vacuum drying system (as the pressure in the MPC is reduced, the saturation temperature for the water is reduced, causing evaporation of residual water) or through the use of a forced helium dehydration (FHD) system (required for high burnup fuel). The design criteria for the FHD system are provided in Section 10.2. The Diablo Canyon ISFSI TS program controls and SAR Section 10.2 specify the dryness acceptance criteria for both methods of drying. After meeting the drying acceptance criteria, the MPC is backfilled with 99.995 percent pure helium to within a pressure range defined by SAR Section 10.2.

When the MPC has been satisfactorily drained, dried, backfilled with helium, and the lid-to-shell weld has been leak tested, the MPC vent and drain port cover plates are welded on, inspected, and leak tested in accordance with the commitments in the HI-STORM 100 System FSAR, including ANSI N14.5-97. Then, the MPC closure ring is welded in place and inspected in accordance with the commitments in the HI-STORM 100 System FSAR. The inner diameter of the closure ring is welded to the MPC lid and the outer diameter is welded to the top of the MPC shell. The MPC-to-transfer cask annulus may be drained at any time after the MPC has been successfully backfilled with helium.

The MPC lift cleats are attached to the MPC lid, and the MPC is now ready for transfer to storage. The transfer cask top lid is installed. The impact limiter is unbolted from the bottom of the transfer cask and the lift yoke is re-engaged with the transfer-cask-lifting trunnions. The bolts attaching the impact limiter are removed. The FHB crane is used to lift the loaded transfer cask to a height sufficient to detach the impact limiter from the transfer cask, and the crane tension links are installed (the transfer cask remains directly above the impact limiter until the tension links are operable). The seismic restraint system in the cask washdown area is then opened. The height to which the transfer cask is lifted is carefully controlled to be equal to the thickness of the cask transport frame plus a minimal clearance needed to move the cask onto the cask transport frame.

The transfer cask is then moved laterally to the cask transport frame, staged nearby in the upright position. The transfer cask is attached to the cask transport frame and the cask transport frame stabilizer is removed. After the crane tension links are removed, an impact limiter is positioned to protect the loaded transfer cask, and to protect the FHB/AB in case of a crane load-handling equipment failure (see Figure 4.4-2). As the loaded transfer cask and cask transport frame are lowered to just above the impact limiter, the impact limiter is removed from the downending path to allow completion of the downending operation onto the rail dolly for movement outside the FHB/AB. The cask transport frame is moved out of the FHB/AB on rails to a position just outside the FHB/AB door.

#### 4.4.1.2.4 MPC Transfer and Overpack Storage at the ISFSI

Outside the FHB/AB, the loaded transfer cask and cask transport frame are rigged to the cask transporter and moved to the CTF in the horizontal position. These evolutions and the cask transport system design, including associated lifting components, are described in more detail in Sections 4.3 and 5.1. The design of the CTF is discussed in Section 4.4.5.

At the CTF, the empty overpack is prestaged in the subterranean vault with approximately the top 3 ft of the overpack extending above grade level. At this stage of the loading process, the platform is in its full-down position, supported by the CTF base pad supports and fitted with a cask-mating device. When the cask transporter arrives at the CTF, the loaded transfer cask and transport frame are placed on the ground horizontally. The horizontal lift rig is removed and the HI-TRAC lift links are installed on the transporter. The lift links are compatible with the HI-TRAC lifting trunnions and are used to upend the loaded transfer cask out of the transport frame to the vertical position. Once in the vertical position, the transfer cask is removed from the cask transport frame and the cask transporter moves the transfer cask over to the overpack and places it atop the cask mating device on the overpack.

After the transfer cask is placed atop the overpack; the MPC downloader and MPC lift slings are used to lift the MPC by the lift cleats just enough to take the weight of the MPC off the transfer cask bottom lid. The MPC downloader system is integral to the cask transporter and is located on the bottom flange of the horizontal lift beam of the cask transporter. Once the weight of the loaded MPC is taken off the bottom lid, the bottom lid is unbolted and the cask-mating device is used to remove the lid, creating a clear path between the transfer cask and the overpack. The MPC is then lowered into the overpack using the MPC downloader slings and the slings are lowered onto the top of the MPC. The transfer cask is removed from the top of the overpack and placed out of the way, allowing the downloader slings and MPC lift cleats to be removed. The overpack lid is installed and the overpack is transported to the storage pad using the cask transporter.

#### 4.4.1.2.5 Off-Normal and Accident Conditions

For off-normal and accident conditions, the necessary response is a function of the nature of the event. Chapter 8 of this SAR describes the off-normal and accident events for which the cask system is designed and provides suggested corrective actions. The HI-STORM 100 System is designed to maintain confinement integrity under all design-basis, off-normal, and accident conditions, including natural phenomena and drop events. For Diablo Canyon, the only credible drops are limited to the FHB/AB as described in Sections 4.4.1.3.1 and 4.4.1.3.2. Based on the circumstances of an actual event, plant personnel will take appropriate action ranging from inspections of the affected cask components to movement of the cask back into the SFP and unloading of the spent fuel assemblies.

#### 4.4.1.2.6 Unloading Operations

To unload a HI-STORM 100 System, the loading operations are essentially performed in reverse order, using the same lifting and handling equipment. Once the transfer cask is returned to the cask washdown area in the FHB/AB, the MPC closure ring and vent and drain port cover plates are removed by cutting their attachment welds. Fuel cooldown is performed, if necessary, using the vent and drain and the helium cooldown system until the helium temperature is reduced to the maximum temperature specified in SAR Section 10.2. Helium cooldown is required prior to reflooding the MPC with water (borated as necessary) to prevent flashing of the water and the associated pressure excursions. Once the fuel is sufficiently cool, the MPC is flooded with borated water and the lid weld is removed using the weld removal system. Then, the lid retention system is installed, and the transfer cask and MPC are lowered into the SFP using the lift yoke and FHB crane. Finally, the lid retention system and MPC lid are removed, and the fuel assemblies are transferred from the MPC to the spent fuel racks.

#### 4.4.1.3 Safety Considerations and Controls

The MPC shell is designed in accordance with ASME Section III (Reference 4), Subsection NB. The MPC fuel basket is designed in accordance with ASME Section III, Subsection NG. As discussed in Reference 4, the MPC is designed to retain its confinement boundary integrity under all normal, off-normal, and accident conditions. The MPC is a fully welded vessel that does not require the use of mechanical seals or leakage monitoring systems. The cask system is completely passive by design and does not require the operability of any supporting systems to safely store the spent nuclear fuel at the ISFSI storage pads. The design features that ensure safe handling of the fuel are described in Section 4.4.1.2 and the ISFSI operations are provided in Section 5.1.

The transfer cask and overpack steel structures are designed in accordance with ASME Section III, Subsection NF with some of the NRC-approved Code exceptions applicable to DCPP (Table 3.4-6). Both the transfer cask and the overpack are designed to withstand the design-basis normal, off-normal, and accident loadings (including natural phenomena) for the Diablo Canyon ISFSI site. The transfer cask design includes shielding design features that keep dose rates ALARA during fuel loading operation and transport of the loaded cask to the storage pads.

The transfer cask shielding is optimized to provide the maximum practicable protection from radiation while staying within the size and weight limits necessary for compatibility with the DCPP facility and the capacity of the FHB/AB crane. Additionally, the design of the transfer cask includes as few pockets and crevices as practicable in the design to minimize the amount of radioactive crud that could be retained in these areas. The paint on the transfer cask is suitable for ready decontamination and removal of loose particles through the use of a standard decontamination practices. The overpack provides the maximum shielding possible while keeping the cask at a reasonable size and weight, compatible with commercially available crawler vehicles. Details of the transfer cask and overpack shielding design features are provided in Chapter 5 of the HI-STORM 100 System FSAR and Section 7.3.1 of this SAR.

##### 4.4.1.3.1 Considerations Inside the 10 CFR 50 Facility

NUREG-0612 provides guidelines to licensees to ensure the safe handling of heavy loads. The guidelines define acceptable alternatives for heavy load movements, which include using a single failure proof handling system or analyzing the effects of a load drop.

Inside the FHB/AB, the cask and any ancillary components are lifted, handled, and moved in accordance with DCPP procedures and the DCPP Control of Heavy Loads Program for lifting heavy loads, as applicable. The FHB/AB crane hoist and auxiliary lift component, as applicable, will be used with a lift yoke to perform all lifts of the cask inside the FHB/AB. The transfer-cask-lifting trunnions and the lift yoke are designed, fabricated, inspected, maintained, and tested in accordance with NUREG-0612 to ensure that structural failures of these items are not credible. PG&E's Control of Heavy Loads Program controls the design of special lifting devices in accordance with ANSI N14.6 (Reference 5). This program is fully described in DCPP FSAR Update, Section 9.1.4.3.5. The existing FHB/AB crane was not designed and purchased as single-failure proof, as defined in NUREG-0612, Section 5.1.2 (Reference 6). The FHB/AB crane auxiliary lift component is a modification to the crane to provide a single failure proof lift capable of limited vertical travel to facilitate the transition of load support between the crane hoist and the auxiliary lift component. The FHB/AB crane auxiliary lift component is a 10 CFR 50 modification described in further detail in the DCPP 10 CFR 50 LAR to support dry cask storage.

Certain load drops during vertical crane movements have been postulated in the FHB/AB as required by NUREG-0612, Section 5.1.2. Two vertical drops have been analyzed to ensure the consequences of such drops are acceptable and do not cause forces on the cask in excess of its design basis of 45 g under 10 CFR 72. The generic design of the transfer cask has been modified to accommodate a removable (or temporary) impact limiter (see Figure 4.4-1) to meet this acceptance criterion. A temporary impact limiter (see Figure 4.4-2) is also used for the tipover event in the cask washdown area with the cask in the cask transport frame to ensure the consequences of the tipover are acceptable and do not cause deceleration values on the fuel in excess of its design-basis limit. These load drop and tipover analyses are summarized in the DCPP 10 CFR 50 LAR supporting the Diablo Canyon ISFSI project.

Loaded cask drops during the loading operation where only horizontal movement of the lifted load is required are precluded by the use of tension links on the FHB/AB crane auxiliary lift component. Tension links are required for certain horizontal movements to preclude any postulated drop that would cause deceleration forces on the loaded cask in excess of its design basis of 45 g under 10 CFR 72 or apply loads to the 10 CFR 50 structure in excess of their capacity. The tension links are engineered to provide redundant support for the case when large vertical movement of the load is not required. This redundancy provides the requisite temporary, single-failure proof protection during these operations.

#### 4.4.1.3.2 Considerations Outside the 10 CFR 50 Facility

Cask drop events are precluded during transport of the loaded cask from the FHB/AB to the CTF, and from the CTF to the storage pad, through the design of the cask transport system, including the cask transporter (Section 4.3). Drop events are precluded by lift devices designed, fabricated, operated, inspected, maintained, and tested in accordance with NUREG-0612. The cask transport system is designed in accordance with these requirements and appropriate design codes and standards to preclude drop events on the transport route. The cask transporter is also designed to withstand applicable, site-design-basis natural phenomena, such as seismic events and tornadoes, without dropping the load or leaving the transport route. The load-path parts of the cask transporter are designed as specified in Section 4.3.2.1. The cask transporter is procured commercial grade and is qualified by functional testing prior to service for MPC and overpack transfer operations at the CTF. Uncontrolled movement of the cask transporter is prevented by setting the brakes, an emergency stop switch, and a dead-man switch, as discussed in Section 4.3.2.1.2;

these components also are procured commercial grade and are qualified by functional testing prior to service.

Similarly, the CTF is designed, fabricated, inspected, maintained, and tested in accordance with NUREG-0612 to make drop events non-credible.

### 4.4.2 DECONTAMINATION SYSTEM

Standard decontamination methods will be used to remove surface contamination, to the extent practicable, from the transfer cask and accessible portions of the MPC (that is, the lid) resulting from their submersion in the SFP. The cask and MPC lid will be rinsed with clean borated water while over the SFP. Final decontamination of the transfer cask and MPC lid will be performed in the cask washdown area in the FHB/AB. Decontamination will typically be performed manually. While the entire MPC is submerged in the SFP during fuel loading, the annulus seal and annulus overpressure system prevent contaminated water from coming in contact with the sides of the MPC, leaving the MPC lid as the only exterior surface of the HI-STORM 100 System at the ISFSI storage pad that has been exposed to SFP water.

### 4.4.3 STORAGE CASK REPAIR AND MAINTENANCE

Chapter 9 of the HI-STORM 100 System FSAR describes the required maintenance for the storage cask system. The HI-STORM 100 System is totally passive by design. There are no active components or monitoring systems required to ensure the performance of its safety functions in the final storage configuration. As a result, only minimal maintenance is required over its lifetime, and this maintenance primarily results from cask handling and weathering effects in storage. Typical of such maintenance is the reapplication of corrosion inhibiting materials on accessible external surfaces. Visual inspection of the overpack inlet and outlet air duct screens is required by the Diablo Canyon ISFSI TS to ensure that they are free from obstruction, including clearing of debris, if necessary.

Repairs and maintenance will be performed by maintenance personnel either in-situ or in another appropriate location, based on the nature of the work to be performed. Radiation protection personnel will provide input to and monitor as necessary these maintenance work activities through the work control process.

#### 4.4.3.1 Structural and Pressure Parts

PG&E anticipates that it will use a cask loading campaign where multiple storage casks are loaded in an essentially continuous work effort. Prior to each transfer cask fuel loading, a visual examination is performed on the transfer-cask-lifting trunnions. The examination consists of inspections for indications of overstress such as cracking, deformation, or wear marks. Repair or replacement is required if unacceptable conditions are identified. The transfer-cask trunnions are maintained and inspected in accordance with ANSI 14.6.

As described in the HI-STORM 100 System FSAR, Chapters 7 and 11, there are no credible normal, off-normal, or accident events that can cause the structural failure of the MPC. Therefore, periodic structural or pressure tests on the MPCs, following the initial acceptance tests, are not required as part of the storage maintenance program.

#### 4.4.3.2 Leakage Tests

There are no seals or gaskets used on the fully welded MPC confinement system. Therefore, confinement boundary leakage testing is not required as part of the storage system maintenance program.

#### 4.4.3.3 Subsystem Maintenance

The HI-STORM 100 System does not include any subsystems that provide auxiliary cooling during loading operations or in its final storage configuration. Normal maintenance and calibration testing is required on the vacuum drying, helium backfill, recirculation and cooldown, and leakage testing systems. Rigging, remote welders, cranes, and lifting beams are inspected prior to each loading campaign to ensure this equipment is ready for service.

#### 4.4.3.4 Pressure Relief Valves

The pressure relief valves used on the water jacket for the transfer cask require calibration on an annual basis (or prior to the next transfer cask use if the period the transfer cask is out of use exceeds 1 year) to ensure the pressure relief setting is within tolerance as controlled by PG&E's DCPP Maintenance Program.

#### 4.4.3.5 Shielding

The gamma and neutron shielding materials in the overpack, transfer cask, and MPC degrade negligibly over time or as a result of usage. Radiation monitoring of the ISFSI provides ongoing evidence and confirmation of shielding integrity and performance. If the monitoring program indicates increased radiation doses, additional surveys of the overpacks will be performed to determine the cause of the increased dose rates.

The Boral panels installed in the MPC baskets are not expected to degrade. The use of Boral as the fixed neutron absorber is discussed in Section 4.2.3.3.5. Therefore, no periodic verification testing of neutron poison material is required on the HI-STORM 100 System.

#### 4.4.3.6 Thermal Performance

In order to ensure that the HI-STORM 100 System continues to provide effective thermal performance during storage operations, surveillance of the passive heat removal system is performed in accordance with the Diablo Canyon ISFSI TS. This involves a periodic inspection to verify that the air duct screens are not blocked.

### 4.4.4 UTILITY SUPPLIES AND SYSTEMS

Electric power is provided for the CTF lifting platform, CTF and storage-pad-area lighting, and the storage-pad-area security system. As the HI-STORM 100 System is a passive system, no other utilities are required for ISFSI operation.

#### 4.4.4.1 Electrical Systems

Electric power is not required to support functions of the Diablo Canyon ISFSI important-to-safety SSCs. Normal power is supplied from the nonsafety-related 12-kV distribution system for the CTF lifting platform, the CTF, and the storage-pad-area normal lighting. Power for the storage-pad-area security equipment is provided by the DCPP security power system. There are no motorized fans, dampers, louvers, valves, pumps, electronic monitoring systems, and no electrically operated cranes. In the event of a DCPP loss of offsite power, power will not be supplied to the ISFSI components, except for the security loads. A discussion of the normal and emergency power for security equipment is provided in the Physical Security Plan (Section 9.6). Section 8.1.6 describes recovery actions to mitigate this event.

##### 4.4.4.1.1 Normal Power Supplies

The existing DCPP 12-kV distribution system is connected to the DCPP power distribution system in the existing DCPP 12-kV startup buses. Either DCPP Unit 1 or Unit 2 can supply the 12-kV system. The 12-kV underground distribution system is connected to the 12-kV startup bus by existing 3-way switches. The existing 12-kV underground distribution system is routed throughout the DCPP site, including near the location of the CTF and ISFSI storage pad area. A combination of new and existing switches and 12-kV/480-V transformers are used to connect the CTF and ISFSI storage-pad-area loads.

##### 4.4.4.1.2 Grounding

The ISFSI storage pad area, perimeter fencing, lighting and poles, and security equipment will be located below the DCPP Unit 1 500-kV transmission lines. The existing DCPP station-to-switchyard ground grid below the ISFSI location will be maintained. The ISFSI area will be provided with a ground grid, and it will be connected to the station-to-switchyard ground grid. Each storage cask will be grounded to the ISFSI-area ground grid.

### 4.4.5 CASK TRANSFER FACILITY

The design criteria for the CTF is provided in Section 3.3.4. Holtec CTF drawing 3770 is provided in Figure 4.4-3. The site-specific structural details of the CTF design and analysis for the Diablo Canyon ISFSI are provided in Section 4.2.1.2. The mechanical design aspects are discussed below.

#### 4.4.5.1 CTF Function

The function of the CTF is to facilitate transfer of a loaded MPC between the transfer cask and the overpack. These operations are discussed in Sections 4.4.1.2.4 and 5.1.1.3.

#### 4.4.5.2 CTF Design

Design criteria for the CTF are provided in Section 3.3.4 of this SAR and Section 2.3.3.1 of the HI-STORM 100 System FSAR. The CTF is used in conjunction with the Diablo Canyon cask transporter to permit MPC transfers between the transfer cask and the overpack. The CTF is designed to position an overpack sufficiently below grade where the transfer cask can be mated to the overpack using a cask transporter and a suitably designed mating device. The CTF lifting platform acts as an elevator to raise and lower an overpack. In the full-up position, the overpack base is approximately 40 inches below grade. At the full-down position, the overpack top surface is approximately 30 inches above grade.

The main components of the CTF include the main shell, lifting jacks, drive and control system, and lift platform (Figure 4.4-3). A description of each of these components and the related design criteria are given in Section 3.3.4.

##### 4.4.5.2.1 Lifting Jacks

The jacks are designed to safely raise and lower a fully loaded overpack (180 tons). The load-bearing structural steel members are designed and fabricated in accordance with Reference 4.

##### 4.4.5.2.2 Mechanical Design Criteria

The design for the cask-lifting platform is based on a dead load of 180 tons.

##### 4.4.5.2.3 Functional/Technical Requirements

The CTF and its components are designed to operate in conjunction with the cask transporter. Together, the cask transporter and the CTF design ensures that there will be no uncontrolled lowering of the lifted load under all design-basis conditions of service, including environmental phenomena.

###### 4.4.5.2.3.1 Main Shell

The CTF main shell supports the jack screws. The cask-lifting platform is raised inside the CTF main shell. As discussed in Sections 4.2.1.2 and 4.4.5.2.3.6, the main shell is equipped with a sump to collect water from the CTF cylinder.

#### 4.4.5.2.3.2 Lifting Platform

The cask-lifting platform is a horizontal, steel-beam structure. Radial stability of the lifting platform is provided by the main shell. Vertical guides or runners are provided to prevent damage of the main shell or lifting platform at the interface locations. These are either wheeled or low friction pads. The guides (or runners) are capable of restraining the lifting platform when applied with the maximum horizontal load from the earthquake applied in two simultaneous orthogonal directions.

The lifting platform is lifted by three, ACME, thread-traveling, nut-type, inverted screw jacks located on the outside edge of the main shell. Raising and lowering of the lifting platform is performed by the simultaneous rotation of the lifting jackscrews. The platform is parked in the up position, with the jackscrews protected from corrosion and dirt by protective boots. The platform bottoms out at the full-down position against the base pad supports to prevent loading of the jacks with the combined weight of the loaded transfer cask and the overpack.

Provisions are provided for personnel access to inspect, maintain, and repair CTF components. Access to the underside of the platform may be via ladder through removable access ports. Access is not allowed if the platform is loaded.

#### 4.4.5.2.3.3 Lifting Jacks

Even loading of the platform is ensured by the simultaneous operation of the lifting jacks. The range of travel of the lifting platform is a minimum of 160 inches. The upper range of travel positions the overpack with its baseplate approximately 30-40 inches below grade. Lift speed is between 6 and 12 inches/minute. The jacks are capable of performing the lift in one continuous motion. The jacks do not require an interim cooling period during the lift. The jacks are designed to preclude unwinding during a loss-of-power event.

#### 4.4.5.2.3.4 Drive and Control System

The cask-lifting platform is operated from a fixed position control station or a pendant. The control station may be located above or below grade as long as reasonable access is provided. The cask-lifting platform drive system ensures coordination of the lifting jacks.

#### 4.4.5.2.3.5 Facility Power

Power for the facility is electric. Power lines are sufficiently protected from interaction with the cask transporter and other operations. Section 8.1.6 describes recovery actions for loss of power to the CTF during operations.

#### 4.4.5.2.3.6 Sump

During periods of nonusage, the CTF will have a cover installed to prevent water entry. To collect any accumulated water, the CTF is equipped with a sump. Any sump water will be collected, sampled for radioactivity, and processed in accordance with applicable administrative procedures.

#### 4.4.5.3 CTF Analysis

The load path parts of the CTF are conservatively designed in accordance with the ASME Code, Section III, Subsection NF. NUREG-0612 was reviewed and the intent of applicable guidance was applied in the design criteria for the load path parts of the CTF. The CTF is purchased commercial grade and is qualified for MPC and overpack transfer operations by functional testing prior to service.

Analyses have been performed to verify that, during MPC transfer from the HI-TRAC to the HI-STORM overpack, the main shell of the CTF and its surrounding foundation are sufficient to maintain the overpack in the vertical position.

All load-bearing components have been evaluated to ensure that they have been sized in compliance with the intent of the applicable sections of ANSI 14.6, NUREG-0612, and ASME Subsection NF.

#### 4.4.5.4 Functional Testing and Inspection

As part of normal storage system operations, the CTF is inspected for operating conditions prior to each ISFSI loading campaign typically consisting of several casks. During the operational testing of this equipment, procedures are followed that will affirm the correct performance of the CTF features that provide for safe fuel-handling operations.

### 4.4.6 REFERENCES

1. Submittal of Holtec Proprietary Design Drawing Packages, PG&E Letter to the NRC, DIL-01-008, December 21, 2001.

2. Final Safety Analysis Report for the HI-STORM 100 System, Holtec International Report No. HI-2002444, Revision 0, July 2000.

3. ANSI N14.5, Leakage Tests on Packages for Shipment, American National Standards Institute, 1997 Edition.

4. Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NF, American Society of Mechanical Engineers, 1995 Edition including 1996 and 1997 addenda.

5. ANSI N14.6, Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More, American National Standards Institute, 1993 Edition.

6. Control of Heavy Loads at Nuclear Power Plants, NUREG-0612, USNRC, July 1980.

## 4.7 OPERATING ENVIRONMENT EVALUATION

In accordance with NRC Bulletin 96-04 and consistent with Interim Staff Guidance (ISG) 15 (References 1 and 2), a review of the potential for chemical, galvanic, or other reactions among the materials of the HI-STORM 100 dry storage system, its contents, and the operating environments, which may produce adverse reactions, has been performed.

### 4.7.1 MULTI-PURPOSE CANISTERS

The passive, non-cyclic nature of dry storage conditions does not subject the MPC to conditions that might lead to structural fatigue failure. Ambient temperature and insolation cycling during normal dry storage conditions and the resulting fluctuations in MPC thermal gradients and internal pressure is the only mechanism for fatigue. These low-stress, high-cycle conditions cannot lead to a fatigue failure of the MPC enclosure vessel or fuel basket structural materials, that are made from austenitic stainless steel, known as "Alloy X." "Alloy X" is a fictitious stainless steel used in the design basis analyses of the MPC to ensure any of the permitted austenitic stainless steels used in MPC fabrication will be bounded by the analyses. (See HI-STORM FSAR Section 1.2.1.1 for a detailed discussion of Alloy X.) A typical MPC construction material specification, ASME SA240-304 stainless steel, has a fatigue endurance limit well in excess of 20,000 psi. All other off-normal or postulated accident conditions are infrequent or one-time occurrences, which cannot produce fatigue failures. The MPC also uses materials that are not susceptible to brittle fracture.

The MPC enclosure vessel and fuel basket will be in contact with air, helium, and spent fuel pool (SFP) water during it various stages of use. The MPC enclosure vessel and fuel basket, with the exception of the Boral neutron absorber panels, and aluminum seal washers used in the vent and drain port caps, is fabricated entirely of austenitic stainless steel. Aluminum heat conduction elements, offered as optional equipment in the HI-STORM 100 System generic MPC design (Section 1.2.1.1 of the HI-STORM FSAR, as modified by LAR 1014-1), will not be used in any of the MPCs deployed at the Diablo Canyon ISFSI. There is no significant chemical or galvanic reaction of stainless steel with air or helium. The aluminum seal washers used with the vent and drain port caps never are in contact with water, so combustible gas generation is not a concern. There are no coatings of any kind used in or on the MPC. The control of combustible gases generated by the interaction of the Boral neutron absorber with the SFP water is discussed in Section 4.7.1.1.

The moisture in the MPC is removed during loading operations to a point where oxidizing liquids and gases are at insignificant levels. The MPC cavity is then backfilled with dry inert helium at the time of closure to maintain an atmosphere in the MPC that provides corrosion protection for the SNF cladding and MPC materials throughout the dry storage period. The specific limits on MPC moisture removal and helium backfilling are included in the technical specifications. Insofar as corrosion is a long-term time-dependent phenomenon, the inert gas environment in the MPC minimizes the incidence of corrosion during storage on the ISFSI to an insignificant amount.

### 4.7.1.1 Boral Neutron Absorber

The Boral neutron absorber panels consist of a boron carbide powder-aluminum powder mixture sandwiched between two solid aluminum surfaces. The corrosion-resistant characteristics of such materials for dry SNF storage canister applications, as well as the protection offered by these materials against other material degradation effects, are well established in the nuclear industry in both wet and dry spent fuel storage applications. The preservation of this non-corrosive atmosphere is assured by the inherent seal-worthiness of the MPC confinement boundary integrity (there are no gasket joints in the MPC).

The Boral neutron absorber panels will be submerged in borated water during fuel loading operations in the SFP, and during MPC lid welding and potential MPC lid cutting in the unlikely event the MPC needs to be unloaded. The aluminum in the as-manufactured Boral panels reacts with water, producing hydrogen gas. Therefore, all Boral surfaces are pre-passivated or anodized before installation in the MPC to minimize the rate of hydrogen production and ensure a combustible concentration of hydrogen does not accumulate under the MPC lid prior to, or during MPC lid welding or cutting operations.

Because the Boral water reaction cannot be completely eliminated by pre-passivation and the Boral material in the MPC will be under varying hydrostatic pressure levels (up to approximately 40 ft of water pressure during fuel loading or unloading in the SFP, and up to approximately 15 ft during lid welding or cutting), continued generation of limited quantities of hydrogen is possible. Pre-passivation has been shown by analysis to preclude the accumulation of combustible quantities of gas under the MPC lid during the welding or cutting operations for over 24 days (Reference 3). The operating procedures for the Diablo Canyon ISFSI will include provisions to to address combustible gas control in the MPC lid area, consistent with the controls discussed in Sections 8.1.5 and 8.3.3 of the HI-STORM 100 System FSAR, Revision 1, for loading and unloading operations, respectively.

## 4.7.2 HI-TRAC TRANSFER CASK

The HI-TRAC transfer cask will be used in an air and borated water environment during the various stages of loading and unloading operations. The use of appropriate coatings and the controlled environment in which the transfer cask is used minimize damage due to direct exposure to corrosive chemicals that may be present during loading and unloading operations. The transfer cask is designed for repeated normal condition handling operations with high factors of safety, particularly for the lifting trunnions, to assure structural integrity. The resulting cyclic loading produces stresses that are well below the endurance limit of the trunnion material, and therefore, will not lead to a fatigue failure in the transfer cask. All other off-normal or postulated accident conditions are infrequent or one-time occurrences that do not contribute significantly to fatigue. In addition, the transfer cask utilizes materials that are not susceptible to brittle fracture during the lowest temperature permitted for loading.

The transient use and relatively low neutron fluence to which the transfer cask materials are subjected do not result in radiation embrittlement or degradation of the transfer cask's shielding materials that could impair its ability to perform its intended safety function. The transfer cask materials are selected for durability and wear resistance for their deployment.

The load-bearing portions of the transfer cask structure are fabricated from carbon steel. Other materials included in the transfer cask design are Holtite-A (in the top lid for neutron shielding); elemental lead (in the body and bottom lid for gamma shielding) and brass, bronze or stainless steel appurtenances (pressure relief valves, drain tube, etc.). A complete description of materials is provided on the transfer cask drawing in Chapter 1 of the HI-STORM 100 System FSAR, Revision 1. The Holtite and lead shielding materials are completely enclosed by the welded steel construction of the transfer cask. Therefore, there will be no significant galvanic or chemical reactions between these shielding materials and the air or borated water. A detailed description of Holtite-A may be found in Section 1.2.1.3.2 of the HI-STORM 100 System FSAR.

The internal and external steel surfaces of the transfer cask, (except threaded plugs and holes, seal areas and trunnions) are sandblasted and coated with an epoxy-based coating system, qualified for borated water use, to preclude surface oxidation. Lid bolts are plated and the threaded holes in the top flange are plugged or sealed during water immersion to prevent borated water intrusion. The transfer cask coating system was chosen based on manufacturer's literature that confirms that the coatings are designed for use in the conditions that the transfer cask will experience. Table 4.7-1 provides the specific coatings to be used on the transfer cask. With the coating system in place, there is no significant galvanic or chemical interaction between the air or SFP water and the steel materials. Minor nicks and dings that may expose the underlying carbon steel will be repaired by maintenance coating between uses of the transfer cask. The small size of any carbon steel exposed by the nicks and dings, the temporary nature of transfer cask use, the relatively short duration of exposure to borated water, and the coating repair maintenance program, combined, eliminate significant corrosion of the carbon steel as a concern.

In summary, significant chemical or galvanic reactions involving the transfer cask and the SFP water are not expected.

### 4.7.3 HI-STORM OVERPACK

The HI-STORM overpack will be used only in an air environment during the various stages of loading and unloading operations. The overpack is never immersed in the SFP or any other source of water. It will be subjected to the environment at the ISFSI, which includes saline water vapor and rain. The overpack consists of two concentric carbon steel cylinders separated by radial plates, with a carbon steel base plate and lid. The drawing in Section 1.5 of the HI-STORM FSAR, Revision 1 provides details on materials used in the overpack. The annulus between the two cylinders is filled with concrete. All exposed carbon steel surfaces of the overpack, including the anchor studs and nuts, are coated with an epoxy-based coating to prevent corrosion due to salinity or other airborne contaminants at the ISFSI. Table 4.7-1 provides the specific coatings to be used on the overpack. Concrete in the overpack body, lid, and pedestal is non-reinforced and completely encased in steel. Therefore, the potential of environmental-induced degradation in an oceanside environment such as the Diablo Canyon ISFSI, including spalling of concrete, are not possible for the overpack.

Under normal storage conditions, the bulk temperature of the overpack will, because of its large thermal inertia, change very gradually with time. Therefore, material degradation from rapid thermal ramping conditions is not credible for the overpack. As discussed in Appendix 1.D of the HI-STORM 100 System FSAR, the aggregates, cement and water used in the storage cask concrete are carefully controlled to provide high durability and resistance to temperature effects. The configuration of the storage overpack assures resistance to freeze-thaw degradation even though this degradation force is expected to be minimal at the site. All other off-normal or postulated accident conditions are infrequent or one-time occurrences that do not contribute significantly to fatigue. In addition, the overpack utilizes materials that are not susceptible to brittle fracture during the lowest temperature permitted for loading.

A maintenance program for coatings on accessible areas of the overpack ensures that nicks or dings that expose the carbon steel components underneath will be repaired before any significant corrosion can occur.

The relatively low neutron flux to which the storage overpack is subjected cannot produce measurable degradation of the cask's material properties and impair its intended safety function.

In summary, the materials of construction of the overpack design are compatible with the environment in which the overpack will operate. These design features and the coating maintenance program ensure that the overpack can perform its design functions for the life of the ISFSI.

### 4.7.4 NEUTRON ABSORBER

The effectiveness of the fixed borated neutron absorbing material used in the MPC fuel basket design requires that sufficient concentrations of boron be present to assure criticality safety during worst case design basis conditions over the 40-year design life of the MPC. Information on the characteristics of the Boral neutron absorbing material used in the MPC fuel basket is provided in Subsection 1.2.1.3.1 of the HI-STORM 100 System FSAR. The relatively low neutron flux, which will continue to decay over time, to which this borated material is subjected, does not result in significant depletion of the material's available boron to perform its intended safety function. In addition, the boron content of the material used in the criticality safety analysis is conservatively based on the minimum specified boron areal density (rather than the nominal), which is further reduced by 25 percent for analysis purposes, as described in Section 4.2.3.3.5 of the Diablo Canyon ISFSI SAR. An evaluation discussed in Section 6.3.2 of the HI-STORM 100 System FSAR demonstrates that the boron depletion in the Boral is negligible over a 50-year duration. Thus, sufficient levels of boron are present in the fuel basket neutron absorbing material to maintain criticality safety functions over the 40-year design life of the MPC.

### 4.7.5 MATERIALS SUMMARY

Table 4.7-1 provides a listing of the materials of fabrication for the HI-STORM 100 dry storage system and summarizes the performance of the material in the expected operating environments during short-term loading/unloading operations and long-term storage operations. As a result of this review, no operations were identified that could produce adverse reactions beyond those conditions already generically evaluated and approved in the licensing of the HI-STORM 100 System.

### 4.7.6 REFERENCES

1. USNRC Bulletin 96-04, Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks.

2. USNRC Interim Staff Guidance Document 15, Materials Evaluation.

3. Holtec International Dry Storage Position Paper DS-248, Revision 2, Chemical Stability of the Holtec MPC Internals During Fuel Loading and Dry Storage.